Management of the posterior malleolus in trimalleolar fractures

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S.M. Verhage

General introduction
and outline of this thesis

CHAPTER 1

INTRODUCTION

Ankle fractures are among the most common fractures diagnosed at the Emergency Department (ED). These fractures are common in both young athletes, due to the trauma mechanism, and in older women due to osteoporosis. Every year, approximately 107 to 187 out of 100.000 people will sustain an ankle fracture[1,2]. An estimated total off around 30.000 people with ankle fractures will visit the EDs in the Netherlands annually[1].

The bony ankle joint consists of the tibia, fibula and talus. On the medial side it is stabilized by the ligamentous complex of the deltoid ligament (figure 1). Laterally several ligamentous complexes of the talofibular complex and syndesmosis stabilize the ankle joint. The syndesmosis, in between the distal tibia and fibula, consists of the Anterior Inferior Tibiofibular Ligament (AITFL), the Posterior Inferior Tibiofibular Ligament (PITFL) and the interosseous membrane.

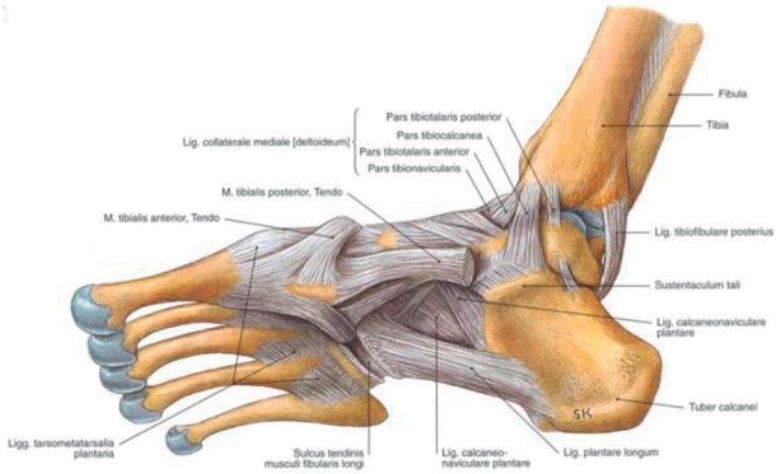

Figure 1: Medial aspect of the ankle and view on lig. tibiofibularis posterius.

The distal posterior tibiofibular ligament (PITFL) is on the posterior side attached to the posterior margin of the distal tibia. The typical rotational injury mechanism of the ankle fracture may cause the posterior inferior tibiofibular ligament to rupture or may lead to an avulsion fracture of the posterior tibial margin. Also known as the posterior malleolar fracture, Volkmann's fracture or tertius fragment (figure 2). A substantial part of all ankle fractures (7-44%) involve the posterior malleolus[3]. Since Coopers' description of the trimalleolar fracture in 1822, several publications have discussed and analyzed the challenges and pitfalls of posterior malleolar fractures[4-7]. Despite all research and publications, a worldwide consensus on the optimal treatment of the posterior fragment in trimalleolar fractures is still lacking.

Figure 2: Posterior view of the ankle.

The diagnosis of a trimalleolar fracture is usually based on findings of combined mortise, AP and lateral X-rays. Dependent of the ankle classification system used, the inter- and intraobserver variability of ankle classification systems on plain radiographs is poor to moderate[8-10]. In daily hospital setting however, standard ankle X-rays are the first means of diagnostics in case of suspicion of an ankle fracture. In the last years, preoperative CT-scanning of the intra-articular ankle fracture has become more and more common, even mandatory in some hospital protocols. Visualisation of the intra-articular fracture fragments, including the posterior malleolus fragment by CT-scan helps to better understand the fracture. It also may have implications for the treatment strategy, as advocated by several authors[10-13]. Therefore a preoperative CT-scan of the ankle joint is highly recommended in all X-ray diagnosed trimalleolar fractures[10-13].

This first CT-based classification was developed by Haraguchi et al and relied on the analysis of axial CT scans of 57 patients (figure 3)[14]. These authors distinguished three types:

- Type I: posterolateral oblique fracture as the most common variant (67%). The fracture involves a triangular fragment separated from the posterolateral part of the distal tibia.
- Type II: medial extension fracture (19%) affects the posterior part of the medial malleolus and may be formed by one or two fragments.
- Type III: small-shell fracture (14%) involves small fragments of the posterior cortex

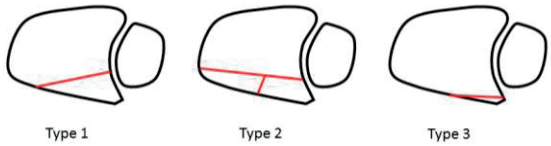

Figure 3: Haraguchi classification of posterior malleolar fractures.

Another classification system is described by Bartonicek and Rammelt[15,16]. These authors, in 2015, analyzed 141 consecutive CT scans of individuals with an ankle fracture or fracture-dislocation of types Weber B or Weber C with fracture of the posterior malleolus. The fragments were analyzed in the transverse, sagittal, and frontal planes; a 3D CT reconstruction was performed in 91 patients. The fractures of posterior malleolus were classified into four basic types having constant pathoanatomic features, with special reference to involvement of the fibular notch (Fig. 4):

- Type 1: extraincisural fragment (8%);
- Type 2: posterolateral fragment (52%). The size varies from small (only the lateral portion of the posterior tubercle) up to involvement of half of the fibular notch. In a substantial amount of the cases a depressed intercalary joint fragment is present;
- Type 3: posteromedial, two-part fragment (28%). All fragments consist of two triangular portions of different size and involve the medial malleolus;
- Type 4: large, posterolateral triangular fragment (9%). A solid posterior tibial fragment (without depressed intercalary fragment) displays a triangular geometry and about one-half of the fibular notch is affected;
- Type 5: irregular osteoporotic fracture (3%). Impossible to classify the posterior malleolar fracture due to a considerable comminution of fragments, most likely caused by osteoporosis.

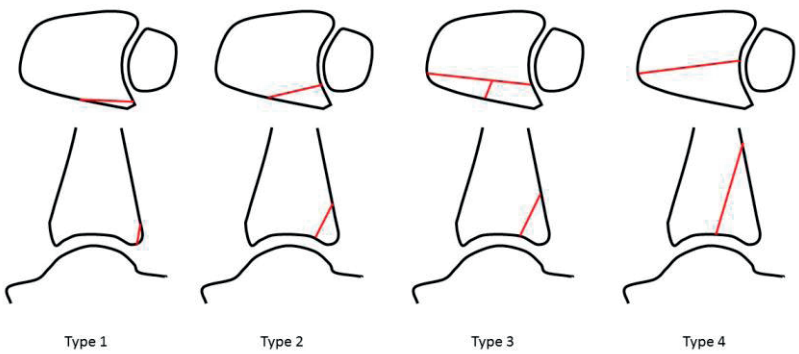

Figure 4: Bartonicek classification of posterior malleolar fractures.

The severity of injury is higher with increasing type in the classification of Bartonicek.

Traditionally, the posterior fragment is fixated if the posterior fragment exceeds 25-33% of the involved intra-articular surface[4-7]. Fixation can be performed percutaneously from anterior to posterior after closed reduction by ligamentotaxis. Until recently, this was the most common approach and way of fixation if the fragment measured more than 25-33% of the involved articular surface. Suboptimal treatment of trimalleolar fractures may result in persistent ankle instability, pain and functional impairment[4-7]. In recent literature, it is advocated to consider fixation if the weight bearing part of the tibiotalar joint is involved in the posterior malleolar fracture[16,17]. To prevent the ankle from development of posttraumatic osteoarthritis fixation is often performed at a low threshold [16,17]. No scientifically substantiated consensus exist, however, on the absolute or proportional size of the posterior malleolus fragment that warrants operative fixation[17-20].

In the past decade, open reduction and internal fixation via the posterolateral approach was advocated for posterior malleolar fractures[17,21]. Via this approach, both the fibula and the posterior tibial margin could be addressed. Theoretically, this approach has some potential benefits. Reduction is performed from posterior under direct visualisation of the fracture and if intra-articular fragments are present, these fragments can be removed by levering the posterior fragment laterally. Possible disadvantage is the relatively larger incision compared to a straight lateral or percutaneous approach only. Also care must be taken to avoid damage of the n. suralis. Complication rates of this approach have been found to be comparable to the traditional approaches[22]. It is unclear if fixation via the posterolateral approach leads to less development of post-traumatic osteoarthritis and better functional outcome.

This thesis is about the management of the posterior malleolar fragment in trimalleolar fractures and subsequently to provide evidence based guidance in treatment strategies, whenever possible. Next to management, diagnosis and optimal treatment, functional outcome and post-traumatic complications will be discussed in this thesis. Indications for fixation and (dis)advantages of different approaches, derived from different studies require to be proven in well-designed prospective studies. It is therefore that next to seven retrospective analyses, two multicenter randomized clinical trials concerning fixation of the posterior malleolar fracture fragment will be discussed in this thesis. Further planning and future perspectives will be discussed in the general discussion.

OUTLINE

This thesis aims to discuss the current and future guidelines for management of posterior malleolar fractures. Several studies were performed to specify the indications for frac-

ture fixation of the posterior malleolar fragment. In total, nine studies were conducted and described in this thesis.

The use of modalities to diagnose a trimalleolar fracture seems to have changed over the last years. CT-scanning of the ankle in case of a posterior malleolar fragment is more and more advocated. In general, inter- and intraobserver agreement of classification systems in fracture surgery are often described as moderate to poor. The interobserver agreement of plain X-ray in malleolar fractures and the rate of comparability is described in **Chapter 2.** This study is performed in order to:

- *Describe interobserver agreement of malleolar fractures on plain X-ray*
- *Describe interobserver agreement of posterior malleolar fractures and reliability of size of posterior fragment on plain X-ray.*

In the past years multiple publications regarding treatment of the posterior malleolar fragment in trimalleolar fractures have been published. Whether and how to fixate the posterior malleolar fragment in trimalleolar fractures remains topic of debate amongst orthopaedic trauma surgeons. A close review of the available literature was indicated to narrow the research goals for this thesis. In **Chapter 3** the published literature regarding treatment and fixation methods of the posterior malleolus in trimalleolar fractures is reviewed. In this chapter the current state of the art in fixation of the posterior malleolar fracture is described. Two questions will be answered:

- *Are there any clear guidelines in current literature whether to fixate the posterior fracture fragment or not?*
- *Are there any clear guidelines regarding the optimal approach in posterior fracture fragment fixation?*

Posterior malleolus fractures are a heterogeneous group of fractures both in fracture morphology and age distribution. Potentially advices can be derived from practice variation studies. An online survey to the treatment of posterior malleolar fragments is performed in order to evaluate the current treatment in the Netherlands. The results of this survey are described in **Chapter 4** to answer the question:

- *What is the current state of practice variation in posterior fracture fragment fixation amongst (orthopaedic) trauma surgeons in the Netherlands?*

Studies that focus on trimalleolar fractures are scarce and in most available cases limited to small groups and case report. In **Chapters 5 and 6** the long-term functional and radiological outcome of a large cohort of trimalleolar fractures is described. The different aspects of a posterior malleolar fracture are analysed regarding to functional and radiological outcomes. Multiple linear regression and logistic regression analysis are used

to assess risk factors for development of post-traumatic osteoarthritis and functional outcome. The following questions will be addressed:

- *Which patient and fracture characteristics lead to post-traumatic osteoarthritis?*
- *Are there significant, independent risk factors for worse functional outcome?*

Different fixation techniques and approaches are described in current literature. Most (orthopaedic) trauma surgeons do prefer a percutaneous fixation from anterior to posterior or an open reduction and internal fixation via a posterolateral approach. A comprehensive and detailed description of the posterolateral approach as used in our studies and the post-operative results and complications are described in **Chapter 7**.

In **Chapter 8**, two different fixation techniques used for fixation of the posterior malleolar fracture are compared. The differences in postoperative gap and postoperative step-off of both fixation techniques were described and evaluated. Also, both fixation methods are compared with no fixation of the posterior fragment at all. The main questions are:

- *Does open reduction and internal fixation via the posterolateral approach lead to a higher rate of anatomical reduction than reduction through ligamentotaxis and additional anterior to posterior screw fixation?*
- *Does fixation of the posterior fragment lead to a higher rate of anatomical reduction than no fixation at all?*

To our knowledge, large comparative studies on long term outcome of malleolar fractures are not available in current literature. Therefore, we performed a large retrospective study on malleolar fractures with a long-term follow-up. The results are presented in **Chapter 9.** In this chapter the different fracture patterns are described and functional outcome and radiological outcomes are compared. The following questions will be answered:

- *What are the functional and radiological outcomes in ankle fractures?*
- *Are there fracture characteristics that negatively influence functional and radiological outcome?*

Chapter 10 describes a relatively common complication**.** The ossification of the distal tibiofibular syndesmosis is called synostosis and is thought to cause a decrease in mobility of the ankle joint. The results in relation to different fracture types are described in this retrospective study.

- *Does development of distal tibiofibular synostosis lead to a worse functional outcome?*

Well-designed randomized clinical trials studying the multiple aspects on treatment and outcome of posterior malleolar fragment are scarce. A protocol for further clarification and answers to our questions is described in **Chapter 11**. Main question of this study is:

Does open reduction and internal fixation of medium-sized posterior fragments lead to better functional and radiological outcome compared to no fixation at all?

All studies and further challenges are discussed in **Chapter 12.** The English summary is written in **Chapter 13.** A short summary in Dutch and further characteristics from the author are described in **Chapter 14** and following appendices.

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Interobserver variation in classification of malleolar fractures.

CHAPTER 2

ABSTRACT

Objectives

Classification of malleolar fractures is a matter of debate. In the ideal situation, a classification-system is easy in use, shows good inter- and intraobserver agreement, and has implications for treatment or research.

Material and methods

Interobserver study. Four observers distributed 100 X-rays to the Weber, AO and Lauge-Hansen classification. In case of a trimalleolar fracture, the size of the posterior fragment was measured. Interobserver agreement was calculated with Cohen's Kappa. Agreement on the size of the posterior fragment was calculated with the intraclass correlation coefficient.

Results

Moderate agreement was found with all classification systems: the Weber (K=0.49), AO (K=0.45) and Lauge-Hansen (K=0.47). Interobserver agreement on the presence of a posterior fracture was substantial (K=0.63). Estimation of the size of the fragment showed moderate agreement (ICC=0.57).

Conclusion

Classification according to the classical systems showed moderate interobserver agreement, probably due to an unclear trauma-mechanism or the difficult relation between the level of the fibular fracture and syndesmosis. Substantial agreement on posterior malleolar fractures is mostly due to small (<5%) posterior fragments. A classification system that describes the presence and location of fibular fractures, presence of medial malleolar fractures or deep deltoid ligament injury, and presence of relevant and dislocated posterior malleolar fractures is more useful in the daily setting than the traditional systems. In case of a trimalleolar fracture, a CT-scan is in our opinion very useful in the detection of small posterior fragments and preoperative planning.

INTRODUCTION

Classification of malleolar fractures is a matter of debate. In the ideal situation, a classification-system is easy in use, shows good inter- and intraobserver agreement and has implications for treatment or research[1]. In most of the literature, the Lauge-Hansen and AO-classifications are defined as complicated, whereas the Weber-classification is often described as too simplistic[2-4]. The Lauge-Hansen classification system is based on experimental cadaveric studies and describes the position of the foot and direction of the applied force[5-9]. The AO-classification classifies fractures according to the localization (bone and segment) and morphology (type, group and subgroup)[10]. The Weber classification divides the fractures depending on the relationship of the fibular fracture to the tibiofibular syndesmosis. Another additional difficulty in ankle fractures is the presence and assessment of posterior malleolar fractures. Additional treatment of posterior fractures depends, according to most of the literature, on the size and dislocation of the posterior fragment[11-14]. This study compares the interobserver variation of the most commonly used ankle fracture classification systems. Also, the presence and size of the posterior fragment are compared.

MATERIAL AND METHODS

This study was approved by the local Medical Ethics Committee of our institution. No WMO requirement (Medical Research in Humans) was needed according to the local Medical Ethical Committee. From 2005, the first consecutive 100 patients operatively treated for an isolated ankle fracture in our hospital with complete set of X-rays were classified according to the Weber, AO and Lauge-Hansen classifications. According to the Weber system, there are three possibilities: fracture distal to the tibiofibular syndesmosis (A), fracture at the level of the tibiofibular syndesmosis (B) and proximal to the tibiofibular syndesmosis (C). The AO-classification has nine possibilities: 44A1-44A3, 44B1-44B3 and 44C1-44C3. The Lauge-Hansen system has 13 groups: supination-adduction fractures (SA) stages I-II, supination-external rotation fractures (SE) stages I-IV, pronation-abduction fractures (PA) stages I-III, pronation-external rotation fractures (PE) stage I-IV. Inclusion could only take place if all digital radiographs were present in our digital data system. All patients had true anteroposterior or mortise views and lateral views. All photographs were blinded to all observers: the photographs were classified without knowledge of the patient and operation characteristics.

Four observers participated in our study. All were consultants with special interest in skeletal trauma with at least 3 years of experience. They were asked to classify the ankle fractures according to the above-mentioned classification systems. In case they

recognized a trimalleolar fracture, they were asked to measure the anterolateral posterior fragment size, which articulates with the talotibial joint.

Interobserver agreement on the classification and presence of posterior fragments was calculated with Cohen's Kappa (K), which is a coefficient of pairwise agreement between observers[15-16]. K=1 implies perfect agreement, and K=0 suggests that the agreement is no better than that which would be obtained by chance. According to Landis, values are judged on a scale as poor if $K \leq 0.20$, fair if $0.21 \leq K \leq 0.40$, moderate if $0.41 \leq K \leq 0.60$, substantial if $0.61 \leq K \leq 0.80$ and almost perfect if $K > 0.80$[17]. Agreement in size of the posterior fragment was analyzed with the intraclass correlation coefficient (ICC). The ICC is the proportion of the variability in the observations due to the differences between pairs. The ICC takes values from zero (no agreement) to 1 (perfect agreement)[17].

RESULTS

The overall interobserver agreement is shown in Table 1. Moderate agreement was found in all classification systems: Weber (K=0.49; 0.34-0.64), AO (K=0.45; 0.42-0.48) and Lauge-Hansen classification (K=0.47; 0.44-0.50).

Table 1: Kappa-statistics of traditional classification systems.

Classification system	Kappa	Agreement
AO classification	K=0.45	Moderate
Lauge-Hansen classification	K=0.47	Moderate
Danis-Weber classification	K=0.52	Moderate

Table 2 shows the overall agreement on the presence of posterior fragments and shows the agreement on the size of the posterior fragment. Six percent of all fractures in this study could not be classified according to the AO classification system because of isolated medial malleolar fractures. Interobserver agreement on the presence of a posterior fracture was substantial (K=0.63; 0.52-0.74) and improved if there was an assumption of a large fragment (K=0.71; 0.61-0.81 or 81% were classified as trimalleolar by all observers). Estimation of the size of the fragment showed moderate agreement (ICC=0.57; 0.38-0.76).

Table 2: ICC-statistics of presence and size of posterior fragment in trimalleolar fractures.

	Kappa and ICC	Agreement
Presence posterior fracture	K=0.63	Substantial
Size of posterior fracture	ICC=0.59	Moderate
Presence of large sized posterior fragments	K=0.75	Substantial

Table 3 shows the contingency tables of all classification systems. Figures 1, 2, 3 and 4 show the individual measurement of posterior malleolar fracture size and mean of all four measurements.

Table 3: Contingency tables of traditional classification systems.

AO-classification	**Observer 1**	**Observer 2**	**Observer 3**	**Observer 4**
Observer 1	x	0.67	0.48	0.38
Observer 2		X	0.47	0.44
Observer 3			X	0.47
Observer 4				X
LH-classification	**Observer 1**	**Observer 2**	**Observer 3**	**Observer 4**
Observer 1	x	0.77	0.59	0.47
Observer 2		X	0.60	0.65
Observer 3			X	0.74
Observer 4				X
Danis-Weber	**Observer 1**	**Observer 2**	**Observer 3**	**Observer 4**
Observer 1	x	0.59	0.43	0.39
Observer 2		X	0.47	0.59
Observer 3			X	0.42
Observer 4				X

DISCUSSION

The classification of ankle fractures remains a matter of debate. Several authors remarked that interpretation of radiographs and use of classification systems is difficult[3,4,18]. Other authors advocate the use a CT scan for severe injured ankles[19,20], particularly when a fracture of the posterior malleolus is present. If the size of the posterior fragment is important for selecting the operative technique, then a CT scan of the ankle should be made to measure the size of the posterior fragment[19]. In figure 5, we present a case with both X-rays and a CT scan which changed our operative strategy.

Based on our results, we can conclude that the interobserver agreement of traditional classification systems remains moderate despite increasing quality of X-rays and more attention to the classification of fractures in clinical practice[2,21]. In our opinion, and according to most of the literature, this agreement is not sufficient for use in daily practice[22]. The main problem with the Lauge-Hansen classification is that in most cases the trauma mechanism is unclear. As a result, fractures can be classified into several groups (Figs. 1, 2 and 3). To our surprise, the Weber classification shows moderate agreement as well (although the best of traditional classification systems), probably due to the difficulty in relating the position of the fibular fracture to the tibiofibular syndesmosis ('proximal' B

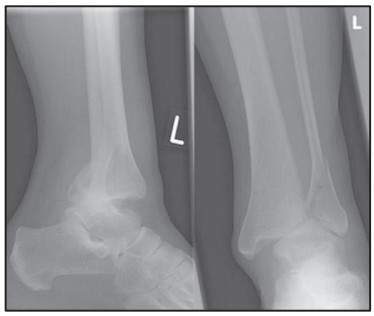

Figure 1: 45-year old woman with a trimalleolar fracture, it remains unclear whether this is a SE4 or a PA3 according to Lauge-Hansen. Clinically it is a trimalleolar fracture with lateralization of the talus and therefore tear of the deltoid ligament and involvement of the posterior malleolus.

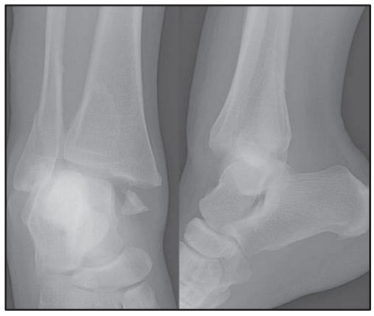

Figure 2: 61-year old woman with a trimalleolar fracture, unclear to classify into SE4 or PE4 according to Lauge-Hansen. Clinically it is a trimalleolar fracture.

Figure 3: 32-year old man with a medial malleolar fracture, possibly PA1 or PE1mfracture. Treatment doesn't differ.

versus 'distal' C). This problem also exists in the AO classification, which consists for the most part in classifying the fibular fracture in relation to the tibiofibular syndesmosis. In addition, it is not possible to classify the isolated medial malleolar fractures.

Due to the moderate agreement, the traditional classification systems have little value in daily use and are more relevant in research or educational purposes[12,13,23,24]. In daily practice, the integration of the number of fractured malleoli and stability of the tibiofibular syndesmosis (i.e. level of the fibular fracture) must be primary considerations in the preoperative planning and choice of treatment[25]. Therefore, we advocate a system in which (1) the presence and level of the fibular fracture, (2) presence of medial malleolar fracture or deep deltoid ligament injury, and (3) presence of a posterior malleolar fracture are noted.

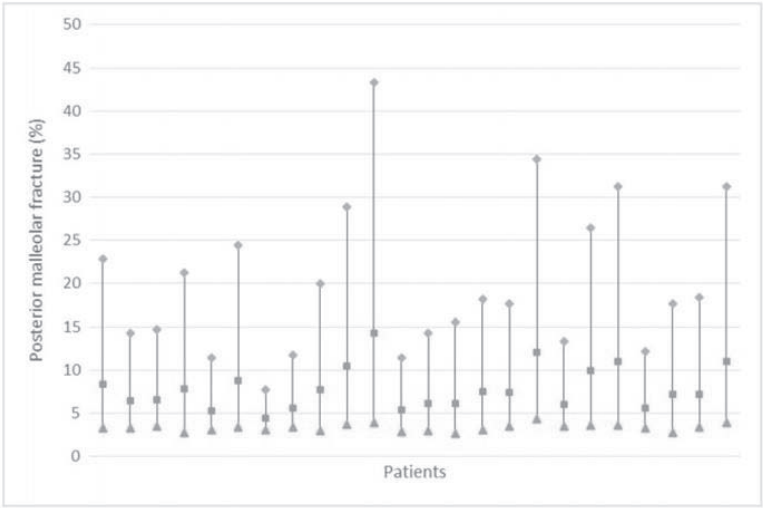

Figure 4: Plot of individual posterior malleolar fracture size measurements with the mean of all four observers.

Our data show substantial agreement in the detection of posterior malleolar fractures. The main problem is detecting small fragments, mostly due to overshadowing of the fibula. However, small fragments (<5% of the involved articular surface) have, according to most of the literature, no implications for surgical treatment. Large fragments, which are clinical relevant, show better agreement[12,13,26-30]. Estimating the size of the posterior fragment on plain radiographs is, given the moderate interobserver agreement, very difficult. Fixation of posterior fragments is, in most of the literature, dependent on the size of the posterior fragments. However, some authors advocate that not only the size, but also, most importantly, the congruency of tibiotalar articular surface should be leading the choice of treatment, and anatomic restoration of these fragments will prevent posttraumatic osteoarthritis[24,30]. In this case, assessment of the size of the posterior fragment is less important where the detection of smaller dislocated posterior fragments is of much more value. This is exactly the problem with plain radiographs, where small fragments or a comminuted fracture can be missed. Therefore, we agree with Büchler et al., who advocate preoperative CT evaluation in all trimalleolar fractures, independent of the size of the posterior fragment[20].

Traditional classification systems show moderate interobserver agreement and have little value in daily use and research purposes, but can be very useful for educational purposes. In the clinical setting, we advocate a system that describes the presence and location of fibular fractures, presence of medial malleolar fractures or deep deltoid ligament injury, and presence of relevant and dislocated posterior malleolar fractures. In most cases, the ankle X-ray is an useful tool for detecting clinically relevant fractures

of the posterior malleolus; however, preoperative CT evaluation might be a very useful addition to both preoperative planning and detection from smaller dislocated posterior fragments.

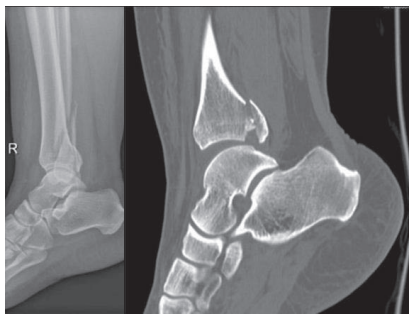

Figure 5A&B: This patient with a trimalleolar fracture was initially not planned to have operative treatment of the posterior malleolar fracture. The CT-scan shows 2 large intra-articular fragment which will disturb anatomic restoration of the tibiotalar joint and increase the change of development of osteoarthritis.

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When and how to operate the posterior malleolus fragment in trimalleolar fractures: A systematic literature review.

CHAPTER 3

ABSTRACT

Objectives

Whether or not and how to fixate the posterior malleolus fracture seems to depend on the fracture fragment size and its amount of dislocation, but clear guidelines for daily practice are lacking. In this review, we summarize the literature on preferred treatment of the posterior fragment in trimalleolar fractures.

Methods

A systematic review of publications between January 1995 and April 30 2017 on this topic in the PubMed, Embase, and Cochrane databases was performed according to the PRISMA statement.

Results

Seventeen (2 prospective and 15 retrospective) of the 180 identified studies were included. Six studies report on indications for fixation of posterior malleolus fracture fragments. Eleven studies compare different fixation approaches and techniques for the posterior fragment. Meta-analysis was not possible due to varying fixation criteria and outcomes. There was no clear association between posterior fragment size and functional outcome or development of osteoarthritis. The non-anatomical reduction of the fragment was of more influence on outcome. Radiological and functional outcome was better after open reduction and internal fixation via the posterolateral approach than after percutaneous anterior-to-posterior screw fixation.

Conclusion

The posterior fragment size is not a clear indication for its fixation. A step-off, however, seems an important indicator for developing posttraumatic osteoarthritis and worse functional outcome. Posterior fragments involving the intra-articular surface need to be reduced and fixated to prevent postoperative persisting step-off. Furthermore, fixation of the posterior malleolus via an open posterolateral approach seems superior to percutaneous anterior-to-posterior fixation. However, these results need to be confirmed in a prospective comparative trial.

INTRODUCTION

Ankle fractures are among the most common fractures diagnosed at the Emergency Department (ED). The typically rotational injury mechanism of the ankle fracture may cause the posterior inferior tibiofibular ligament (PITFL) to rupture or lead to an avulsion fracture of the posterior tibial margin, also known as the posterior malleolar fracture or Volkmann's fracture. A substantial part of all ankle fractures (between 7 and 44%) involve the posterior malleolus[1]. Since Coopers' description of the trimalleolar fracture in 1822, many publications regarding its treatment challenges have been published[2-7].

When

Functional outcome of trimalleolar fractures is found to be worse compared to uni- and bimalleolar fractures[2-5,8]. A fracture of the posterior tibial margin larger than 5% of the involved articular surface may lead to the development of posttraumatic osteoarthritis, especially in fractures that involve the weight-bearing part of the tibiotalar joint[9,10]. Moreover, persistent postoperative dislocation of the posterior fragment in trimalleolar fractures may result in ankle instability, osteoarthritis, and functional impairment. According to the Arbeitsgemeinschaft für Osteosynthesefragen (AO), a posterior fragment comprising more than 25% of the intra-articular surface needs to be fixated, as do fragments larger than 10% that remain persistently instable after fixation of the lateral and medial malleolus. Recent literature shows a changing tendency towards anatomical correction of the joint, based on the presence of intra-articular step-off rather than the size of posterior fragment[9-11]. Despite all research and publications, a worldwide consensus on which posterior fragments in trimalleolar fractures should be fixated still lacks, as does a guideline on the amount of dislocation or step-off that can be accepted without compromising functional outcome.

How

The best way to reduce and fixate the posterior malleolar fracture fragment is another matter of debate[11]. The approach and the type of fixation are related treatment decisions. The percutaneous AP approach involves screw fixation, whereas the posterolateral approach most frequently concerns open reduction and plate fixation. Fixation of the posterior malleolus is traditionally done by percutaneous anterior-to-posterior screw fixation after closed reduction through ligamentotaxis. Advantages of this approach are the minimally invasive technique and the possibility to fix the fragment in supine position. Possible disadvantages are the challenging reduction technique and the inability to remove intra-articular loose fragments. In 2005, Talbot et al. described their experiences with the posterolateral approach for trimalleolar fractures[12]. This started an era in which the posterolateral approach gained popularity[13-16]. The posterolateral approach has the

advantages of direct control on anatomical reduction and stable screw or plate fixation from posterior to anterior. It also provides the possibility to remove loose intra-articular fragments that may obstruct anatomical reduction. A possible disadvantage is the prone or, in some cases, lateral position of the patient. Fixation of lateral, medial, and posterior fractures without turning over the patient poses a challenge. Some other approaches including the posteromedial approach and a lateral transmalleolar approach[17,18] have recently been described but are not widely used in daily practice.

The when and the how of fixation of posterior malleolus fractures are closely related. If we should reduce fracture dislocation to a minimum to obtain a favourable long-term outcome, the threshold for surgical treatment and subsequently open anatomical reduction and fixation will be lowered. Alternatively, if some dislocation can be accepted in either small or large posterior malleolar fractures without compromising the clinical outcome, the tendency will be more towards non-operative treatment or anterior-to-posterior fixation of the posterior malleolus fracture fragment.

Since no national and international guidelines on this topic have been published, we systematically reviewed the published literature on the topic, with the aim to provide an overview of the current scientific evidence and, if possible, to provide directions for clinical treatment strategies concerning the fixation of posterior malleolus fractures.

MATERIALS AND METHODS

This review was performed according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines[19].

Search strategy

We conducted two extensive literature searches in Pubmed, Embase, and the Cochrane library to find the answers to the questions when and how to fix the posterior fragment in trimalleolar fractures. The following search terms were used for the question when to fix the posterior fragment in trimalleolar fractures: trimalleolar fracture, posterior malleolar fracture, Volkmann's fracture, and ankle fracture. In addition, we used the following MeSH terms: indication, management, treatment, outcome, fragment size, and fixation.

For the question how to fix the posterior fragment the following MeSH terms were added: fixation method, approach, posterolateral approach, and posterior fixation. Only studies in the English language were selected. Case reports and case series with less than 10 patients were excluded. All studies from January 1 1995 till April 30 2017 were included. Our search strategy for PubMed is presented in Table 1.

Table 1: Search strategy for PubMed.

((trimalleolar*[tiab] OR trimalleolar*[tiab] OR (posterior*[ti] AND malleolar*[ti]) OR "posterior malleolar"[tiab] OR posterior malleolus*[tiab] OR volkmann*[tiab]) AND ankle[tiab] AND ("Fractures, Bone"[Mesh] OR fracture*[tiab]) AND ("Treatment Outcome"[Mesh] OR treatment[tiab] OR management[tiab] OR indication[tiab] OR fixat*[tiab] OR "fragment size" OR "Cohort Studies"[Mesh] OR follow-up*[tiab] OR outcome[tiab] OR outcomes[tiab] OR approach[tiab] OR surg*[tiab] OR fixat*[tiab] OR "Radiography"[Mesh] OR radiol*[tiab]) AND ("1995/01/01"[PDAT]: "2017/04/30"[PDAT])) NOT (("Case Reports" [Publication Type]) OR "Case series" [Publication Type]))

Study selection

The title and abstract of the identified studies were carefully screened by the author (SV) on subject and content. We included publications that contained patient data in randomized clinical trials and prospective or retrospective cohort studies on fixation of the posterior malleolus in trimalleolar fractures. Only studies with a follow-up of at least 1 year or studies that evaluated postoperative complications on the short-term (without functional outcome) were eligible for inclusion. Articles that described patients with isolated posterior malleolar fractures, posterior malleolar fractures as a result of a pilon fracture, posterior malleolar fractures in multitraumatized patients, or study groups that included patients only with nonoperative treatment of the posterior malleolar fracture in trimalleolar fractures were excluded. Of potentially eligible studies, the full-text publication was read and evaluated by two authors (SV and JH), using the same inclusion criteria. If the full-text publication could not be retrieved, the study was excluded. The reference lists of the selected publications were screened for other potentially relevant publications.

Data extraction

Author, publication date, and study characteristics (study design, number of included patients, age, sex, size of posterior fragment, follow-up time, indication for fixation, type of approach, and fixation method) were recorded. Data on outcome parameters including functional scores, complications, range of motion, rate of postoperative step-off, and osteoarthritis were also extracted from the articles.

Assessment of risk of bias

The risk of bias in the selected studies was assessed using the "Methodological Index for Non-Randomized Studies" (MINORS) criteria. This tool includes eight methodological aspects of the study design, which are scored as 0 (not reported), 1 (reported but inadequate), or 2 (reported and adequate). In comparative studies, 12 methodological aspects were scored. The optimal sum score is 16 for cohort studies and 24 for comparative studies.

RESULTS

After the search, 180 studies were found and screened. 17 studies were selected for this review following the selection procedure as shown in figure 1. The 17 included two prospective cohort studies and 15 retrospective cohort studies. No randomized-controlled trials were found.

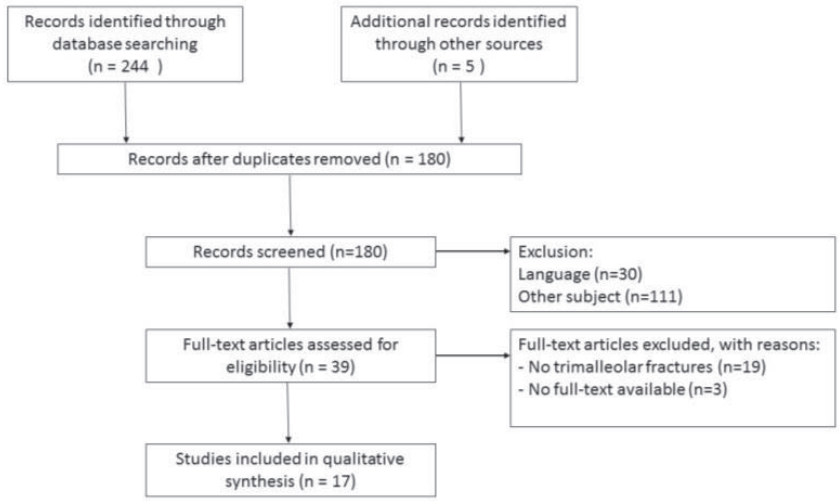

Figure 1: Flowchart of included publications.

Methodological quality

The methodological quality of the selected studies was moderate (Table 2). Bias in the cohort studies may have occurred mainly due to an unbiased assessment of the study endpoints and due to a considerable amount of loss to follow-up. For none of the selected studies, a sample size calculation had not been performed, so that the power of all the studies may have been inadequate.

When to fixate the posterior fragment

Six studies on indications for fixation of posterior malleolus fracture fragments were included (Table 3). These studies mostly described results on functional outcome and development of osteoarthritis in relation to fragment size and in relation to the operative or conservative treatment of the posterior fragment. Five of the six studies compared functional outcome with respect to size of the posterior fragment. These studies described different outcome scores (AOFAS, AAOS, Weber) to assess functional outcome. One study found a significantly worse functional outcome (AOFAS) in large posterior fragments (>25%) compared to smaller fragments(<25%)[20]. The other four

Table 2: PRISMA analysis of included publications.

	Langenhuijsen[6]	De Vries[7]	Drijfhout[9]	Xu[10]	MingoRobinet[21]	Evers[22]
(a) Studies evaluating functional outcome in relation to the size of the posterior malleolus fracture fragment						
1. A clearly stated aim	2	2	2	2	2	2
2. Inclusion of consecutive patients	1	1	1	2	1	1
3. Prospective collection of data	2	2	2	2	2	2
4. Endpoints appropriate to the aim of the study	2	2	2	2	2	2
5. Unbiased assessment of the study endpoint	1	1	1	1	1	1
6. Follow-up period appropriate to the aim of the study	2	2	2	2	2	2
7. Loss to follow-up less than 5%	1	1	2	1	1	1
8. Prospective Calculation of the study size	0	0	0	0	0	0
Total	11	11	12	12	11	11
	Kim et al.[19]	Verhage[23]	Abdelgawad[24]	Ruokun[25]	Forberger[26]	Karaca[27]
(b) Cohort studies describing functional outcome in relation to fixation of the posterior fragment via the posterolateral approach						
1. A clearly stated aim	2	2	2	2	2	2
2. Inclusion of consecutive patients	2	2	0	1	2	1
3. Prospective collection of data	2	2	2	2	2	2
4. Endpoints appropriate to the aim of the study	2	2	1	2	2	2
5. Unbiased assessment of the study endpoint	1	1	1	0	1	1
6. Follow-up period appropriate to the aim of the study	2	1	1	2	1	2
7. Loss to follow-up less than 5%	1	2	1	1	0	1
8. Prospective Calculation of the study size	0	0	0	0	0	0
Total	12	12	8	10	10	11
	Huber[28]	Shi[29]	O'Connor[30]	Erdem[31]	Zhong[32]	
(c) Studies comparing different approaches for fixation of posterior fragments in trimalleolar fractures						
1. A clearly stated aim	2	2	2	2	2	
2. Inclusion of consecutive patients	1	2	2	2	2	
3. Prospective collection of data	2	2	2	2	2	
4. Endpoints appropriate to the aim of the study	2	2	2	2	2	
5. Unbiased assessment of the study endpoint	1	1	1	1	1	
6. Follow-up period appropriate to the aim of the study	1	2	2	2	2	
7. Loss to follow-up less than 5%	0	1	1	2	2	
8. Prospective Calculation of the study size	0	0	0	0	0	
9. An adequate control group	2	2	2	2	2	
10. Contemporary groups	0	2	2	2	2	
11. Baseline equivalence of groups	0	2	2	2	2	
12. Adequate statistical analyses	0	2	2	2	2	
Total	11	20	12	21	21	

Table 3: Studies evaluating functional outcome in relation to the size of the posterior malleolus fracture fragment.

Study(year of publication), included patients (n), study type.	FU (years, SD)	Fragment size (%)	AO 44B (n, % of total group)	Step-off (n, % of total group)	Fixated fragments (n, % of total group)	Fixated fragments (n), size of fragment (%)	non-fix fragments (n), mean size fragments	Function
Langenhuijsen(2002), n=57 retrospective cohort	6.9 (±1.6)	Range 8-55% Mean not listed	32 (56%)	18 (32%)	14 (25%)	n=1 in fragment >10% n=3 in fragment 10-25% n=10 in fragment >25%	n=23 in fragment <10% n=16 in fragment 10-25% n=4 in fragment >25%	Weber Score (5-20, 5 is excellent) <10% = 8 >10% = 8 (NS)
De Vries(2005), n=45 retrospective cohort	13 (range 2-24)	19.4% (range 3-49%)	Not listed	Not listed	11 (24%)	n=3 in fragment <25% n=8 in fragment >25%	n=29 in fragment <25% n=5 in fragment >25%	AFSS (0-150, 150 is excellent) non-fix 119 (85-115) fix 126 (63-149) (NS)
Mingo-Robinet (2011) n=45, retrospective cohort	2 (2-2)	Not listed	36 (80%)	12 (27%)	18 (40%)	n=18 (mean size not specified)	n=27 (mean size not specified)	AOFAS % excellent or good <25% = 89% >25% = 62% (p=0.05)
Xu(2012), n=102 retrospective cohort	2.8 (0.6-8.5 years)	19.1% (3-55%)	78 (76%)	24 (24%)	42 (41%)	n=42 (mean size 28.5%)	n=60 (mean size 12.5%)	AOFAS (0-100, 100 is excellent) >10% = 96 10-25% = 97 >25% = 94 (NS)
Drijfhout(2015), n=131 retrospective cohort	6.9 (2.5-15.9)	18%	92 (70%)	56 (43%)	24 (18%)	n=24 (mean size 29%)	n=103 (mean size 15%)	AAOS (0-100, 100 is excellent) <5%= 94 5-25% = 92 >25% = 88 (NS)
Evers(2015), n=42 retrospective cohort	2.5 (0.7-7.1)	Not listed	Not listed	Not listed	16 (35%)	n=16 (mean size not listed)	n=26 (mean size not listed)	AOFAS (0-100, 100 is excellent) <25% = 69 >25% = 71 (NS)

AFSS: Ankle Fracture Scoring System, AOFAS: American Orthopaedic Foot & Ankle Society, AAOS: American Academy of Orthopaedic Surgeons.

studies did not find a significant difference in functional outcome with respect to different posterior fragment size[6,9,10,21]. De Vries et al. compared functional outcome (SMFA) based on whether the fragment was fixated at all versus non-operative treatment[7]. They found no statistically significant differences in functional outcome when fixated fragments were compared with non-fixated fragments.

The relation between development of osteoarthritis was described by two of the six studies. These were large retrospective cohorts performed by Xu and Drijfhout with an mean follow-up of 2.8 and 6.9 years, respectively[9,10]. Both studies found no relation between fragment size and development of osteoarthritis. Xu reported, in his study, a higher incidence of intra-articular step-off in large posterior fragments. Persisting postoperative intra-articular step-off of the posterior fragment was associated with worse functional outcome and development of osteoarthritis. He, therefore, advised to anatomically reduce all posterior fragments with intra-articular involvement, especially fragments larger than 25% of the involved articular surface[10]. Drijfhout et al. found a persisting postoperative step-off in 42% of their fixated posterior fragments and, therefore, advocated to reduce all posterior fragments that involve more than 5% of the articular surface through a posterolateral approach[9].

How to fixate the posterior fragment

A total of 11 studies on this topic were included. Six of these studies (Table 4) described the functional or radiological results of a cohort of patients with fixated posterior fragments via the posterolateral approach after a mean follow-up ranging between 0.5 and 3.9 years. The mean fragment size in these studies varied from 19 to 44%. A persisting step-off after fixation was present in 0–17% of the cases[22-24]. Functional results were described as good-to-excellent in four studies[18,24-26]. Different outcome scores were used to describe functional outcome (measured with the AAOS, AOFAS, or SMFA) (Table 4). Complication rates varied from 0% to almost 16% in these studies. Wound infections, temporary numbness of the sural nerve area, and complex regional pain syndrome (CRPS) were the most common complications described.

Three studies compared fixation of the posterior malleolus fragment through open reduction and internal fixation via the posterolateral approach with reduction through ligamentotaxis followed by percutaneous anterior-to-posterior screw fixation (Table 5a). A persisting postoperative step-off was present in 8–17% of the cases in the ORIF group and in 17–73% of the percutaneous 'A to P' group[27-29]. Huber and Shi found a significant difference between the two different approaches[27,28]. Shi also found a significantly better function (AOFAS) in patients treated by open reduction and internal fixation compared to the percutaneous 'A to P' group. O'Connor did not find a significant difference between the two approaches. Erdem et al. compared functional and radiological outcome after ORIF via the posterolateral approach followed by either screw fixation or plate fixation

Table 4: Cohort studies describing functional outcome in relation to fixation of the posterior fragment via the posterolateral approach.

Study (year of publication), included patients (n), study type	FU (years, SD)	Mean fixated fragment size (%)	AO 44B (n,%)	postoperative step-off (ORIF posterolateral)	Function (ORIF posterolateral)
Forberger(2008), n=45, retrospective cohort	2.1 years	23%	35 (78%)	Not reported	AAOS (0-100, 100 is best) = 93
Abdelgawad(2012), n=12, retrospective cohort	0.5 years	Not reported	Not reported	17% (n=2)	Not reported
Ruokun(2014), n=32, retrospective cohort	3.2 years	19%	15 (47%)	9% (n=3)	AOFAS (0-100, 100 is best) = 92
Kim(2015), n=36*, retrospective cohort	3.3 years	43.6% (35.6-57.9%)	24 (67%)	Not reported	SMFA dysfunction index (0-100, 0 is best) = 8.2
Karaca(2016), n=57, retrospective cohort	3.9 years	21.1% (SD 6.2%)	38 (67%)	Not reported	AAOS (0-100, 100 is best) = 92
Verhage(2016), n=52, retrospective cohort	0.7 years	27% (10-52%)	41 (79%)	0% (n=0)	Not reported

FU: Follow-up, AO: Arbeitsgemeinschaft für Osteosynthesefragen, ORIF: Open Reduction and Internal Fixation, AAOS: American Academy of Orthopaedic Surgeons questionnaire,
AOFAS: American Orthopaedic Foot & Ankle Society questionnaire, SMFA: Short Musculoskeletal Function Assessment.
* Study performed with a lateral transmalleolar approach and miniscrews fixation.

Table 5: Studies comparing different approaches for fixation of posterior fragments in trimalleolar fractures:

Study(year of publication), included patients (n), Studytype	FU (years, SD)	Mean fixation fragment size (%)	AO 44B (n,%)	Step-off (n,%)	Fixation characteristics	Step-off	Function
(a) open reduction and internal fixation via the posterolateral approach versus reduction through ligamentotaxis followed by percutaneous anterior to posterior screw fixation							
Huber(1996), n=60, retrospective cohort	No FU	Not reported	Not reported	16 (27%)	AP: n=30 ORIF: n=30	AP: 73% (n=22) ORIF: 17% (n=5) *(p<0.001)*	Not reported
O'Connor(2015), n=27, retrospective cohort	3.7 years	Mean 22.2%	Not reported	4 (15%)	AP: n=11 ORIF: n=16	AP: 18% (n=2) ORIF: 13% (n=2) *(P=0.63)*	SMFA AP: 20.2 ORIF: 9.4 *(NS)*
Shi(2017), n=116, prospective cohort	1.7 years	All >25%	82 (71%)	14 (12%)	AP: n=52 ORIF: n=64	AP: 17% (n=9) ORIF: 8% (n=5) *(p=0.038)*	AOFAS AP: 80 ORIF: 87 *(p=0.034)*
(b) approaches and techniques with open reduction and internal fixation							
Erdem(2014), n=40, prospective cohort	3.2 years	>20%	36 (90%)	2 (5%)	ORIF plate: n=20 ORIF screws: n=20	ORIF plate: 5% (n=1) ORIF Screws: 5% (n=1) *(P>0.05)*	AOFAS ORIF plate: 95 ORIF screws: 94 *(NS)*
Zhong(2017), n=48*, retrospective cohort	1.8 years	mean 22.8%	35 (73%)	2 (4%)	PM: n=20 PL: n=28	PM: 5% (n=1) PL: 4% (n=1) *(P=0.665)*	AOFAS PM: 93 PL: 92 *(NS)*

FU: Follow-up, AO: Arbeitsgemeinschaft für Osteosynthesefragen, ORIF: Open Reduction and Internal Fixation, AOFAS: American Orthopaedic Foot & Ankle Society questionnaire. * posteromedial approach (PM) versus posterolateral approach (PL)

in a cohort of 40 patients (Table 5b)[30]. They found no significant difference between the two fixation methods after a mean follow-up of 3.2 years.

One study performed by Zhong et al. compared the functional and radiological outcome after ORIF via a posterolateral approach with ORIF via a posteromedial approach (Table 5)[17]. There was no significant difference in both postoperative step-off and functional outcome assessed by the AOFAS score after a mean follow-up of 1.8 years.

DISCUSSION

The main results of this study show that the size of the posterior fragment does not determine whether there is an indication for fixation the posterior malleolus fragment or not. A step-off, however, clearly needs to be reduced and the fragment anatomically fixated to prevent a redislocation. Concerning how to fixate the posterior malleolus, the results show that fixation of the posterior malleolus via an open posterolateral approach and screw or plate fixation seems to be radiologically and functionally superior to percutaneous anterior-to-posterior fixation. Where many studies have been published about the indications to fixate the posterior fragment, only a few have been published about the preferred method of fixation. In our literature search, no randomized clinical trials have been found and only two studies were prospective clinical cohort studies[28,30]. All other analysed studies were retrospective studies and described a total of four different fixation methods.

In total, six studies could be included that addressed the question which posterior fragments need to be fixated to improve functional outcome (Table 3). Four different patient-reported outcome measures for functional outcome were used in these studies, which renders a valid comparison impossible. There was only one study that found a significant difference in functional outcome based on fragment size. All other studies did not find any relation between the fragment sizes and functional outcome. Based on these results, a clear guideline for fixation of posterior fragments cannot be made. Even more so because of the retrospective character of all of these studies; they have the obvious disadvantages of possible selection and observer bias. The two studies with the least risk of bias according to the MINORS criteria described worse functional outcomes in case of persisting postoperative intra-articular step-off of the posterior fracture fragments[9,10]. Based on the findings described above, one may conclude that irrespective of the size of the posterior malleolar fragment, which may be as small as 5–10% of the articular surface; anatomical reduction needs to be achieved and maintained by fixation.

The fixation is needed to prevent redislocation and thus a persistent postoperative step-off.

Eleven studies were included to address the question how we should fixate the posterior fragment, once the need for fixation has been determined. Six publications de-

scribed a retrospective cohort of open reduced and internal fixated posterior fragments via the posterolateral approach. The results of these studies all showed good radiological and functional results[18,22-26]. Complication rates varied from 0% to almost 16% in the studies describing the posterolateral approach. In the literature, complication rates in the "common" approach to the ankle were reported to be 5–40%[31]. Complication rates in ankle fracture surgery via a posterolateral approach are, therefore, comparable with other approaches to the ankle. The methodological quality of the included studies was also moderate (MINORS score 8–11) with the obvious risk of selection and observer bias, which makes the findings difficult to interpret. We provisionally conclude that ORIF via the posterolateral approach seems to be promising, but a careful evaluation by means of prospective comparative studies is needed to further substantiate the current results.

Three comparative studies of the posterolateral and A-to-P approaches were found. These studies showed step-off (>1 or >2 mm) rates of 8–17%, respectively, in the open reduction and direct fixation group. Step-off (>1 or >2 mm) rates in anterior-to-posterior percutaneous fixation were significantly higher (17–73%)[27-29]. A direct posterolateral approach, therefore, seems to decrease postoperative persisting step-off. The studies of Huber and O'Connor were performed with plain radiographs only. Detection of a step-off smaller than 1 mm is, therefore, difficult, but may also prove clinically irrelevant. Nevertheless, CT-scan or even 3D-CT might be of value in detecting smaller fragment dislocations and step-offs[32-35].

Fixation of the posterior fragment through a posteromedial approach was described in only one study, and showed comparable functional and radiological outcomes in both approaches[17]. This study is particularly interesting because of its prospective design and showed that an anatomical reduction is probably more important than the way of fixation. More prospective comparative studies are needed to confirm this preliminary conclusion which is only based on a single study. According to the study of Erdem et al.[30], fixation with either plates and screws or lag screws alone does not seem to be of influence on the quality of reduction or functional outcome. Fixation of the posterior fragment can, therefore, be done with both fixation methods after anatomical reduction, best achieved via the posterolateral route.

Conclusion

According to the available literature, the size of the posterior malleolus fragment is not a clear indication for fixation or non-operative treatment of the posterior malleolus fragment. The anatomical intra-articular reduction of the fragment not leaving room for a step-off has far more impact on clinical outcome. Concerning the approach for fixation, the use of an open posterolateral approach for screw or plate fixation seems radiologically and functionally superior to percutaneous anterior-to-posterior fixation.

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Variation in posterior fragment fixation in the Netherlands, a nationwide study.

CHAPTER 4

ABSTRACT

Introduction

The treatment of the posterior fragment in trimalleolar fractures differs from hospital to hospital in the Netherlands. A nationwide survey was performed in order to evaluate the fixation criteria and practice variation.

Material and methods

An online cross-sectional survey amongst (orthopaedic) trauma surgeons was performed in the Netherlands. It consisted of three sections: a general section, a section showing preoperative images of six cases and a section with postoperative images of nine cases.

Results

A total of 151 surgeons completed the online survey. 45% of the respondents indicated to fixate the posterior fragment if smaller than 25% of the intra-articular surface. 48% preferred an open posterior approach to fixate the posterior fragment. There was good consensus in treatment for the two cases with Bartonicek type 4 fractures (operative treatment in 73% and 72% respectively). Little consensus was found for Bartonicek type 2 and 3 fractures (88% opted for operative treatment in one case but 89% for conservative treatment in the second case). Re-operation was mostly considered in cases with a step-off of more than 1mm (by 33- 38% of the respondents). There was great variation in the choice of treatment if only the size of the posterior fragment was considered. Other fixation criteria like postoperative step-off or instability after fixation of lateral and medial malleoli are taken into account. In cases where fixation was needed, a percutaneous approach and an open posterolateral approach were equally preferred.

Conclusion

There is much variation in treatment of the posterior malleolar fracture amongst orthopaedic and trauma surgeons in the Netherlands. The percutaneous approach and open posterolateral approach to fixate the posterior malleolar fracture seem to be equally used in the Netherlands. Still, there is no uniformity in treatment of the posterior malleolar fracture, especially for Bartonicek 2 and Bartonicek 3 fractures. Re-operation is considered by less than half of the surgeons in case of post-operative persistent step-off of more than 1mm.

INTRODUCTION

The optimal treatment of the posterior malleolus is a matter of debate amongst orthopaedic trauma surgeons. Traditionally the posterior malleolus was fixated if the posterior fragment size exceeded 25% to 33% of the intra-articular surface. Smaller fragments were only to be fixated in case of persistent instability after fixation of the lateral and medial malleolar fractures. Clinical studies published in the last decade have shown that worse functional and radiological outcome is predominantly associated with the fracture pattern and persistent postoperative step-off, also in case of medium-sized (10-25% of the involved intra-articular surface) posterior fragments[1-7]. Therefore, the size of the posterior fragment no longer seems the only determinant for fixation[1,2,8]. Up till now, it is unclear which posterior fragments are commonly fixated in daily practice and whether the recent publications have changed the indication for fixation of the posterior malleolus. An online survey was performed among orthopaedic and trauma surgeons in the Netherlands in order to evaluate the fixation criteria and practice variation in the Netherlands.

MATERIAL AND METHODS

Study design

A cross-sectional study was performed amongst orthopaedic surgeons and trauma surgeons in the Netherlands. A general invitation to participate in an online survey was sent out to all 565 Dutch trauma surgeons and orthopaedic surgeons by email between July 2017 and October 2017. We specifically invited surgeons with fracture care as part of their daily practice to reply. The Medical Ethics Committee South-West Netherlands approved of this study and decided that written informed consent was not required, since no patients were actively involved in the study and anonymized images were presented in the survey (protocol number 16-115).

Survey

The survey was designed by three authors. It consisted of three sections; the first section included eight questions about the respondents' general experience and preferences in fixation of the posterior malleolus. The second section presented the preoperative X-rays and CT-scans of six patients with a malleolar fracture, with questions regarding the indication for fixation of the posterior fragment. The posterior malleolar fractures in the cases were classified according to the Bartonicek classification by the authors (Figure 1). The classification was not shown to the respondents. In the third section, postoperative X-rays and CT-scans of nine cases were presented with questions about reduction

quality and about the need for reoperation. The surgeons were asked to determine the fragment size and the dislocation, and to state their fixation preferences, use of CT-scan pre and postoperatively and preferred treatment for each case. The cases in the second and third section of the survey were presented in random order.

Statistical analysis

Differences in working experience, fixation preference and treatment proposals between orthopaedic and trauma surgeons were analyzed using chi-square tests. A subgroup analysis with respect to working experience was performed using the ANOVA-test. A p-value of <0.05 was considered as statistically significant.

RESULTS

General characteristics and questions

A total of 151 surgeons, all with fracture surgery as their main speciality, completed the online survey (response rate 27%). Two thirds of the respondents (n=104; 69%) were trauma surgeons, the other 47 were orthopaedic surgeons. Approximately half of the respondents were experienced surgeons with at least 10 years' experience in fracture surgery (Table 1).

Table 1: Characteristics of 151 participating surgeons.

Surgeons' characteristics	n (%)
Speciality	
Trauma surgeon	104 (69)
Orthopaedic surgeon	47 (31)
Experience	
<5 years	21 (14)
5-10 years	50 (33)
>10 years	80 (53)
Hospital	
University	22 (15)
Top clinical/teaching	94 (62)
Local	35 (23)

All regions of the Netherlands and the majority of the hospitals in the Netherlands (62/81, 76,5%) were represented by the respondents in this survey. About 62% of the respondents were employed in top clinical hospitals, 23% in smaller local hospitals and 15% in academic centers (Table 1). Respondents were equally distributed over the 8 surgical training regions in the Netherlands.

Regarding the general question about fixation of the posterior malleolus fragment, 51% of the respondents stated that they fixate this fragment only if it involves more than 25% of the tibiotalar articular surface (Table 2). Another 45% of the respondents stated that they also fixate smaller fragments with or without posterior instability present after fixation of the lateral and medial malleolus. Four percent of the respondents based their decision to fixate the posterior fragment on other factors like gross displacement or medial extension of the fracture. Regarding the type of fixation of the posterior fragment, 39% of the respondents preferred a percutaneous A-P fixation, whereas 48% preferred an open reduction and internal fixation via the posterolateral approach. 13% of the respondents chose their approach dependent on the type of fracture. Most of the orthopaedic surgeons preferred a percutaneous A-P fixation whereas the majority of the trauma surgeons preferred an open reduction and internal fixation via the posterolateral approach (p=0.03). A preoperative CT-scan in order to determine the exact size of the posterior fragment in trimalleolar fractures was routinely made by 25% of the respondents. About 38% of the respondents did not accept any postoperative step-off (Table 2). Also surgeons with more than 10 years' experience accepted less postoperative step-off than surgeons with less than 5 years' experience (p=0.03).

Table 2: Surgeons' preferences in fixation of the posterior malleolus. Results are presented as number (%).

	Trauma surgeons (n=104)	Orthopaedic Surgeons (n=47)	Total (n=151)
Fixation in case of			
>25-33% of the intra-articular surface	53 (51)	24 (51)	77 (51)
>10% and persistent instability	30 (29)	18 (38)	48 (32)
>10%	18 (17)	2 (4)	20 (13)
Other criteria	3 (3)	3 (6)	6 (4)
Fixation preference*			
Percutaneous anterior to posterior	34 (33)	25 (53)	59 (39)
ORIF via a posterior approach	57 (55)	16 (34)	73 (48)
Other	13 (13)	6 (13)	19 (13)
Pre-operative CT-scan			
Always	29 (28)	9 (19)	38 (25)
If fragment >25%	27 (26)	18 (38)	45 (30)
If fragment >10%	24 (23)	13 (28)	37 (25)
Other	24 (23)	7 (15)	31 (21)
Acceptance of postoperative step-off			
Yes	32 (31)	25 (53)	57 (38)
Yes if <2mm	23 (22)	10 (21)	33 (22)
No	46 (44)	11 (23)	57 (38)
No, not if >1mm	3 (3)	1 (2)	4 (3)

*p=0.03, ORIF = open reduction and internal fixation

Indications for fixation and reduction quality – cases

In section 2 of the questionnaire, preoperative X-rays and CT-scans of six cases with a trimalleolar fracture were presented in order to determine need for and method of fixation. A brief description of the cases presented in section two and the corresponding survey results are shown in Table 3. Most consensus on fixation type was seen for cases #1and #2, both Bartonicek type 2 fractures which would be treated conservatively by 88% of the respondents (case #1) and treated by ORIF via the posterolateral approach by 89% of the respondents (case #2). There was also much consensus on treatment for the cases with a Bartonicek type 4 fracture (cases #5 and #6), who would be treated with ORIF via the posterolateral approach by 73% and 72% of the respondents, respectively. However, for the two other cases, a Bartonicek type 2 fracture (case #4) and a Bartonicek type 3 fracture (case #1) there was little consensus. These cases are described somewhat more extensively below:

In case #1 (a healthy, 62 year old woman), a medium-sized (approximately 20% of the involved articular surface) intra-articular posterior fragment with 1-2 mm step-off was visible (Bartonicek type 2, Haraguchi type 1, Figure 2). For this case, a percutaneous anterior to posterior fixation was preferred by 21% of the respondents and open reduction and internal fixation via the posterolateral approach was preferred by 37%. No fixation at all was preferred by 42% of the respondents.

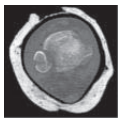
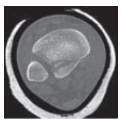
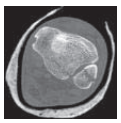
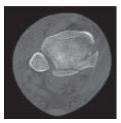
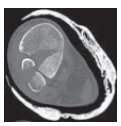
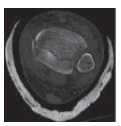
In case #4 (a healthy, 47 year old woman), a small-sized posterior fragment with medial extension and 2mm dislocation (Bartonicek type 3, Haraguchi type 2) was presented to the surgeons (Figure 3). The majority (57%) of the respondents would not fixate the posterior fragment, 7% preferred to fixate via a percutaneous anterior approach and 36% preferred a fixation via the posterolateral approach.

The respondents' opinion about reduction quality and the need for reoperation for the 9 postoperative cases is shown in Table 4. With increasing step-off, more respondents did not accept the postoperative results of fixation. Reoperation was considered by 1-7% of the respondents in case no step-off was present, depending on the presented case (Table 4). In case of 1mm step-off, reoperation was considered in 10-26% of the respondents. 20-79% of the respondents considered reoperation in case of persistent postoperative step-off of more than 1mm. Approximately 20% of the respondents would perform a postoperative CT scan in order to determine the quality of reduction.

DISCUSSION

Fixation of the posterior fragment in trimalleolar fractures remains a matter of debate amongst (orthopaedic) trauma surgeons. This is confirmed by most results of our survey.

Table 3: Preference of 151 surgeons on fixation for 6 cases with a malleolar fracture presented with pre-operative X-rays and CT-scans in the survey.

	No. of surgeons (%)	
Case 1, Bartonicek type 2.		
No fixation	121 (88)	
Percutaneous via anterior approach	6 (4)	
ORIF via posterolateral approach	10 (7)	
Case 2, Bartonicek type 2.		
No fixation	6 (4)	
Percutaneous via anterior approach	10 (7)	
ORIF via posterolateral approach	125 (89)	
Case 3, Bartonicek type 2.		
No fixation	56 (42)	
Percutaneous via anterior approach	28 (21)	
ORIF via posterolateral approach	50 (37)	
Case 4, Bartonicek type 3.		
No fixation	78 (57)	
Percutaneous via anterior approach	9 (7)	
ORIF via posterolateral approach	49 (36)	
Case 5, Bartonicek type 4.		
No fixation	1 (1)	
Percutaneous via anterior approach	34 (26)	
ORIF via posterolateral approach	96 (73)	
Case 6, Bartonicek type 4.		
No fixation	1 (1)	
Percutaneous via anterior approach	37 (27)	
ORIF via posterolateral approach	97 (72)	

There was considerable variation in choice of treatment if only the size of the posterior fragment was considered (Table 2). Second, the respondents preferred a percutaneous approach as often as an open posterolateral approach for the same cases (Table 2). Third, most variation in treatment preference was found for Bartonicek type 2 fractures (with medium-sized posterior fragments) and for Bartonicek type 3 fractures (with an additional posteromedial fragment). And last, reoperation was considered by 20-79% of the respondents in case of a postoperative step-off of more than 1mm. A step-off is therefore considered as an important indication for reoperation.

Table 4: Judgement of postoperative step-off for 9 malleolar fractures cases by 151 surgeons.

	No. of surgeons (%)
Case 1, Step-off 0mm	
Acceptable	33 (22)
Not acceptable	29 (19)
First CT	76 (50)
Other	13 (9)
Consider reoperation	11 (7)
Evaluation with CT	80 (53)

Case 2, Step-off 0mm	
Acceptable	114 (75)
Not acceptable	3 (2)
First CT	10 (7)
Other	24 (16)
Consider reoperation	2 (1)
Evaluation with CT	10 (7)

Case 3, Step-off 0mm	
Acceptable	135 (89)
Not acceptable	1 (1)
First CT	2 (1)
Other	13 (9)
Consider reoperation	2 (1)
Evaluation with CT	5 (3)

Case 4, Step-off 1mm	
Acceptable	55 (36)
Not acceptable	40 (26)
First CT	36 (24)
Other	20 (13)
Consider reoperation	15 (10)
Evaluation with CT	38 (25)

Case 5, Step-off 1mm	
Acceptable	44 (29)
Not acceptable	86 (57)
First CT	0 (0)
Other	21 (14)
Consider reoperation	40 (26)
Evaluation with CT	0 (0)

Table 4: Judgement of postoperative step-off for 9 malleolar fractures cases by 151 surgeons. (continued)

	No. of surgeons (%)	
Case 6, Step-off 2mm		
Acceptable	0 (0)	
Not acceptable	120 (79)	
First CT	13 (9)	
Other	18 (12)	
Consider reoperation	84 (56)	
Evaluation with CT	41 (27)	
Case 7, Step-off 2mm		
Acceptable	58 (38)	
Not acceptable	74 (49)	
First CT	1 (1)	
Other	18 (12)	
Consider reoperation	30 (20)	
Evaluation with CT	0 (0)	
Case 8, Step-off 3mm		
Acceptable	0 (0)	
Not acceptable	125 (83)	
First CT	13 (9)	
Other	13 (9)	
Consider reoperation	119 (79)	
Evaluation with CT	23 (15)	
Case 9, Step-off 3mm		
Acceptable	20 (13)	
Not acceptable	64 (42)	
First CT	49 (32)	
Other	18 (12)	
Consider reoperation	36 (24)	
Evaluation with CT	53 (35)	

Regarding fixation criteria, the focus seems to have shifted from fragment size to specific fracture characteristics such as loose intra-articular fragments, medial fracture extension, involvement of the fibular notch and step-off. Traditionally, treatment was based on plain radiographs. However, inter-observer agreement on this modality is poor[9,10] and nowadays preoperative CT-scanning is advised to obtain more detailed

information about the posterior malleolar fracture and to determine other specific fracture characteristics, particularly since these preoperative characteristics also influence radiological and functional outcome[11-13]. New protocols for 3-dimensional CT-scanning and evaluation of the volume of the posterior fracture are gaining more popularity, but are currently still reserved for research purposes[11-13]. The value of a standard preoperative CT-scan in daily practice is regarded of substantial importance. In this study 46% to 69% of the respondents would routinely perform a CT-scan in case of a relatively small-sized posterior fragment (>10%) or when in doubt of the fracture pattern. Only 31% would perform a CT-scan for preoperative planning in case of a fragment larger than 25% of the involved articular surface.

The variation in the literature concerning fixation of posterior fragments in trimalleolar fractures was also seen in our study. There was clearly no consensus in fixation criteria and preferred approach. While the literature does not indicate above which cut-off size a posterior fragment needs to be fixated[14-16], our respondents also varied greatly in their need for fixation based on fragment size.

In recent literature, different systems are described for classifying the posterior malleolar fragment, since size is not the only criterion to fixate the posterior fragment. In the classification systems of Haraguchi, and later Bartonicek fracture stage increases with increasing complexity (Figure 1). Fixation was advocated from stage 2 by Bartonicek, but has up till now not been shown to correlate with functional outcome in large cohort studies. In our study, there was great variation in preference on fixation of Bartonicek stage 2 and stage 3 fractures. Although these fractures would preferably be treated conservatively according to the older literature[16-18], a substantial part of our respondents is nowadays treating these fractures operatively, probably due to the posterolateral approach which is gaining popularity amongst orthopaedic trauma surgeons.

With increasing step-off more respondents did not accept the postoperative results. A comparison with current literature could not be made due to lacking studies on this specific topic. Post-operative CT-scan for evaluation of the intra-articular step-off was advocated by a substantial part of the respondents in our study (20%).

Study limitations

Although the response rate was relatively low (21%), still a large group of (orthopaedic) surgeons from throughout the country have filled out this survey. There is potential selection bias, because surgeons who are familiar with these types of fractures may be more eager to complete the survey. Other than that we feel that the respondents represent the (orthopaedic) trauma surgeons in the Netherlands well, regarding experience, type of hospital, and geographical distribution.

This study does not contain any functional data, with can been considered a limitation. But it was beyond the scope of this study to relate the pre- and post-operative

findings to functional outcome. This would require a different study set up. The radiography based expert opinion of this large group of surgeons however may be used in the management of these difficult fractures in daily setting.

Well-designed randomized clinical trials comparing the fixation criteria and approaches for the posterior malleolus are lacking. Practice variation could therefore offer indications for practical guidelines regarding the indications and way of fixation. As stated above, the threshold for fixation of the posterior malleolus in trimalleolar fractures has changed over time. Size of the posterior malleolar fragment is no longer considered the only important indicator, as it was before. Other criteria like fracture pattern on preoperative CT-scan and postoperative persistent step-off are important indicators for anatomical reduction and internal fixation. The posterolateral approach offers an anatomical reduction and stable fixation in nearly all cases[8,19]. The results for different cases in our study are heterogeneous but fixation of medium-sized and large-sized intra-incisural posterior fragments via mostly the posterolateral approach are considered by most respondents in our study. Fixation of smaller intra-incisural fragments and fragments with medial extension are more disputed amongst Dutch trauma surgeons. Although the posterolateral approach offers clear advantages in fixation of posterior fragments, it is surprising that only 48% of the surgeons did prefer this approach over a percutaneous anterior-posterior fixation.

CONCLUSION

There is much variation in treatment of the posterior malleolar fracture amongst orthopaedic and trauma surgeons in the Netherlands. The percutaneous approach and open posterolateral approach to fixate the posterior malleolar fracture seem to be equally used in the Netherlands. Still, there is no uniformity in treatment of the tertius fracture, especially when it concerns Bartonicek 2 and Bartonicek 3 fractures. Re-operation is considered by less than half of the surgeons in case of post-operative persistent step-off of more than 1mm.

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Influence of Fragment Size and Postoperative Joint Congruency on Long-Term Outcome of Posterior Malleolar Fractures.

CHAPTER 5

ABSTRACT

Background

One of the factors contributing to long-term outcome of posterior malleolar fractures is the development of osteoarthritis. Based on biomechanical, cadaveric, and small population studies, fixation of posterior malleolar fracture fragments (PMFFs) is usually performed when fragment size exceeds 25-33%. However, the influence of fragment size on long-term clinical and radiological outcome size remains unclear.

Methods

A retrospective cohort study of 131 patients treated for an isolated ankle fracture with involvement of the posterior malleolus was performed. Mean follow-up was 6.9 (range, 2.5-15.9) years. Patients were divided into groups depending on size of the fragment, small (<5%, n = 20), medium (5-25%, n = 86), or large (>25%, n = 25), and presence of step-off after operative treatment. We have compared functional outcome measures (AOFAS, AAOS), pain (VAS), and dorsiflexion restriction compared to the contralateral ankle and the incidence of osteoarthritis on X-ray.

Results

There were no non-unions, 56% of patients had no radiographic osteoarthritis, VAS was 10 of 100, and median clinical score was 90 of 100. More osteoarthritis occurred in ankle fractures with medium and large PMFFs compared to small fragments (small 16%, medium 48%, large 54%; P= .006). Also when comparing small with medium-sized fragments (P= .02), larger fragment size did not lead to a significantly decreased function (median AOFAS 95 vs 88, P= .16). If the PMFF size was >5%, osteoarthritis occurred more frequently when there was a postoperative step-off ≥1 mm in the tibiotalar joint surface (41% vs 61%, P= .02) (whether the posterior fragment had been fixed or not). In this group, fixing the PMFF did not influence development of osteoarthritis. However, in 42% of the cases with fixation of the fragment a postoperative step-off remained (vs 45% in the group without fixation).

Conclusion

Osteoarthritis is 1 component of long-term outcome of malleolar fractures, and the results of this study demonstrate that there was more radiographic osteoarthritis in patients with medium and large posterior fragments than in those with small fragments. Radiographic osteoarthritis also occurred more frequently when postoperative step-off was 1 mm or more, whether the posterior fragment was fixed or not. However, clinical scores were not different for these groups.

INTRODUCTION

Ankle fractures are relatively common with an incidence of roughly 187 fractures per 100 000 people each year[1]. In most cases (67%) there is a unimalleolar fracture (lateral or medial), in 25% a bimalleolar (lateral and medial) fracture and in the remaining 7% of the ankle fractures, there is also a fracture on the posterior side of the distal tibia (posterior malleolar fracture fragment [PMFF] or Volkmann's fragment)[2]. Ankle fractures with a PMFF tend to have less satisfactory clinical outcome when compared to uni- and bimalleolar ankle fractures[3].The long-term influence of fragment size and postoperative articular step-off of the PMFF has not been clearly demonstrated in the literature. There are many factors that contribute to long-term outcome: union, pain, range of motion, proprioception, osteoarthritis (clinical and radiographic), preinjury function, and expectation of the patient. Several authors have suggested that large PMFFs are associated with the development of osteoarthritis[4,5]. It has also been suggested that joint congruity is the important factor associated with superior clinical outcome after surgery[6,7]. Based on biomechanical, cadaveric, and small population studies, fixation of PMFFs is often performed only when fragment size exceeds 25% to 33% of the joint surface[3-5,7-13]. However, up to now, there has not been any strong clinical evidence for this practice. The question remains whether fragment size, anatomical restoration of the articular surface, and fixation of the PMFF influence the development of osteoarthritis and long-term functional outcome. We performed a retrospective clinical cohort study on all patients who had operative treatment for trimalleolar ankle fractures (ie, ankle fractures with a PMFF). In this study we chose to evaluate radiographic osteoarthritis, function, and pain.

Methods

A retrospective review of all patients between the age of 18 and 75 treated for an ankle fracture with a PMFF in the period 1996 to 2010 was performed with a minimum follow-up of 2.5 years. To collect these ankle fractures, we reviewed the X-rays of all operated isolated ankle fractures in this period (n = 564) in our clinic. Patients with impaired ankle function prior to the injury were excluded. A total of 249 patients were eligible for inclusion. All these patients were contacted by letter, followed by multiple attempts to contact them by phone. If contact information was missing or outdated, we tried to acquire recent information via the patients' general practitioner. After a mean follow-up of 6.9 (range, 2.5-15.9) years, 131 of 249 (53%) patients were seen at the outpatient clinic. Patient demographics can be found in Table 1. Patients were divided into 3 groups depending on the size of the fragment: small (<5% of the joint surface, n = 20), medium (5-25%, n = 86), and large (>25%, n = 25). The last 2 groups were subdivided into presence or absence of articular step-off (≥1 mm on lateral X-ray) after operative treatment.

Division also took place for short-term (2.5-5 years, n = 54) and long-term (>5 years, n = 77) follow-up. Those who agreed to participate in the study were seen at the outpatient clinic where physical examination was performed, X-rays (mortise, AP, and lateral radiographs) were taken, questionnaires were discussed, and medical history and general patient characteristics were evaluated.

Table 1: Patient demographics.

Demographic	
n	131
Follow-up (years)	6.9 (2.5-15.9)
Male	55 (42%)
Age	51 (24-74)
Diabetes	10 (8%)
Smoking	33 (25%)
BMI	28 (SD 5.2)
AO-44B	92 (70%)
AO-44C	39 (30%)
<5% PMFF	20 (15%)
5-25% PMFF	86 (66%)
>25% PMFF	25 (19%)
Medial malleolus fracture	95 (73%)

Abbreviations: BMI=Body Mass Index, PMFF=Posterior Malleolus Fracture Fragment

To describe fractures, we used the AO classification.

Posterior malleolar fragment size was characterized as the percentage of articular involvement as measured on the lateral preoperative X-ray. Persisting articular gap and step-off were measured on the postoperative radiographs. The Kellgren-Lawrence osteoarthritis (OA) classification[14] modified by Kijowski et al[15] was used to quantify the amount of OA on X-ray:

0. No radiographic findings of OA
1. Minute osteophytes of doubtful clinical significance
2. Definite osteophytes with unimpaired joint space
3. Definite osteophytes with moderate joint space narrowing
4. Definite osteophytes with severe joint space narrowing and subchondral sclerosis.

Kijowski et al[15] validated this classification when comparing the radiographic scaling to results found in arthroscopy. The AOFAS[16] (American Orthopaedic Foot & Ankle Society Ankle-Hindfoot Scale) and AAOS[17] (American Academy of Orthopedic Surgeons Foot and Ankle Questionnaire) questionnaires were used to asses functional outcome. Both have a range from 0 to 100, where 0 is the worst result possible. The AOFAS question-

naire consists of a questionnaire examining pain (40 points), function in daily living (28 points), range of motion (22 points), and ankle alignment (10 points). The AAOS questionnaire consists of 25 questions regarding experiences of disability of the ankle in the past week. The Visual Analog Scale (VAS) was used to quantify pain at present time (range 0: no pain to 100: unbearable pain). Finally, general physical examination of the ankle was performed. We examined range of motion, ankle stability, and stance. The restriction in dorsiflexion was compared to the contralateral, uninjured side, the difference was noted as dorsiflexion restriction. Therefore, a greater dorsiflexion restriction reflects a worse outcome. There was 1 patient who underwent ankle arthroplasty; in this case OA was graded 4.

SPSS (version 20) was used for data entry and statistical analysis. P-values < .05 were considered significant. When comparing multiple groups we have used the one-way ANOVA test.

RESULTS

There were no non-unions, 56% of patients had no OA on X-ray, and mean VAS was 10 of 100. Median AOFAS score was 90 with an excellent/good rate (>75) of 75%, and median AAOS was 91. With the numbers available, no significant difference could be detected in pain, function, or OA when comparing long- and short-term follow-up (Table 2). Also, no significant difference was found in function, pain, and range of motion when comparing patients with a small fragment size to those with medium and large fragments (AOFAS P= .16, AAOS P= .42, VAS P= .60, dorsiflexion restriction P= .58). However, patients with PMFFs larger than 5% developed more OA (P= .006). A postoperative articular step-off (≥1 mm) did not lead to a significant decrease in function (in medium and large fragments). However a step-off did lead to more radiographic OA (41% vs 61%, P= .015). Both groups had comparable mean PMFF size (18%) (Table 3). When divided for fragment size, step-off led to a significant difference in radiographic OA for medium fragments (36% vs 63% P= .006), but not for large fragments. Nor did step-off lead to a difference in functional outcome when divided in fragment size (Table 3). In 24 patients, the posterior fragment was fixed (mainly percutaneously in AP direction). There was no difference in OA or function compared to unfixed fragments. However, groups were obviously not comparable due to a difference in fragment size (15% no fixation vs 29% fixation). Further analyses of the fixation group revealed that in 42% (n = 10/24) of the cases a step-off ≥1 mm remained after fixation, versus 45% in the group without fixation. Table 4 shows the results of step-off ≥1 mm versus no step-off after fixation of the PMFF. Fragment size in these groups was comparable (29% vs 30% of articular surface). No significant differences were found in function or radiographic OA (50% vs 70% P= .33).

Table 2: Outcome variables for different groups.

	Total	2.5- to 5-year follow-up	>5 year follow-up	Small (<5%)	Medium (5-25%)	Large (>25%)
n	131	54	77	20	86	25
Osteoarthritis (OA)	55 (44%)	21 (40%)	35 (47%)	3 (16%)*	40 (48%)*	13 (54%)*
OA grade 0	70 (56%)	31 (60%)	39 (53%)	16 (84%)	43 (52%)	11 (46%)
OA grade 1	20 (16%)	7 (14%)	13 (18%)	3 (16%)	14 (17%)	3 (13%)
OA grade 2	11 (9%)	3 (6%)	8 (11%)	0	9 (11%)	2 (8%)
OA grade 3	17 (14%)	7 (14%)	10 (14%)	0	13 (16%)	4 (17%)
OA grade 4	8 (6%)	4 (8%)	4 (5%)	0	4 (5%)	4 (17%)
VAS pain (median)	10 (0-94)	8.5 (0-94)	10.5 (0-85)	8 (0-94)	5 (0-85)	16 (0-80)
AOFAS (median)	90 (11-100)	93 (14-100)	88 (11-100)	95 (14-100)	88 (11-100)	81 (20-100)
AAOS (median)	91 (13-100)	90.5 (16-100)	92 (13-100)	94 (37-100)	91.5 (13-100)	88 (16-100)
Dorsiflexion restriction	6.3 (SD 8.1)	7.2 (SD 9.7)	5.7 (SD 6.9)	5.5 (SD 9.6)	6.6 (SD 6.7)	6.2 (SD 11.6)

* More osteoarthritis in medium and large groups (p=0.006), also when comparing small and medium fragments (p=0.02)

Table 3: Outcome variables considering postoperative articular step-off (≥1mm).

	>5% fragment size		Medium (5-25%)		Large (>25%)	
	no step-off	step-off	no step-off	step-off	no step-off	step-off
n	51	56	40	43	11	13
Mean fragment size	18%	18%	13%	15%	33%	31%
Osteoarthritis (OA)	20 (41%)*	34 (61%)*	13 (36%)**	37 (63%)**	6 (38%)	7 (54%)
OA grade 0	32 (59%)	22 (39%)	27 (64%)	16 (37%)	5 (42%)	6 (46%)
OA grade 1	7 (13%)	10 (18%)	4 (10%)	10 (23%)	3 (25%)	0
OA grade 2	4 (7%)	7 (13%)	3 (7%)	6 (14%)	1 (8%)	1 (8%)
OA grade 3	5 (9%)	12 (21%)	4 (10%)	9 (21%)	1 (8%)	3 (23%)
OA grade 4	3 (6%)	5 (9%)	2 (5%)	2 (5%)	1 (8%)	3 (23%)
VAS-pain (median)	12 (0-80)	10 (0-85)	9 (0-68)	9 (0-85)	16 (1-80)	14 (0-54)
AOFAS (median)	90.5 (20-100)	86.5 (11-100)	91 (57-100)	87.5 (11-100)	90 (20-100)	81 (30-100)
AAOS (median)	90 (16-100)	91 (13-100)	91.5 (58-100)	89 (13-100)	84.5 (16-98)	92 (57-100)
Dorsiflexion restriction	6.2 (SD 8.6)	6.7 (SD 7.1)	6.7 (SD 7.1)	6.5 (SD 6.3)	4.5 (SD 13.4)	7.7 (SD 10.1)

* More OA in step-off group (p=0.015).
** Divided for fragment size, step-off led to a significant difference in radiographic OA for medium fragments (p=0.006).

DISCUSSION

This study found that the development of OA in ankle fractures with involvement of the posterior malleolus occurred more frequently in fractures with medium or large sized PMFFs. It also showed that OA develops more frequently when there is a remaining

postoperative articular step-off of 1 mm or more. Separately analyzing medium fragments, step-off also led to an increase of radiographic OA. The symptoms that occur in OA are mainly pain, stiffness, and fatigue of the ankle. It is often assumed OA is detected only after a very long time (at least 5 to 10 years)[18,19]. However, we see a similar amount of radiographic OA at short-term (2.5-5 years) and longer term (>5 years) follow-up. The median AOFAS score was 90 with an excellent/good rate of 75%, which is comparable to other studies on the long-term outcome after ankle fractures[11,20]. Contrary to what one might expect, AOFAS and AAOS scores were not significantly worse in the larger (>25%) fragment groups compared to the smaller fragments (<5%). This is contradictory to some other studies[11,21] but not uncommon[7].

This might be explained by the fact that the small fracture fragment group was relatively small and included 1 patient with very poor results with an AOFAS score of 14 and AAOS of 34. Excluding this patient would lead to much better results in the small fragment group. The median VAS pain score was 10 (range, 0-100), which is comparable to the findings of Xu et al[22]. The strength of this study is that this is the largest retrospective cohort study with long-term follow-up for this fracture type to date. Published studies on this topic in general have a small patient group[7,10,12,13] or short-term follow-up period[6,10,11], and therefore it is hard to draw conclusions from them. Weaknesses of this study are that a large percentage of the patients were lost to follow-up despite maximum effort of the researchers to contact all patients. However, the patients lost to follow-up, who were eligible for inclusion, were comparable to the included group concerning patient characteristics and fracture type as seen on initial and postoperative X-rays. The retrospective nature of this study contributes to a certain amount of bias. Another weakness was that posterior malleolar fragment size was measured on x-ray. Ferries et al[23] showed that conventional x-rays poorly assess posterior malleolar fragment size. In contrast, Buchler et al[24] concluded that fragment size is measured reliably on plain radiographs. It may be that fragment size is not a large determinant of clinical outcome. Alternatively, it may be that fragment size is a determinant of clinical outcome, however our method of measuring fragment size (one dimensional appearance on lateral plain radiograph) might be so inaccurate that the correlation may be lost because we are assessing truly large fragments as small or truly small fragments as large. In recent years, there has been an increase in interest in fixing PMFFs. Possibly because they expect less development of OA which would ultimately result in better function. As of yet, however, there is no good scientific evidence for this. Various authors report no difference in VAS and functional outcome when comparing fixed and unfixed posterior malleolar fragments, although the number of cases in these studies are low (11 to 14 patients)[7,13]. In accordance with current treatment, until recently in our institution, PMFFs were only fixated when ≥25% of the joint surface was affected and mainly by indirect reduction with percutaneously placed screws in anterior to posterior direction (Figure 1). A disad-

vantage of this technique is a frequent postoperative step-off ≥1 mm (42% in our study). More recently, therefore not done in this series, the medium (5-25%) fragments are often fixated. Usually by an open reduction via a posterolateral approach using an antiglide plate and/or screws inserted in the PA direction (Figure 2). With an open approach of the PMFF it is usually possible to create an anatomical joint surface thus theoretically leading to less OA.

In a recent patient-series in our clinic, using a posterolateral approach to fix posterior malleolar fractures, 28 of 30 patients did not have a postoperative step-off, and in the remaining 2 cases there was a step-off of just 1 mm[25]. Table 4 shows the results of step-off ≥1 mm versus no step-off after fixation of the PMFF. Fragment size in these groups was comparable. OA, function, and pain were not significantly different when there was an anatomical fixation of the PMFF. However this might be due to the small group size. We found no differences in outcome between medium (5-25%) and large (>25%) PMFF groups. We therefore assume that anatomical fixation of posterior malleolar fractures fragments between 5% and 25% may lead to improved outcome in addition to fragments larger than 25% as is commonly assumed[3,12,20]. Considering this, we might conclude that more scientific evidence is needed to confirm that anatomical fixation of PMFF larger than 5% will lead to less OA and improved ankle function. In 2014, we started a multicenter randomized controlled trial on the treatment of AO type 44-B ankle fractures with a PMFF size between 5% and 25%. In group 1 the fragment will be reduced and fixed via open posterolateral approach; in group 2 the fragment will not be fixed (POSTFIX-trial). Fragment size and step-off will be measured by CT-scan (both pre- and postoperatively).

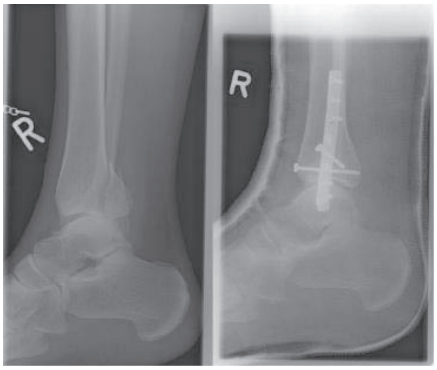

Figure 1: Ankle fracture involving posterior malleolar fracture fragment fixed by indirect repositioning with percutaneously placed screws in AP direction.

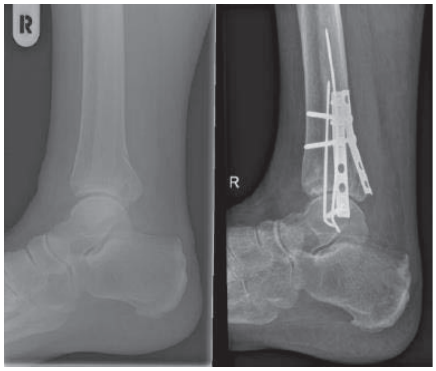

Figure 2: Ankle fracture with posterior malleolar fracture fragment fixed by direct repositioning with antiglade plate in PA direction via posterolateral approach.

Table 4: Outcome variables regarding fixation of the posterior malleolar fracture fragment (PMFF), with and without postoperative articular step-off (≥1mm).

	Fixation	No fixation	No step-off after fixation	Step-off ≥1mm after fixation
n	83	24	14	10
Mean fragment size	15%	29%	29%	30%
Osteoarthritis (OA)	39 (49%)	14 (60%)	7 (50%)*	7 (70%)
OA grade 0	44 (51%)	10 (40%)	7 (50%)	3 (30%)
OA grade 1	13 (15%)	4 (16%)	3 (21%)	1 (10%)
OA grade 2	10 (11%)	1 (4%)	0	1 (10%)
OA grade 3	11 (13%)	6 (25%)	3 (21%)	3 (30%)
OA grade 4	5 (6%)	3 (12%)	1 (7%)	2 (20%)
VAS-pain (median)	9 (0-85)	14 (0-80)	15 (1-80)	4 (0-42)
AOFAS (median)	88 (11-100)	87.5 (20-100)	90 (20-100)	82 (30-100)
AAOS (median)	91 (13-100)	90 (16-100)	86 (16-98)	92.5 (62-100)
Dorsiflexion restriction	6.2 (SD 6.8)	7.5 (SD 11)	4.6 (SD 11.6)*	11.7 (SD 9.3)*

*Step-off after fixation of PMFF did not lead to a significant (p=0.34) increase in development of OA or dorsiflexion restriction (p=0.15)

CONCLUSION

Our study is the largest long-term cohort study on ankle fractures with involvement of the posterior malleolus. Outcome was generally good. On average, medium, and large fragments have increased radiographic OA at 7 years. A non-anatomical restoration of the tibiotalar joint surface (whether or not fixed) was a risk factor for developing OA. Contrary to popular belief this does apply not only to PMFFs larger than 25% of the articular surface, but also to those 5-25%. However, clinical scores were not different for these groups. Anatomical reduction and fixation are usually not achieved closed or percutaneously and therefore might lead to increased development of OA.

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Persistent postoperative step-off of the posterior malleolus leads to higher incidence of post-traumatic osteoarthritis in trimalleolar fractures.

CHAPTER 6

ABSTRACT

Background

Traditionally, size of the posterior fragment is considered the most important indicator for fixation in trimalleolar fractures. It remains unclear which factors contribute to worse functional and radiological outcome. This study was designed to determine predictors for the development of posttraumatic osteoarthritis and worse functional outcome in trimalleolar fractures.

Methods

This retrospective cohort study evaluated outcomes of 169 patients with a trimalleolar fracture treated between 1996 and 2013 in a level-1 trauma hospital in the Netherlands after a mean follow-up of 6.3 (range 2.4 to 15.9) years. The average fragment size was 17%. Twenty patients had a posterior fragment smaller than 5% of the intra-articular surface, 119 patients a fragment of 5–25% and 30 patients a posterior fragment larger than 25%. In total, 39 patients (23%) underwent fixation of the posterior fragment.

Results

Clinical union was achieved in all 169 patients. The median AOFAS score after follow-up was 93 (interquartile range 76–100) and the median AAOS score was 92 (interquartile range 81–98). A persistent postoperative step-off larger than 1 mm was found in 65 patients (39%) and osteoarthritis was present in 49 patients (30%). Higher age and post-operative step-off > 1 mm were independent, significant risk factors for the development of osteoarthritis. Osteoarthritis and BMI were independent, significant risk factors for worse functional outcome.

Conclusion

It is advisable to correct intra-articular step-off of intraarticular posterior malleolar fragments to reduce the risk of developing osteoarthritis and, consequently, the risk of worse functional outcome after long-term follow-up.

INTRODUCTION

The optimal treatment of the posterior malleolus in trimalleolar fractures is a matter of debate amongst orthopaedic trauma surgeons. According to several studies, a fracture of the posterior malleolus has a negative influence on the functional outcome[1-4]. Traditionally, the size of the posterior malleolar fracture fragment is considered the most important indicator for fixation. This is based on the results of biomechanical cadaver studies and several retrospective cohort studies[1,5-10]. Recent studies showed that both the postoperative position of the posterior malleolar fragment and the postoperative joint congruency are important predictors for functional outcome[11-13]. According to the current guidelines of the Arbeitsgemeinschaft für Osteosynthesefragen (AO) for the treatment of posterior malleolar fragments, fixation of the posterior fragment is not necessary if the fragment is smaller than 25% of the involved intraarticular surface AND if the joint is stable after fixation of the lateral and medial malleolus. Fixation with lag screws is advised if the posterior fragment is larger than 25% of the involved intra-articular surface and long proximal extension is absent. The use of an additional buttress plate is advised in case of a large posterior fragment (> 25%) and long proximal extension. Recently, three CT-based classification systems of posterior malleolar fractures were developed[14-16]. With increasing stage the need for anatomical reduction and fixation increases to restore intra-articular unevenness. Several authors, therefore, advocate a lower threshold for fixating the posterior malleolus[16-18]. The recommendations in these studies however are based on CT-scans only and not on patient-reported functional outcome. Due to changing indications, the fixation of the posterior fragment via a posterolateral approach is gaining popularity[12,19-21]. Open reduction and internal fixation of the posterior fragment are assumed to reduce intra-articular step-off better than reduction by ligamentotaxis with additional percutaneous anterior-to-posterior screw fixation[12,17,18]. In addition, the posterolateral approach enables the removal of intra-articular loose fragments that may interfere with anatomical reduction.

As stated above, no clear guidelines based on large clinical studies about when and how to fixate the posterior fragment in trimalleolar fractures are available. This large retrospective study was designed to determine predictors for the development of post-traumatic osteoarthritis and worse functional outcome in trimalleolar fractures.

MATERIALS AND METHODS

We conducted a retrospective study of all patients with a posterior malleolar fracture who were operatively treated between 1996 and 2013 in a level 1 trauma hospital (Haaglanden Medical Center, The Hague, The Netherlands) with a follow-up of minimally two

years. Since 2011, we gradually changed our operative strategy to an open reduction and internal fixation via the posterolateral approach. The study was approved by the institutional medical ethics review board (protocol number NL55397.098.15). All patients provided written informed consent before study participation. Only patients treated with open reduction and internal fixation of an isolated trimalleolar fracture older than 18 years at date of trauma and younger than 75 years at date of follow-up were included. Patients with impaired ankle function prior to injury were excluded. Also patients with an isolated injury of the posterior malleolus were excluded.

All 327 eligible patients in the study period 1996–2013 were invited to participate by letter. Patients who did not respond were contacted by phone. If contact data were missing or outdated, we tried to acquire the recent contact data via the patient's general practitioner. Patients who agreed to participate in the study were physically examined at the outpatient clinic. Range of Motion, ankle stability and stance of both feet were measured. The difference in dorsiflexion between the two ankles was noted as dorsiflexion restriction. In addition the patients completed a questionnaire and lateral, AP and mortise X-rays were performed. All fractures were classified according to the AO- and Lauge-Hansen classification by two independent observers. All fractures had both lateral and posterior malleolar fractures and, in most cases, also a medial malleolar fracture. Posterior fragment size was measured on the lateral preoperative X-ray (Fig. 1). Persistent postoperative articular step-off and gap were measured on postoperative lateral X-rays.

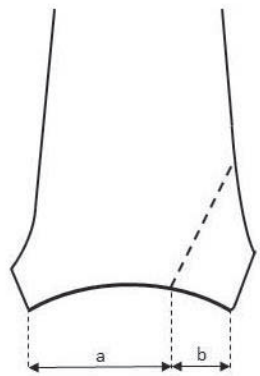

Figure 1: Measurement of posterior malleolus on lateral radiograph, with size defined as: b/(a+b).

Anatomical reduction was defined as a step-off or gap of 1 mm or less. Post-traumatic osteoarthritis was measured on X-ray at time of follow-up and classified according to Domic et al.[19], with 0 indicating a normal joint, 1 indicating osteophytes without joint space narrowing, 2 indicating presence of osteophytes with joint space narrowing and 3 indicating severe joint space narrowing or absence of joint space. The AAOS (American Academy of Orthopedic Surgeons Foot and Ankle questionnaire)[20] and AOFAS (American Orthopaedic Foot and Ankle Society Ankle-Hindfoot scale)[21] questionnaires were used to assess functional outcome. Both questionnaires are scored on a scale from 0 (worst possible function) to 100 (best possible function). A Visual Analogue Scale (VAS) was used to assess pain at time of follow-up on a scale from 0 (no pain) to 10 (worst imaginable pain).

IBM SPSS Statistics for Windows version 22 (IBM Corp., Armonk, NY, USA) was used for data entry and statistical analysis. Baseline and outcome data of the study group were described using summary statistics. To identify risk factors for the development of osteoarthritis, logistic regression analysis was performed with age, BMI, time to follow-up, fragment size, fragment fixation, postoperative step-off > 1 mm and postoperative gap > 1 mm as independent variables. To identify risk factors for a poor functional outcome, linear regression analyses were performed with the same patient-related factors and presence of osteoarthritis as independent variables and functional outcome (AAOS and AOFAS) as dependent variables. First, univariable regression analyses were performed. Then, the factors with a univariable association of $p < 0.20$ with the outcome were combined in the multivariable analysis. p-values < 0.05 were considered statistically significant.

Table 1: Patient characteristics.

Number of patients	**169**
Follow-up in years, mean (range)	6.3 (2.4-15.9)
Age in years, mean (SD)	52.3 (13.0)
Male, n (%)	67 (39.6)
Smoking, n (%)	41 (24.3)
Diabetes (n,%)	12 (7.1)
BMI, mean (SD)	27.6 (5.2)
Lauge-Hansen classification, n (%)	
PA3	9 (5.3)
SE3	6 (3.6)
SE4	106 (62.7)
PE4	48 (28.4)
AO classification, n (%)	
AO-44B	122 (72.2)
AO-44C	47 (27.8)
PMFF size in %, mean (SD)	16.9 (10.1)
PMFF size, n (%)	
<5%	20 (11.8)
5-25%	119 (70.4)
>25%	30 (17.8)
Medial Malleolus Fracture, n (%)	121 (71.6)
PMFF Fixation, n (%)	
No fixation	130 (76.9)
Fixation 'A to P'	16 (9.5)
ORIF	23 (13.6)

SD=standard deviation, BMI=body mass index, PMFF=posterior malleolar fracture fragment, ORIF=open reduction and internal fixation.

RESULTS

Patient characteristics

In this study, 169 patients (52% of the 327 eligible patients) were evaluated at the outpatient clinic with a mean follow-up of 6.3 years (range 2.4–15.9 years). The characteristics at baseline are presented in Table 1. The average fragment size was 17% with range from 3 to 44%. Twenty patients (12%) had a posterior fragment smaller than 5% of the intraarticular surface, 119 patients (70%) a fragment between 5 and 25% and 30 patients (18%) a posterior fragment larger than 25%. In total, 39 patients (23%) underwent fixation of the posterior fragment, 23 patients of whom underwent open reduction and internal fixation via a posterolateral approach. None of the posterior fragments with a size < 5% were fixated, whereas this was done in 15 (13%) of the 5–25% sized fragments and in 24 (80%) of the fragments with a size > 25% ($p < 0.0001$). Fixation took place in 39 cases (23%). Anatomical reduction of the posterior fragment was only achieved in 23 out of 39 patients (69%; ORIF 7/23; AP 9/16). If persistent syndesmotic instability was present after fixation, a syndesmotic positioning screw was placed to stabilize the distal tibiofibular syndesmosis. All fractures were clinically stable after fixation.

Clinical outcome

Clinical union was achieved in all 169 patients. A persistent postoperative step-off larger than 1 mm was found in 65 patients (39%) of the cases and a postoperative gap larger than 1 mm was found in 58 (35%) of the cases. Osteoarthritis was present in 49 patients (30%), no re-operations due to osteoarthritis were performed during the follow-up period.

The median AOFAS score after follow-up was 93 (interquartile range [IQR] 76–100) and the median AAOS score was 92 (IQR 81–98) (Table 2). The median pain score after follow-up was 9 (IQR 0–25).

Risk factors for osteoarthritis

In the univariable analyses, age, fragment size, fragment fixation and postoperative step-off > 1 mm and gap > 1 mm were potential risk factors for osteoarthritis ($p < 0.20$; Table 3), and were entered in the multivariable logistic regression model. Two independent and statistically significant risk factors for development of osteoarthritis were identified: higher age (odds ratio [OR] per one-year increase 1.03, 95% confidence interval [CI] 1.001 to 1.06, $p = 0.04$) and postoperative step-off > 1 mm (OR 4.16, 95% CI 1.50–11.57, $p = 0.006$). Fragment size, fragment fixation and postoperative gap > 1 mm were not associated with osteoarthritis after follow-up in the multivariable model ($p > 0.05$; Table 3).

Table 2: Functional and radiological outcome.

AOFAS, median (IQR)	**93 (76-100)**
AAOS, median (IQR)	92 (81-98)
VAS pain, median (IQR)	9 (0-25)
Dorsiflexion restriction in °, median (IQR)	5 (0-10)
Step-off >1mm, n (%)	65 (39)
Gap >1mm. n (%)	58 (35)
Osteoarthritis grade, n (%)	
0	113 (70)
1	23 (14)
2	18 (11)
3	8 (5)

Risk factors for worse functional outcome

In the univariable analyses, BMI, fragment size and presence of osteoarthritis were potential risk factors ($p < 0.20$) for lower scores for both the AAOS and AOFAS. Fragment fixation was a potential risk factor for lower AOFAS scores, but not for lower AAOS scores (Table 4). In the multivariable analyses, the presence of osteoarthritis was a statistically significant risk factor for a worse functional outcome: osteoarthritis was associated with a 12.55 points lower AAOS score (95% CI 5.99–19.11, $p < 0.0001$) and with a 15.43 points lower AOFAS score (95% CI 8.06–22.80, $p < 0.0001$). BMI was a statistically significant risk factor for worse AAOS score: a 1-point increase in BMI was associated with a decrease of 0.77 points on the AAOS scale (95% CI 0.21–1.33, $p = 0.008$). In the multivariable model for AOFAS, BMI was borderline significant ($p = 0.06$, Table 4).

Table 3: Risk factors for development of osteoarthritis. Results are presented as odds ratio with 95% confidence interval and p-value.

Factor	**Univariable analysis**	**Multivariable analysis**
Age (years)	1.04 (1.01 to 1.07; p=0.01)	1.03 (1.00 to 1.06, p=0.04)
BMI	1.02 (0.95 to 1.10, p=62)	(not entered)
Time to follow-up (years)	1.03 (0.94 to 1.14, p=0.50)	(not entered)
PMFF size (%)	1.03 (1.00 to 1.07, p=0.05)	1.00 (0.96 to 1.05, p=0.95)
PMFF fixation	2.03 (0.95 to 4.32, p=0.07)	2.09 (0.70 to 6.29, p=0.19)
Postoperative step-off >1mm	3.27 (1.63 to 6.56, p=0.001)	4.16 (1.50 to 11.57, p=0.006)
Postoperative gap >1mm	1.82 (0.91 to 3.62, p=0.09)	0.80 (0.28 to 2.26, p=0.67)

Table 4: Risk factors for worse functional outcome measured with (A) AAOS and (B) AOFAS.
Results are presented as difference in functional outcome score with 95% confidence interval and p-value.

(A) AAOS

Factor	Univariable analysis	Multivariable analysis
Age (years)	-0.06 (-0.26 to 0.13; p=0.53)	(not entered)
BMI	-0.80 (-1.39 to -0.20, p=0.009)	-0.77 (-1.33 to -0.21, p=0.008)
Time to follow-up (years)	-0.05 (-0.42 to 0.09, p=0.89)	(not entered)
PMFF size (%)	-0.17 (-0.51 to 0.08, p=0.19)	-0.16 (-0.46 to 0.14, p=0.28)
PMFF fixation	-3.78 (-9.96 to 2.40, p=0.23)	(not entered)
Postoperative step-off >1mm	-2.68 (-7.99 to 2.63, p=0.32)	(not entered)
Postoperative gap >1mm	-0.37 (-5.84 to 5.11, p=0.90)	(not entered)
Presence of osteoarthritis	-12.55 (-17.85 to -7.25, p<0.0001)	-12.55 (-19.11 to -5.99, p<0.0001)

(B) AOFAS

Factor	Univariable analysis	Multivariable analysis
Age (years)	-0.08 (-0.31 to 0.15; p=0.49)	(not entered)
BMI	-0.66 (-1.35 to 0.03, p=0.06)	-0.62 (-1.27 to 0.02, p=0.06)
Time to follow-up (years)	-0.36 (-1.24 to 0.52, p=0.43)	(not entered)
PMFF size (%)	-0.22 (-0.51 to 0.08, p=0.15)	-0.17 (-0.60 to 0.26, p=0.43)
PMFF fixation	-6.54 (-13.58 to 0.50, p=0.07)	-1.52 (-12.34 to 9.30, p=0.78)
Postoperative step-off >1mm	-3.18 (-9.22 to 2.87, p=0.30)	(not entered)
Postoperative gap >1mm	-1.87 (-8.05 to 4.31, p=0.55)	(not entered)
Presence of osteoarthritis	-15.89 (-21.94 to -9.85, p<0.0001)	-15.43 (-22.80 to -8.06, p<0.0001)

DISCUSSION

Optimal treatment of trimalleolar fractures, especially treatment of the posterior malleolus in trimalleolar fractures remains a matter of debate amongst orthopaedic trauma surgeons. For a long period, the size of the posterior fragment was the decisive factor for reduction and fixation of the fragment. Traditionally, this is done for fragments larger than one quarter or one-third of the articular surface via ligamentotaxis followed by percutaneous anterior-to-posterior screw placement. In clinical practice, however, it is difficult to estimate the size of the posterior fragment on lateral photographs and even on 2D CT-scans [14,16,22,23]. This retrospective study showed that postoperative step off (> 1 mm) and age were independent risk factors for the development of osteoarthritis. The presence of osteoarthritis and a high BMI were identified as independent and significant risk factors for worse functional outcome. Notably, both the size and the fixation of the posterior fragment were associated neither with the development of osteoarthritis nor with functional outcome. Since postoperative intra-articular step-off is an independent risk factor for osteoarthritis irrespective of fragment size on lateral X-rays, it seems advisable to anatomically reduce and fixate all intra-articular posterior fragments. We

already know from previous studies that fractures without articular involvement do not need anatomical reduction and fixation. Anatomical reduction and fixation of these fragments do not improve posterior stability and the risk of osteoarthritis is comparable with uni- or bimalleolar fractures without involvement of the posterior malleolus[5,9]. Fixation of intra-articular posterior malleolar fractures was not identified as an independent protective factor for an adverse outcome in this study. Probably because of the 16 anterior to posterior fixated fragments, which leads to a higher risk of non-anatomical reduction. Since a few years, the posterolateral approach is gaining more and more popularity amongst orthopaedic surgeons. An anatomical reduction and stable fixation via this approach is more easily to achieve and leads to a reduction of persistent post-operative step-off[24,25]. A postoperative gap (> 1 mm) was not identified as independent risk factor for an adverse outcome in our analysis. Closing the gap seems, therefore, less important than correction of the postoperative step-off. The strongest point of this study is the large cohort with a mean follow-up time of more than 6 years. Up to now, this is the largest cohort of trimalleolar fractures describing functional outcome and development of osteoarthritis as outcome parameters. Previously published studies on this topic included smaller cohorts[1,3,7,8,11,13] or described a shorter follow-up period[26-28] which makes it more difficult to draw strong conclusions.

A limitation of this study is the relatively large part of the eligible patients were lost to follow-up or did not want to participate in the study. In addition, the retrospective design of this study may have led to an observer bias. Another important limitation concerns the measurement of posterior malleolar fragment size on lateral preoperative X-rays and the measurement of postoperative step-off on lateral X-rays. Some articles that were published in the last few years have reported that the interobserver agreement of fragment size on lateral X-rays is poor[29,30] and even CT-scanning is not reliable to compare different fragment sizes[22,23]. Therefore, the possible relation between fragment size and functional outcome may have been missed in our study because of inaccurate measurements. In our opinion, however, the measurement on lateral X-rays is good enough to distinguish a truly intra-articular fracture from a small extra-articular fracture. Other studies suggest an important role of fracture localization and geometry instead of fracture size as diagnosed on CT-scan[14-16,31]. Anatomical reduction and posterior fragment fixation is advocated for nearly all posterior fractures except the small extra-incisural fractures[31,32]. These recommendations however are only derived from CT-based studies without any functional outcome. Unfortunately, we could not relate these different posterior fracture characteristics due to lack of a large part of pre-operative CT-scans. Clear indications for fixation of the posterior malleolus based on clinical studies are lacking in the current literature. With respect to the size of the posterior malleolus, the cut-off value above which the posterior fragment should be fixated is at least inconclusive. A number of biomechanical cadaveric studies have been

performed without providing one clear conclusion[5,6,9,10,33]. Comparative clinical studies are also inconsistent in their results. Most authors of clinical studies agree that operative treatment is indicated for large posterior fragments and prefer conservative treatment in small avulsion fractures[1,7,11,13,14,24]. Although there is some evidence that open reduction and internal fixation of posterior fragments up to 25% lead to better results than conservative treatment, this statement is at least controversial[1,7,8,11,13,27]. All of these studies have limitations due to their retrospective design. On the basis of these publications the AO advises fixation of the posterior fragment only in case of a large fragment (> 25%) or for smaller fragments with persistent instability after fixation of both the lateral and medial malleolus. This largest retrospective study involving trimalleolar fractures up to now suggests that size of the posterior fragment is not an independent risk factor for both development of osteoarthritis and functional outcome. Postoperative step-off is an important risk factor that can be influenced to reduce the risk of post-traumatic osteoarthritis and consequently increase the probability of a good functional outcome on the long term. In addition, reducing obesity may help to improve functional outcome. Open reduction and internal fixation via the posterolateral approach leads to a decrease in postoperative step-off compared to closed reduction through ligamentotaxis followed by anterior to posterior screw fixation[12,17,18]. It is, therefore, advisable to treat posterior fragments via a posterolateral approach to correct intra-articular step-off. At this moment the POSTFIX study (RCT) is enrolled in our hospitals to prove this statement[34].

CONCLUSION

Increasing age and persistent postoperative step-off are independent risk factors in the development of post-traumatic osteoarthritis in patients with trimalleolar fractures. In turn, development of osteoarthritis as well as high BMI are associated with worse functional outcome. Of these, persistent postoperative step-off is the only risk factor that can be influenced by surgeons. Therefore, it is advisable to correct intra-articular step-off of intra-articular posterior malleolar fragments.

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Open reduction and internal fixation of posterior malleolar fractures using the posterolateral approach.

CHAPTER 7

ABSTRACT

Aims

Involvement of the posterior malleolus in fractures of the ankle probably adversely affects the functional outcome and may be associated with the development of post-traumatic osteoarthritis. Anatomical reduction is a predictor of a successful outcome. The purpose of this study was to describe the technique and short-term outcome of patients with trimalleolar fractures, who were treated surgically using a posterolateral approach in our hospital between 2010 and 2014.

Patients and Methods

The study involved 52 patients. Their mean age was 49 years (22 to 79). There were 41 (79%) AO 44B-type and 11 (21%) 44C-type fractures. The mean size of the posterior fragment was 27% (10% to 52%) of the tibiotalar joint surface.

Results

Reduction was anatomical in all patients with a residual step in the articular surface of ≤1 mm. In nine of the C-type fractures (82%), the syndesmosis was stable after fixation of the posterior fragment and a syndesmosis screw was not required. Apart from one superficial wound infection, there were no wound healing problems. At a mean radiological follow-up of 34 weeks (seven to 131), one patient with a 44C-type fracture had widening of the syndesmosis which required further surgery.

Conclusion

We conclude that the posterolateral surgical approach to the ankle gives adequate access to the posterior malleolus, allowing its anatomical reduction and stable fixation: it has few complications.

Take home message

Fixation of the posterior malleolus in trimalleolar fractures can be easily done via the posterolateral approach whereby anatomical reduction and stable fixation can be reached due to adequate visualisation of the fracture.

INTRODUCTION

The treatment of fractures of the ankle which involve the posterior malleolus remains controversial. Although there is some recent evidence that a fracture of the posterior malleolus will result in an increased incidence of posttraumatic osteoarthritis(OA) and therefore a worse functional outcome, there is no agreement as to how such fractures should be treated[1-3]. Usually the posterior malleolus is only fixed if the fragment exceeds 25% of the articular surface or if there is instability of the ankle joint after fixation of the medial and lateral malleoli[4,5]. It has recently been shown that anatomical reduction is an important predictor of a successful functional outcome[1-6]. The disadvantages of percutaneous reduction with anterior to posterior (A to P) screw fixation of the posterior malleolus are that anatomical reduction is more difficult due to the interposition of soft tissue or loose bony fragments, that it is hard to assess reduction satisfactorily using an image intensifier, and that the fixation of small or comminuted fragments is technically difficult. Incomplete reduction leads to a residual step in the articular surface[2,6]. A recently published cohort study from our hospital showed a persisting articular step of > 1 mm in 42% of 131 cases after percutaneous reduction and A to P screw fixation of the posterior malleolus[2]. We favour open, anatomical reduction of posterior malleolar fragments using a posterolateral approach with the patient in a prone position. In this article we describe the technique and its short-term outcome in 52 patients with a trimalleolar fracture who were treated using this approach.

PATIENTS AND METHODS

Between 2010 and 2014, 52 patients with a trimalleolar fracture of the ankle were treated at our level one trauma center using the posterolateral approach to reduce and fix the posterior malleolus. There were 11 men and 41 women with a mean age of 49 years (22 to 79). A total of 40 patients (77%) had a fracture subluxation. Baseline characteristics of these patients and their fractures are shown in Tables I and II.

The size of the posterior malleolar fragment was calculated as the percentage of the tibiotalar surface area involved. The anteroposterior (AP) diameter of the fragment was measured on the lateral radiograph, or CT scan if available, and divided by the total AP diameter of the tibiotalar articular surface. The mean size of the poste-

Table 1: Basic characteristics (n=52).

Age (years)	**49**
Men n, (%)	11 (21%)
Follow-up (weeks, mean, range)	34 (7-131)
ASA 1 n, (%)	20 (39%)
ASA 2 n, (%)	25 (48%)
ASA 3 n, (%)	7 (13%)
Diabetes Mellitus n, (%)	4 (8%)
Body Mass Index (mean, range)	29 (22-50)
Smoking n, (%)	16 (31%)

ASA: American Society of Anasthesiologists

rior malleolar fragment was 27% (10% to 52%) of the joint surface (Table II). There was comminution of the fragment in 16 patients (31%). An external fixator was used prior to definitive reconstruction in 22 patients (42%) due to soft tissue swelling and/or blistering. The mean follow-up was 34 weeks (seven to 131). The congruency of the joint (step-off) and the quality of reduction and fixation of the lateral, medial and posterior malleoli was assessed on the post-operative and follow-up radiographs by two of the authors (SV, JH). Reduction was considered anatomical if any displacement was ≤1 mm. Ethical approval for the study was not deemed to be required by the local ethical committee.

Table 2: Fracture characteristics (n=52).

Fracture subluxation n, (%)	**40 (77)**
Size of posterior fragment (%)	27%
Medial malleolar fragment n, (%)	43 (83%)
Supination-external rotation stage 3 n, (%)	2 (4%)
Supination-external rotation stage 4 n, (%)	38 (73%)
Pronation-abduction stage 3 n, (%)	1 (2%)
Pronation- external rotation stage 3 n, (%)	1 (2%)
Pronation- external rotation stage 4 n, (%)	10 (19%)
AO-type B3 n, (%)	41 (79%)
AO-type C2 n, (%)	5 (10%)
AO-type C3 n, (%)	6 (12%)

AO, Arbeitsgemeinschaft für Osteosynthesefragen

TECHNIQUE

The illustrated example shows a patient with a trimalleolar fracture, type AO44B3 or Lauge-Hansen supination-external rotation 4 (Fig. 1) of the left ankle. The patient is prone for the operation. The distal part of the lower leg is placed on a foam cushion with the knee slightly flexed to allow maximal dorsiflexion of the ankle during reduction. A longitudinal incision is made between the lateral border of the Achilles tendon and the medial border of the fibula (Fig. 2). Fixation of the fibular fracture before fixation of the posterior malleolar fracture has its advantages and disadvantages. Fixation of the fibula first will, in most cases, lead to an adequate reduction of the posterior malleolar fracture. Sometimes, however, its fixation will limit the movement of the posterior malleolar fracture and therefore interfere with reduction. In our opinion, dissection of both fractures and careful anatomical reduction of both is the best strategy. Here, we describe the fixation of the fibular fracture first. During blunt subcutaneous dissection onto the peroneal tendon, care is taken to avoid injury to the sural nerve. The posterior aspect of the fibula is easily reached through the interval just lateral to the peroneal tendon. After debriding the fracture, it can be reduced and fixed using lag screws and/or a buttress plate (Fig. 3). The belly of flexor halluces longus is bluntly dissected off the interosseous membrane and the lateral side of the tibia through the interval medial to the peroneal tendon. Particular care is taken to avoid injury to the peroneal artery and its smaller branches. By retracting the muscle belly medially, the posterior aspect of the tibia can

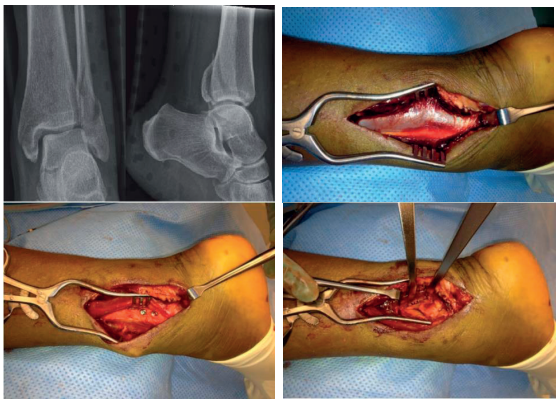

Figure 1-4: (1) SE-4 fracture of the ankle. (2) Longitudinal incision lateral of the Achilles tendon and medial to the border of the fibula. (3) Reduction and fixation of the fibula with two lag screws. (4) Incision of the periosteum in order to expose the posterior malleolus and provide anatomical reduction.

be seen. The periosteum is incised to expose the posterior malleolar fracture (Fig. 4). It is important not to damage the posterior inferior tibiofibular ligament (PITFL) at this stage. The posterior malleolar fragment is almost always displaced in a craniolateral direction by traction from the PITFL. Loose fragments can be removed by levering the fragment distally. After maximal dorsiflexion of the ankle, a dental pick or bone tamp can be used to reduce the posterior fragment. An anatomical reduction is almost always achieved and is held temporarily by Kirschner (K-) wires. When anatomical reduction is confirmed on image intensification, fixation is undertaken using either lag screws or a slightly pre-bent three-hole buttress plate (Fig. 5). Placement of a lag screw through the most distal hole of the plate can help to close any possible gaps. By slightly internally rotating the lower leg, the medial malleolus can be approached and fixed. The incision is closed in layers after confirmation of reduction (Fig. 6). Postoperatively a cast or bandage is retained for a maximum of two weeks: non-weight-bearing continues for six weeks.

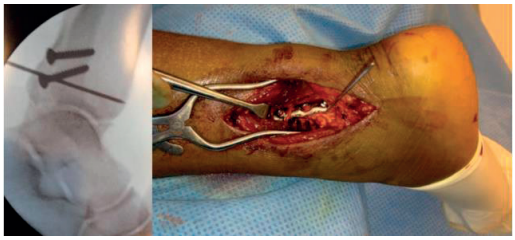

Figure 5: Fixation with buttress plate.

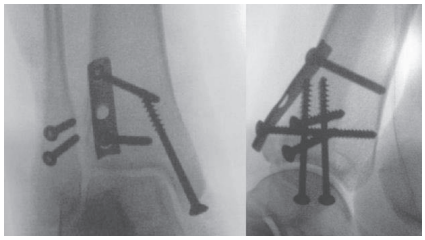

Figure 6: Postoperative x-rays showing anatomical reduction and fixation with buttress plate.

RESULTS

In 12 patients (23%), the fragment was fixed using lag screws only: in 40 (77%) it was fixed using a buttress plate. After fixation, 50 ankles (96%) were found to be stable when

clinically tested (Cotton test)[7]: no additional syndesmosis screws were needed in these patients, even in those with AO type 44C fractures. A syndesmosis screw was required in two patients (4%). Post-operative radiographs showed an anatomical reduction with a congruent ankle joint in all cases. There was one superficial wound infection, which was successfully treated with antibiotics. Two patients (4%) suffered from a temporary numbness in the distribution of the lateral sural cutaneous nerve. This resolved unremarkably in both within a few weeks. Congruency was lost in one patient with an AO-type 44C fracture, and a syndesmosis screw was introduced five days post-operatively which stabilised the ankle joint. Congruency was maintained after all other patients bore weight. One patient had a pulmonary embolus post-operatively but recovered fully following six months of anticoagulation. One patient had a second injury within six months which caused a further trimalleolar fracture which was similarly treated. In 15 patients (29%), the medial and lateral hardware was removed at a later date after consolidation of the fracture. All material used to fix the posterior malleolus was left in place. A total of four patients developed post-traumatic osteoarthritis in this follow-up period as a result of cartilage damage of the tibial plafond and talus on lateral or mortise radiographs. One patient with grade three OA[8] of the ankle joint underwent prosthetic replacement two years after the initial trauma.

DISCUSSION

In recent years increased attention has been paid to the importance of anatomical reduction and internal fixation of the posterior malleolus[4-6,9,10]. It is assumed that a congruent ankle joint without a step in the articular surface is needed to achieve a good functional outcome in patients who undergo surgical treatment for a fracture of the ankle. Inadequate reduction of the posterior malleolar fragment with a persistent articular step diminishes the tibiotalar articular surface and leads to altered biomechanics in the ankle joint. A change in peak pressure distribution probably plays an important role in the development of post-traumatic OA[1,11]. There is no consensus about the main cause of post-traumatic OA after a fracture of the ankle[12]. According to the AO guidelines[13], a posterior malleolar fragment is usually only reduced and fixed if it involves >25% of the tibiotalar articular surface or when there is persistent instability after fixation of the medial and lateral malleoli[13]. The recommendations are partially based on biomechanical studies[11]. Clinical studies are not consistent in the recommendation of the size of posterior fragment that requires fixation. De Vries[14] et al and Langenhuijsen[15] et al recommend fixation of posterior fragments which are larger than 25% or 10%, respectively. Mingo-Robinet et al[5] suggest in a retrospective study involving 45 trimalleolar fractures,

that anatomical reduction, and not size of the fragment, was the most important determinant of outcome.

In 2013 we conducted a retrospective study of 131 patients, in whom outcome was assessed using the American College of Foot and Ankle Surgeons (AOFAS) score, at a mean of 6.9 years (2.5 to 15.9) after internal fixation of a trimalleolar fracture of the ankle. Patients with a persistent articular step of > 1 mm after fixation of the posterior malleolus were significantly more likely to develop post-traumatic OA than those with no articular step (46% versus 25%, p = 0.02). This was the case in patients with medium-sized posterior malleolar fragments (5% to 25% of the articular surface) as well as in those with large (> 25%) fragments. The size of the fragment (larger than 25% of the involved articular surface) was the leading indication for fixation of the posterior malleolus. In the sub-group of patients (24 patients) who underwent fixation of the posterior fragment, the functional outcome was no better than in the sub-group without fixation. There was a persistent articular step of > 1mm in ten (42%) of the fixed posterior malleolar fragments, compared with 46 (55%) of those in whom the posterior malleolar fragment was not fixed. In the study period, nearly all posterior fragments which were fixed were reduced by ligamentotaxis and fixation was undertaken percutaneously in an AP direction[2]. The results of this retrospective study strengthened us in our belief to strive for an anatomical, open reduction.

Similar results have been published in a recent Chinese study which described 102 patients with a trimalleolar fracture[3]. Mean follow-up was 2.8 years (0.5 to 8.5 years). In all, 42 patients underwent fixation of the posterior fragment, 23 of them posterior to anterior fixation. Fixation of the posterior fragment was performed if fragment was around or larger than 25% of the involved articular surface as measured on plain lateral radiographs. Functional outcome was assessed by the AOFAS score and osteoarthritis was assessed on plain radiographs. A persistent articular step of > 1 mm was seen in 24 (24%) patients and this correlated with a worse functional outcome[3]. In the fixation group a persistent articular step of >1 mm was seen in 14 (33%) patients.

Anatomical reduction and fixation of the posterior malleolar fragment also reconstructs the fibular notch and the syndesmosis. Cadaver studies show that this technique is biomechanically superior to the use of syndesmosis screws in injuries proximal to the syndesmosis[9]. In AO type 44C fractures, even small posterior malleolar fragments can be fixed. Syndesmosis screws are not needed if the syndesmosis is clinically stable after fixation[10]. In Figures 7 to 9, we present a case (AO-44C2 fracture) with a relatively small posterior fragment, shown on preoperative CT scans with comminution and several intraarticular fragments (Fig. 8). The fibula was dislocated. After fixation of the posterior fragment with a buttress plate the joint was congruent and the fibula was reduced (Fig. 9). The syndesmosis was stable. One patient developed an incongruent ankle and a syndesmosis screw was introduced at a further operation. This emphasises the need for

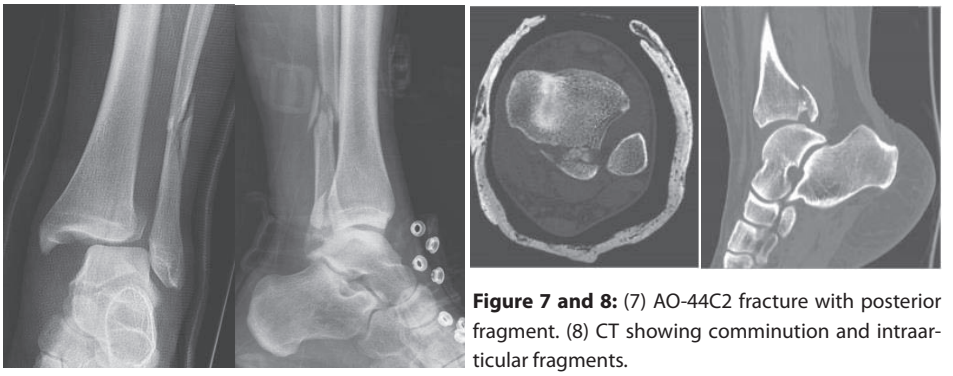

Figure 7 and 8: (7) AO-44C2 fracture with posterior fragment. (8) CT showing comminution and intraarticular fragments.

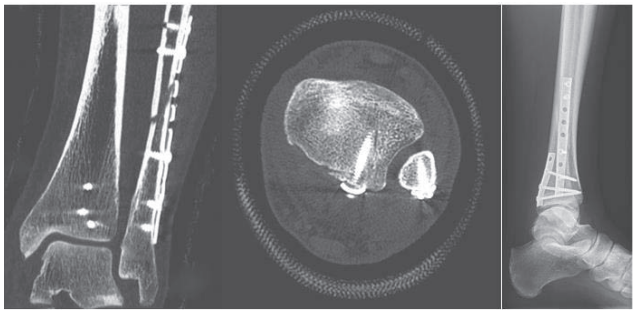

Figure 9: Postoperative X-rays after posterior fixation of both the fibula and posterior fragment.

adequate clinical testing at the end of the operation. When there is any doubt about the stability of the ankle after fixation of the posterior malleolar fragment there should be a low threshold for using a syndesmosis screw.

There are several limitations to this study. First, it is retrospective with data gathered from the notes. This aim was to describe the technical advantages of the posterolateral approach with better radiological outcome and the study was not designed to report functional outcome. Secondly, the size of posterior fragment and articular step in the ankle joint was measured on plain radiographs in most patients because this is daily practice world-wide. CT scans were not available for most patients. In our opinion, measurement on a plain radiograph is not as good as measurement by CT scans. Future studies should only use CT scans when assessing articular congruency[16]. Another limitation is that only trimalleolar fractures which were fixed using a posterolateral approach are included. There are no data available on unfixed posterior malleolar fragments or those treated with 'anterior to posterior' percutaneous fixation. Little has been published on the subject of the technique of reduction and fixation for these fractures. Traditionally an indirect reduction technique by ligamentotaxis or percutaneous reduction using a Weber clamp followed by percutaneous screw fixation in an AP direction is used[17,18]. This technique does not lead to anatomical reduction of the fragment in many patients. The

correct positioning of the screw in smaller fragments can be difficult. In recent years, several authors have recommended the posterolateral approach with the patient in a prone position with open reduction of the posterior malleolar fragment followed by internal fixation with lag screws and/or a buttress plate, reporting few complications and a good functional outcome[2,3,10,19-21]. We confirm these findings in this study.

This technique gives an adequate view of the fracture, an anatomical reduction in most cases and sound fixation of the posterior malleolar fragment[19,20]. Another advantage is that small fragments are easier to fix and small intra-articular fragments can be removed from the site of the fracture. There has, as yet, been no prospective study to investigate the functional and radiological outcome after anatomical reduction and fixation of medium-sized posterior malleolar fragments (those involving between 5% and 25% of the articular surface). Whether anatomical reduction and fixation of these fragments leads to a better functional outcome and a reduced rate of post-traumatic OA therefore remains unknown. We are currently involved in two multicenter, randomised trials, which are attempting to answer this question (the POSTFIX and POSTFIX-C trials).

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Open reduction and internal fixation of the posterior malleolus fragment via the posterolateral approach is radiologically superior to 'A to P' screw fixation.

CHAPTER 8

ABSTRACT

Introduction

Functional outcome in trimalleolar fractures is largely correlated to the reduction of the posterior fragment. Until recently, fixation was mainly performed for large fragments, by percutaneous anterior to posterior ('A to P') screw placement after closed reduction. Nowadays, ORIF via a posterolateral approach seems to gain in popularity. The aim of this study was to compare the postoperative photographs of operated trimalleolar fractures after either fracture treatment method, for fracture diastasis and step-off.

Material and methods

All consecutive patients with trimalleolar fractures, including posterior fragments of >5% of the articular surface and operated between 2007 - 2013 were analysed on size of posterior fragment, post-operative gap and step-off by three observers. The patients were divided into three groups; A to P screw fixation, ORIF via the posterolateral approach and no posterior fragment fixation at all.

Results

180 patients with trimalleolar ankle fractures were included for analyses. Twenty five posterior fragments were fixated percutaneously from anterior to posterior (group 1) and 51 underwent open reduction and internal fixation through a posterolateral approach (group 2). 104 patients underwent no posterior malleolus fixation (group 3). The average size of posterior fragment was 34% in group 1, 27% in group 2 and 16% in group 3. A postoperative step-off >1mm was found in 40% (group 1), 9% (group 2) or 34% respectively (group 3).

Conclusion

Fixation of the posterior malleolus through an open posterolateral approach leads to better radiological results as compared to percutaneous 'A to P' screw fixation or no fixation at all.

INTRODUCTION

Functional outcome in trimalleolar fractures is influenced by many factors. Postoperative joint congruency, size and position of the posterior malleolar fragment, and the presence of an open (luxation) fracture or severe cartilage damage are demonstrated to have considerable impact on outcome[1-5]. Although historically most attention was given to the size of the posterior malleolar fragment, in recent years more and more evidence has been published regarding the importance of the reduction of the posterior fragment after operative treatment. Several studies showed a correlation between a persistent postoperative step-off and the development of osteoarthritis and worse functional outcome[1-3].

The Arbeitsgemeinschaft für Osteosynthesefragen (AO) currently advices the following concerning treatment of posterior malleolar fragments: fixation of the posterior fragment is not necessary if a fragment is smaller than 25% of the involved intra-articular surface AND in case of joint stability after fixation of the lateral and medial malleolus. Fixation with lag screws is advised in case of a posterior fragment larger than 25% of the involved intra-articular surface and absence of long proximal extension. Fixation with lag screws and additional buttress plate are advised in case of a large posterior fragment (>25%) and long proximal extension[6].

Recent literature suggests that better radiological and functional results can be achieved by also fixating smaller posterior fragments, starting from 5% of the articular surface[2,3,7,8]. Historically, fixation is mainly performed by percutaneous anterior to posterior ('A to P') screw fixation after closed reduction (Figure 1). Nowadays, the open reduction and internal fixation via a posterolateral approach seems to gain in popularity. The posterolateral approach has the potential benefits of a stable fixation after anatomical reduction under direct visualisation (Figure 2). Only a few studies that looked into the radiological outcome of posterior fragments in trimalleolar fractures after initial treatment have been published[9,10]. The aim of the current study was to compare the radiological postoperative outcome i.e. reduction of the posterior fragment, after both operative methods (percutaneous 'A to P' and posterolateral) and after non-operative treatment of the posterior fragment (Figure 3).

Material and methods

All patients age 18 years or older with malleolar fractures, operated in a level 1 trauma center in the western part of The Netherlands, from January 1st 2007 till December 31st 2013, were analysed (Figure 4). 272 patients had an additional fracture of the posterior malleolus. 84 fractures were excluded due to small (<5%) fragment size and eight fractures due to poor postoperative radiograph quality. Therefore, a total of 180 trimalleolar fractures could be included in this study.

Figure 1: Example of reduction through ligamentotaxis followed by percutaneous ' A to P' screw fixation.

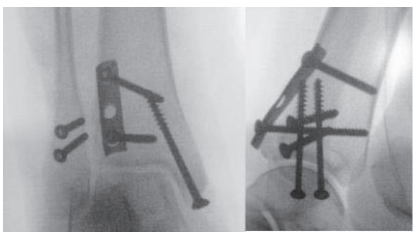

Figure 2: Example of Open Reduction and Internal Fixation of the posterior malleolus via a posterolateral approach.

Figure 3: Example of conservative treatment of the posterior malleolus with persisting postoperative step-off.

The Medical Ethical Committee South-West Netherlands approved of this study and decided that no written informed consents were required.

Treatment

All included trimalleolar fractures were treated operatively. The lateral and medial malleoli were fixated as indicated according to standard protocol. The choice of treatment and approach for the posterior malleolus fragment was to the discretion of the treating surgeon: either fixation by percutaneous anterior to posterior screws or open reduction and internal fixation via a posterolateral approach[11], or no fixation at all.

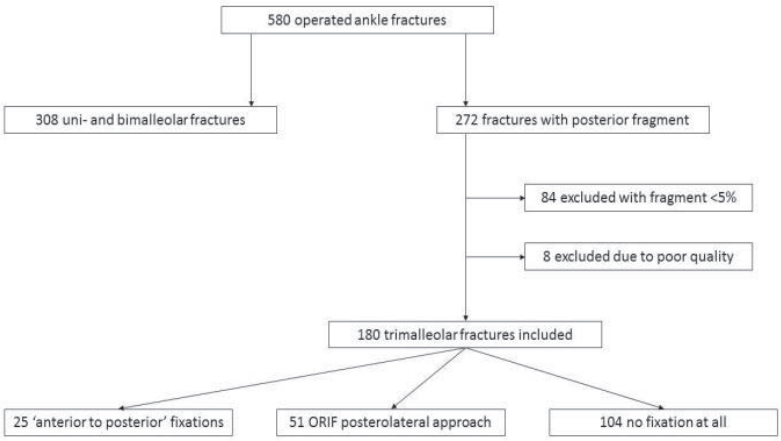

Figure 4: Flow-chart of included and excluded patients.

Data collection

The postoperative ankle X-rays (2-6 weeks postoperative) of all included patients were reviewed for the postoperative gap and step-off independently by three observers (2 trauma surgeons, 1 trauma surgery resident). Measurement of the size of the posterior fragment was done with an online ruler on plain preoperative lateral radiographs as shown in figure 5. Fragments that involved less than 5% of the articular surface and cases without postoperative photographs were excluded. Intra-articular step-off and gap was measured with an online ruler on postoperative plain lateral radiographs. Despite the overlap of the fibula plate in some cases, the step-off and gap measurements were reproducible in all included cases. A step-off or gap of more than 1 mm was set as a non-anatomical reduction. Outcomes of the three observers were compared and in case of disagreement the majority of the measurements was decisive.

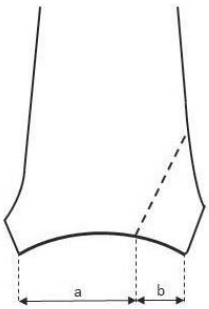

Figure 5: Measurement of posterior malleolus on lateral radiograph, size = b/(a+b).

Statistical analysis

For analysis, patients were subdivided into three groups by the method of treatment of the posterior malleolus fragment: 1. Closed reduction and percutaneous anterior to posterior ('A to P') screw fixation; 2. Open reduction and posterior to anterior fixation; 3 no fixation of the posterior fragment at all. Percentages of anatomical reduction and non-anatomical reduction were determined and compared for the three separate groups. Statistical analysis was done with the Statistical Package for the Social Sciences Version 22 or higher. The unpaired t-test or chi-square test was used to analyse baseline

characteristics. The percentages of articular involvement of the posterior fragment by the three different observers were combined to one score and presented as one percentage. These radiological outcomes (gap and step-off incidences) were analysed with the chi-square test. A P-value of <0.05 was considered as statistically significant.

RESULTS

In total, 180 patients were included for analyses (Figure 4). After fixation of the lateral and medial malleoli, 25 patients underwent additional 'A to P' screw fixation of the posterior fragment (group 1), 51 had open reduction and internal fixation ('ORIF') through a posterolateral approach (group 2) and 104 patients underwent fixation of lateral and medial malleolus as needed without posterior malleolus fixation (group 3).

Baseline characteristics are shown in table 1. No significant differences were found regarding the age or ASA-classification of the included patients.

Table 1: Baseline characteristics

	Group 1 (n=25)	Group 2 (n=51)	Group 3 (n=104)
Age (years, SD)	57 (±17)	49 (±13)	52 (±18)
BMI (SD)	28.6 (4.7)	28.3 (5.2)	26.2 (5.2)
Percentage ASA I and II	92%	92%	92%
Diabetes (n,%)	0 (0%)	1 (2%)	4 (4%)
Smoking (n,%)	4 (16%)	12 (24%)	21 (20%)
Open fracture	0 (0%)	1 (2%)	2 (2%)

SD = Standard Deviation, Group 1 = Anterior to posterior screw fixation of the posterior fragment, Group 2 = ORIF of the posterior fragment via the posterolateral approach, Group 3 = No fixation of the posterior fragment.

The posterior fragment size was significantly larger in both fixation groups compared to the no-fixation group (Table 2, resp. p<0.0001). Differences in fragment size were not significantly different between both fixation groups (group 1 and group 2, p=0.57).

Table 2: Postoperative gap and step-off

	Group 1 (n=25)	Group 2 (n=51)	Group 3 (n=104)
Size of posterior fragment (%,SD)*	34 (±13)	27 (±11)	16 (±6)
Step-off >1mm (n,%)**	10 (40%)	4 (9%)	35 (34%)
Gap > 1mm (n,%)***	6 (24%)	3 (7%)	26 (25%)

* group 1 vs group 2; p< 0.001, group 1 vs group 3; p=0.570, group 2 vs group 3; p<0.001.
** group 1 vs group 2; p= 0.001, group 1 vs group 3; p=0.550, group 2 vs group 3; p=0.001.
***group 1 vs group 2; p= 0.019, group 1 vs group 3; p=0.76, group 2 vs group 3; p=0.011.

In 49 of the 180 patients an intra-articular step off remained. The presence of a postoperative step-off was significantly more frequent in the 'A to P' screw fixation and the no-fixation groups compared to 'ORIF' group (both p=0.001, table 2). There was no significant difference in incidence of step-off between the group 1 ('A to P') and group 3 (no-fixation). Identical results were found in incidence of postoperative gap for group 1 and group 3 (Table 2). In 35 of the 180 patients a gap persisted after treatment. An intra-articular gap was more often present in groups 1 and 3 (p=0.019 and 0.011 respectively) compared to group 2. No significant difference in incidence of an intra-articular gap was found between the first and third group (p=0.76).

When analysing fragments larger than 25% of the intra-articular surface only, a similar distribution of step-off percentage was found (table 3). The presence of a step-off was significantly more frequent in the first and third group compared to the second group (p=0.017 and p=0.044 respectively).

Table 3: Postoperative step-off in fragments >25%.

	Group 1 (n=17)	Group 2 (n=28)	Group 3 (n=7)
Step-off >1mm (n,%)*	7 (41%)	3 (11%)	3 (43%)

* group 1 vs group 2; p= 0.017, group 1 vs group 3; p=0.939, group 2 vs group 3; p=0.044.

DISCUSSION

This study intended to analyse the influence of the treatment method of the posterior malleolar fragment in trimalleolar fractures on the postoperative radiological outcome. Over the past years, several studies described the importance of anatomical reduction of the posterior fragment[1,3,7,8,12]. Postoperative step-off has become the most important predictor for development of osteoarthritis and functional outcome rather than size of the posterior fragment[2,3,8]. Percutaneous 'A to P' screw fixation after closed reduction by ligamentotaxis was, and probably still is, the most common method of fixation of posterior malleolus fragments. It is a minimal invasive technique with 1 or 2 stab incisions, relatively easy, and quick. Possible disadvantages are the frequent inability of anatomical reduction due to interfragmentary loose fragments and the challenging placement of screws in smaller fragments. The open, posterolateral approach was described in detail by Talbot et al in 2005[13] and later by Tornetta et al[14]. Via this approach, anatomical reduction and a biomechanical favourable fixation from posterior to anterior can be achieved[9]. Possible disadvantages are the sometimes larger incision in selected cases and less-known dissection procedure. Even damage to the sural nerve is described in some cases and the more challenging way of fixation of the medial malleolus in prone position. Wound healing problems after the posterolateral approach are comparable to the regularly used direct lateral approach for fixation of distal fibular fractures[1,8,9,15].

Wound-infections for instance, in the posterolateral approach was described in 4-11% of the patients[8,9,15].

To our knowledge this study is the only study that compares the radiological results of 2 fixation methods for posterior malleolus fractures with no fixation at all. In this present study both fixation methods and no posterior fracture fragment fixation are compared, regarding radiological results on postoperative X-rays. We found a significant better fracture reduction (both postoperative step-off and gap) in the group that had been treated using an open posterolateral approach followed by screw fixation or buttress plating compared to closed and percutaneous 'A to P' screw fixation or non-operative treatment of the fragment. This is in accordance with the study of Huber et al but in contradiction to the study of O'Connor et al who did not find a significant relation between both approaches[7,12]. Interestingly, closed reduction followed by percutaneous 'A to P' did not improve anatomical reduction at all if compared to the nonoperative group (Table 3), regardless of the size of the fragment. Baseline characteristics were comparable except for the size of the posterior fragment, which is probably due to selection for fixation of the posterior fragment by the treating surgeon. Fragment size was however comparable in both fixation groups.

A limitation of this study is that measurements were done on X-rays and not on CT scan. Recent literature shows that it is difficult to estimate the amount of articular involvement on lateral X-rays[16,17]. Measurements can be done in a more reliable way on CT scans[17]. Common practice in most hospitals however, is the measurement on plain X-ray both in preoperative and postoperative evaluation. In line with this fact we performed our measurements on radiographs only, thus resembling the common daily clinical practice. CT-scans postoperatively are mainly made on indication, and not so much routinely performed. Unfortunately, in the study period, we did not have postoperative CT-scan available of the majority of the patients. Postoperative step-off was also measured on postoperative X-rays instead of a CT-scan. However, a cut-off value of more than 1 millimeter was defined as step-off and this distance is generally well detectable on X-rays.

This study was designed and executed in order to evaluate the radiological results in treating the fractured posterior malleolus. No functional outcomes were measured in this study, which may be considered a limitation. Although it was not the aim of this study it would have been of extra value to study the relationship between radiological result and functional outcome in relation to treatment strategy. On the other hand, due to the nature of this study, the complete cohort could be analysed without patients being lost of follow-up.

CONCLUSION

Fixation of the posterior malleolus fracture through an open posterolateral approach leads to better postoperative radiographic results: A reduced presence of step-off and gap, compared to no fixation or percutaneous 'A to P' screw fixation. Remarkably, percutaneous 'A to P' fixation of the posterior malleolar fragment in trimalleolar fractures has similar radiographic results as non-operative treatment. These results seem to be independent of the size of the fracture fragment and warrant the liberal use of open reduction and fixation of posterior malleolar fractures via a posterolateral approach.

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Long-term functional and radiographic outcome in 243 operated ankle fractures.

CHAPTER 9

ABSTRACT

Background

Large comparative studies that have evaluated long-term functional outcome of operatively treated ankle fractures are lacking. This study was performed to analyse the influence of several combinations of malleolar fractures on long-term functional outcome and development of osteoarthritis.

Methods

Retrospective cohort-study on operated (1995–2007) malleolar fractures. Results were assessed with use of the AAOS- and AOFAS-questionnaires, VAS-pain score, dorsiflexion restriction (range of motion) and osteoarthritis. Categorisation was determined using the number of malleoli involved.

Results

243 participants with a mean follow-up of 9.6 years were included. Significant differences for all outcomes were found between unimalleolar (isolated fibular) and bimalleolar (a combination of fibular and medial) fractures (AOFAS 97 vs 91, p= 0.035; AAOS 97 vs 90,p= 0.026; dorsiflexion restriction 2.8° vs 6.7°,p= 0.003). Outcomes after fibular fractures with an additional posterior fragment were similar to isolated fibular fractures. However, significant differences were found between unimalleolar and trimalleolar (a combination of lateral, medial and posterior) fractures (AOFAS 97 vs 88, p< 0.001; AAOS 97 vs 90,p= 0.003; VAS-pain 1.1 vs 2.3p< 0.001; dorsiflexion restriction 2.9° vs 6.9°,p< 0.001). There was no significant difference in isolated fibular fractures with or without additional deltoid ligament injury. In addition, no functional differences were found between bimalleolar and trimalleolar fractures. Surprisingly, poor outcomes were found for isolated medial malleolar fractures. Development of osteoarthritis occurred mainly in trimalleolar fractures with a posterior fragment larger than 5 %.

Conclusions

The results of our study show that long-term functional outcome is strongly associated to medial malleolar fractures, isolated or as part of bi- or trimalleolar fractures. More cases of osteoarthritis are found in trimalleolar fractures

BACKGROUND

Ankle fractures are commonly seen at emergency departments, accounting for approximately 10 % of all fractures[1]. In general, stable fractures are treated with cast immobilisation, whereas unstable fractures are mainly treated by internal fixation[2,3]. In the literature, little attention is given to the long-term functional outcome of operatively treated ankle fractures. Some studies have compared combined uni and bimalleolar fractures to trimalleolar fractures[4,5]. Whereas other studies have focused on the long-term influence of deltoid ligamentous injury in addition to a fibular fracture, or on the role of the posterior fragment in ankle fractures[6-10]. To our knowledge, no study has compared the long-term results of operatively treated unimalleolar fractures with bimalleolar and trimalleolar fractures. In this study, we analysed the influence of the number and location of malleolar fractures on long-term function, pain, range of motion and development of osteoarthritis in 243 operatively treated participants.

METHODS

Participants

In this retrospective cohort study we included all participants with an ankle fracture, who were operatively treated in our clinic from 1995 until 2007. Exclusion criteria were open fractures, epiphyseal fractures, pathological fractures, pilon fractures, previous ankle fracture on the same side, polytrauma patients, age under 18 years at the time of trauma and older than 75 years at the time of follow-up. No Wet Medisch Onderzoek requirement (Medical Research in Humans) was needed according to the local Medical Ethical Committee. All participants who met the inclusion criteria were invited to participate in the study.

If the patient did not have a current phone number or address, the family doctor's registry was used to obtain the current phone number or address. If patients still could not be reached, the patients were considered lost to follow-up. Patients willing to participate provided written informed consent after being informed about the study. Radiographic assessment and surgical procedure All initial radiographs were grouped according to the AO and Lauge-Hansen[11] classifications by two independent observers. In addition, we grouped all fractures on the basis of the initial x-ray into the following groups based on the location and number of fractures: isolated fibular fracture (F), fibular fracture with additional posterior fracture (FP), isolated medial fracture (M), bimalleolar (combination of fibular and medial) fracture (FM) or trimalleolar fracture if a lateral, medial and posterior fracture were present (T). Dislocation of the fragments, congruency of the joint space, medial clear space in isolated fibular fractures, and the size of the posterior fragment in

cases of involvement of the posterior malleolus were measured both on preoperative and postoperative X-rays. Medial clear space was measured on the mortise view as the distance between the lateral border of the medial malleolus and the medial border of the talus. A space greater than 4 mm was considered as abnormal because it indicates a lateral shift of the talus due to deltoid ligamentous injury leading to incongruency of the ankle joint[12]. The indication for surgical intervention in isolated fibular fractures without deltoid ligament injury was dislocation ≥2 mm of the fragments. Evaluation of syndesmotic widening was performed by measuring the distance between the medial wall of the fibula and the incisural surface of the tibia, which should be less than 6 mm both on AP and mortise views[12]. Size of posterior fragment was defined as the length of the joint-involved part of the posterior fragment divided by the total length of the joint surface in anterior-posterior direction (Fig. 1). All participants were treated surgically and fixation took place according to AO principles. Large posterior fragments were reduced closed or percutaneously and fixed by anterior-posterior placement of 1 or 2 screws under fluoroscopic control. Type of surgery depended on preference of the attending surgeon.

Study procedure

Baseline participant characteristics as well as data on operation delay, immobilisation duration, fixation technique and complications were obtained from the hospital records. The participants were seen at the outpatient clinic where physical examination was performed including range of motion, two questionnaires to assess functional outcome and x-rays of the injured ankle to assess osteoarthritis (mortise and lateral) were performed. Maximum dorsiflexion was measured using a goniometer after the patient had placed the affected foot on a 2.5 cm elevation (Fig. 2). This was done for both ankles and the difference was registered as dorsiflexion restriction, which is mostly limited if ankle problems exists.

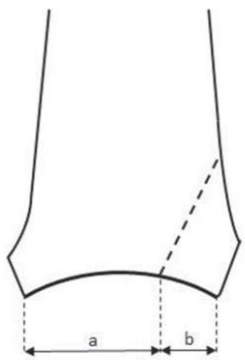

Figure 1: Measurement of size of posterior malleolus, size= b/(a+b).

Figure 2: Measurement of dorsiflexion restriction.

Functional outcome was assessed using the American Orthopaedic Foot and Ankle Society (AOFAS)[13,14], the American Academy of Orthopaedic Surgeons (AAOS)[15] and the VAS-pain scale. Evaluation of osteoarthritis was performed with a standardised model that grades osteoarthritis into 4 categories; Grade 1: no osteophytes, no joint space narrowing; Grade 2: small osteophytes, no joint space narrowing; Grade 3: moderate osteophytes, joint space narrowing; Grade 4: large osteophytes, severe joint space narrowing[16]. The collected data were statistically analysed with SPSS, Version 17.0. Major endpoints were function, VAS-pain, dorsiflexion restriction of the affected ankle compared to the contralateral non-fractured side and degree of osteoarthritis. Normally distributed continuous data were compared between groups with parametric tests (t-test or ANOVA). In case of skewed distribution in numerical data, the Mann–Whitney test or the Kruskal-Wallis test was used. For categorical data, the Fisher's exact test or chi-squared test was used. A two-tailed p-value below 0.05 was considered as statistically significant.

RESULTS

Of the 611 patients with an operatively treated ankle fracture in the study period, 434 met the inclusion criteria and were invited to participate in the study. Of these, 243 agreed to participate and were evaluated between January and May 2012 (Fig. 3). The average age of the participants was 52 years at the time of evaluation after a mean follow-up of 9.6 years (range 5–17 years). One hundred and fourteen participants (47 %) were men; mean Body Mass Index at time of evaluation was 28.0 kg/m2. According to the radiographic classification, the study population consisted of 112 participants with an isolated fibular fractures (group F), 20 participants with a combination of fibular and posterior malleolar fracture (group FP), 9 participants with an isolated medial fracture (group M), 43 participants with bimalleolar fractures (group FM), and 59 participants with trimalleolar fractures (group T). Baseline characteristics of the groups are presented in Table 1. The mean size of the posterior fragment was 16 % (range, 3–53 %). The mean time between trauma and internal fixation (operation delay) was 5 days. Postoperatively, all x-rays showed proper reduction (less than 2 mm dislocation) and a good joint congruency. Fixation of the posterior fragment took place in 11 cases: 8 fragments were larger than 25 % of the involved articular surface, and 3 were between 5–25 %. Nineteen complications occurred in 19 (7.8 %) participants, mainly in those with trimalleolar fractures. In the total population, mechanical or technical problems (loose screws) occurred in 5 cases, reoperation was necessary in 3 participants (all because of secondary widening of the syndesmosis), and superficial or deep infection occurred in 14 participants (all participants were sufficiently treated by oral antibiotics). Talocrural

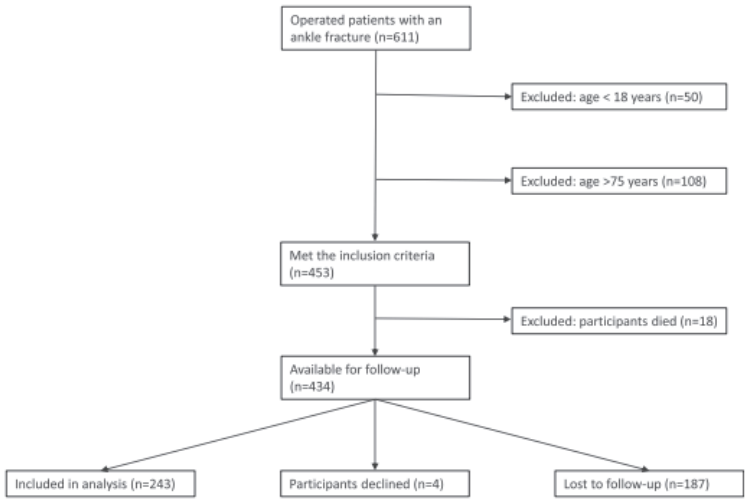

Figure 3: Flowchart of included patients

Table 1: Baseline characteristics

Group	N	Age (y)	Follow-up (y)	BMI	Posterior fragment (%)	Male (%)	Diabetes (%)	Smoking (%)
Total	243	52	9.7	28.0		47%	16%	31%
F	112	52	9.8	27.8		48%	15%	33%
FP	20	48	8.6	29.1	13.0	40%	0%	47%
M	9	43	10.9	26.2		67%	13%	50%
FM	43	53	10.1	28.6		51%	18%	24%
T	59	55	9.2	27.2	16.7	41%	13%	25%

arthrodesis (2 participants) or ankle-prosthesis (1 participant) was necessary due to severe post-traumatic osteoarthritis. Due to pain or discomfort removal of the implants took place in 70 (29 %) participants after 13 months on average. The median scores of the outcome measures in this population are presented in Table 2. Our data show that there was no significant difference between fibular fractures with or without additional deltoid ligamentous injury (AOFAS 98 vs 95, p= 0.255; AAOS 96 vs 97,p=0.497; VAS 1.0 vs 1.1,p= 0.064, dorsiflexion-restriction 3.3° vs 1.8°, p= 0.221). An additional fracture of the posterior malleolus in fibular fractures leads to comparable outcome (Table 2; AOFAS 97 vs 97,p=0.801;AAOS 97 vs 98,p= 0.772; VAS 1.1 vs 1.0,p= 0.990; dorsiflexion restriction 2.8° vs 3.3°, p= 0.565). Significant differences were found between isolated fibular and bimalleolar fractures, except for VAS-pain, (Table 2; AOFAS 97 vs 91,p= 0.035; AAOS 97 vs 90,p= 0.026; VAS 1.1 vs 1.8,p=0.263; dorsiflexion restriction 2.8° vs 6.7°,p= 0.003) and between isolated fibular and trimalleolar fractures (AOFAS 97 vs 88,p< 0.001; AAOS 97 vs 90,p= 0.003; VAS 1.1 vs 2.3 p< 0.001; dorsiflexion restriction 2.9° vs 6.9°,p<

Table 2: Functional and radiological outcome

Group	N	AAOS	AOFAS	VAS-pain	Dorsiflexion-restriction	OA grade 1	OA grade 2	OA grade 3	OA grade 4
Total	243	95	95	1.5	4.6°	205	20	14	4
F	112	97	97	1.1	2.8°	104	5	3	0
FP	20	97	98	1.0	3.3°	16	3	1	0
M	9	89	83	2.5	5.0°	9	0	0	0
FM	43	90	91	1.8	6.7°	39	2	2	0
T	59	90	88	2.3	69°	45	10	8	4

F = isolated fibular fracture, FP = fibular fracture with additional posterior fracture, M = isolated medial fracture, FM = bimalleolar (combination of fibular and medial) fracture, T = trimalleolar fracture.

0.001). Fibular fractures with additional posterior fragment had a significantly better functional outcome than trimalleolar fractures (Table 2; AOFAS 97 vs 88, p=0.040; AAOS 98 vs 90, p= 0.011; VAS 1.0 vs 2.3,p= 0.006; dorsiflexion restriction 3.3° vs 6.9°,p= 0.034). The size of the posterior fragment did not differ significantly between these two groups (respectively 13 and 17 %). No significant differences were found between bimalleolar and trimalleolar fractures on all outcomes (Table 2; AOFAS 91 vs 88, p= 0.180; AAOS 90 vs 90,p= 0.220; VAS-pain 1.8 vs 2.3,p= 0.191; dorsiflexion restriction 6.7° vs 6.9°,p= 0.822). Isolated medial fractures had surprisingly bad results. However, due to the small group size there was no significant difference compared to the other groups.

All fractures with a posterior fragment were further subdivided by size of the posterior fragment; group 1 consisted of fragments <5 %, group 2 of fragments between 5 and 25 % and group 3 of fragments > 25 % of involved articular surface (Table 3). We found that fragments larger than 5 % resulted in a worse functional outcome than fragments smaller than 5 %, although this difference was not statistically significant. Some degree of osteoarthritis was found in 8 (7 %) unimalleolar fibular fractures, 4 (20 %) fibular fractures with additional posterior malleolar fracture, 4 (9 %) bimalleolar fractures and 22 (37 %) trimalleolar fractures (Table 2). Grade 2 osteoarthritis was present in 20 cases, grade 3 in 14 cases, and grade 4 in only 4 cases (all of whom had trimalleolar fractures). The 3 participants with an ankle-prosthesis or arthrodesis were included in this analysis and all were part of the trimalleolar group. In fractures with involvement of the posterior tibial margin, osteoarthritis was only found in medium-sized (33 %) and large-sized posterior fragments (29 %) (Table 3).

To compare our results with other publications, we also classified the participants according to the AO and Lauge-Hansen classifications. No significant differences between the 3 main groups of the AO-classification were found (Table 4). Likewise, no significant differences were found between the 4 main-groups of the Lauge-Hansen classification (Table 5).

Table 3: Functional and radiological outcome in trimalleolar fractures.

Size of posterior fragment	N	AOFAS	VAS-pain	Dorsiflexion-restriction	OA grade 1	OA grade 2	OA grade 3	OA grade 4
<5%	8	95	1.4	2.9°	8	0	0	0
5-25%	56	88	2.1	6.2°	38	9	7	2
>25%	14	90	1.6	7.8°	10	1	1	2

Table 4: Results in total population classified according the AO-classification.

	N	AAOS	AOFAS	VAS-pain	Dorsiflexion-restriction
AO 44-A	6	99	95	0.7	5.0
AO 44-B	168	96	95	1.4	4.2
AO 44-C	61	94	94	1.8	5.6

Table 5: Results in total population classified according the Lauge-Hansen classification.

	N	AAOS	AOFAS	VAS-pain	Dorsiflexion-restriction
Supination-adduction	6	94	95	1.5	5.0
Supination-external rotation	149	95	95	1.5	3.6
Pronation-abduction	26	96	96	0.9	7.0
Pronation-external rotation	62	94	94	1.8	5.9

DISCUSSION

The majority of the participants in this, as far as we know, the largest long-term cohort study of operated ankle fractures showed good results after a mean follow-up of nearly 10 years. In contrast to earlier studies, this study compares large subgroups of operatively treated ankle fractures on long-term outcome where other study groups were small groups or had a short follow-up period. Previous long-term studies mainly focus on trimalleolar fractures, and especially on the influence of the size of the involved articular surface, and whether or not the posterior fragment should be fixed[7-9]. In other articles, a combined group of uni and bimalleolar fractures are compared to trimalleolar fractures[4,5]. In 1989, Jaskulka et al. were the first authors to compare the long-term outcome of uni and bimalleolar fractures with trimalleolar fractures[4]. They described a significantly worse outcome in trimalleolar fractures. They also found a worse outcome on function, development of osteoarthritis and pain in trimalleolar fractures with a posterior fragment larger than 5 % compared to posterior fragments smaller than 5 % of the involved articular surface.

Limitations of this study are the relatively short follow-up period (5.7 years) and the fact that unimalleolar and bimalleolar fractures were not analysed separately. In a prospective cohort-study with a follow-up period of one year, Tejwani et al. also described a worse outcome of trimalleolar fractures compared to uni and bimalleolar fractures[10]. A small part of that cohort, which was followed for 2 years, showed decreasing differences between the two groups and therefore, the authors concluded that there is no difference between long-term outcome of uni, bi or trimalleolar fractures. In this study, analysis of isolated fibular fractures was conducted in two subgroups: with or without suspicion of an additional ruptured deltoid ligament (if the medial clear space was >4 mm). There were no significant differences between these subgroups. Therefore, we agree with Donken et al. that additional deltoid ligament injury does not lead to a worse functional outcome in the longterm in operatively treated fibular fractures[6]. Surprisingly, the outcomes of fibular fractures with an additional posterior fragment were similar to isolated fibular fractures. If bimalleolar fractures are compared with trimalleolar fractures there is no significant difference in functional outcome, except for pain. However, a fracture of the medial malleolus is, according to our data, strongly associated with worse functional outcome. Despite the large cohort, this study did not show a clear and significant relation between size of the posterior fragment and long-term functional outcome in trimalleolar fractures. Our results suggest that a posterior fragment larger than 5 % leads to a worse outcome compared to posterior fragments smaller than 5 % of the involved articular surface. This is in accordance with Jaskulka et al.[4]. Langenhuijsen et al. described a worse outcome if the posterior fragment is larger than 10 % of the involved articular surface[8]. De Vries et al., Mingo-Robinet et al. and Xu et al. found no clear relationship between posterior fragment size or fixation of the posterior fragment and long-term functional outcome[7,9,17]. To clarify these inconsistent findings, we are currently expanding our study with a more recently operated cohort of participants with trimalleolar fractures. Due to the small sample size of the present study, we cannot draw any conclusions with respect to fixation of posterior fragments and the influence on long-term functional outcome as yet.

Unimalleolar and bimalleolar fractures lead to osteoarthritis in only a small percentage of cases. Osteoarthritis in this type of fractures is mainly caused by other factors such as screw displacement or infection. In our series, osteoarthritis occurred mainly in trimalleolar fractures and is therefore thought to be a result of the combination of a posterior malleolar fracture and a medial malleolar fracture. In trimalleolar fractures, the initial cartilage damage in the weight-bearing part of the joint, in combination with the increased peak contact stress and the weight-bearing shift to anterior and medial, with a non-anatomical reduction of the posterior fragment could lead to an increase in development of osteoarthritis[18-22].

A limitation of this study is the 56 % response rate. This study was completed in an inner-city hospital with a poor patient compliance and a highly variable patient population (seasonal workers and several different nationalities). Despite maximum effort to trace these patients many potential participants were lost to follow-up, so there is a risk of selection bias. However, the baseline data and fracture characteristics of the study group were similar to the total group of patients who met the inclusion criteria for the study. This indicates that our study group was representative.

CONCLUSIONS

Our data support the assumption that in operated isolated fibular fractures, an additional rupture of the deltoid ligament does not lead to worse outcome. Moreover, the results of our study show that long-term functional outcome is strongly associated to the medial malleolus. Bimalleolar fractures lead to significantly worse functional results than isolated fibular fractures and are comparable to trimalleolar fractures. In case of a posterior fracture, the involvement of the medial malleolus will lead to worse functional outcome, more pain and more development of osteoarthritis.

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Incidence and clinical relevance of tibiofibular synostosis in fractures of the ankle which have been treated surgically.

CHAPTER10

ABSTRACT

Introduction

In this retrospective cohort study, we analysed the incidence and functional outcome of a distal tibiofibular synostosis. Patients with an isolated AO type 44-B or C fracture of the ankle who underwent surgical treatment between 1995 and 2007 were invited for clinical and radiological review. The American Orthopaedic Foot and Ankle Society score, the American Academy of Orthopaedic Surgeons score and a visual analogue score for pain were used to assess outcome.

Results

A total of 274 patients were available; the mean follow-up was 9.7 years (8 to 18). The extent of any calcification or synostosis at the level of the distal interosseous membrane or syndesmosis on the contemporary radiographs was defined as: no or minor calcifications (group 1), severe calcifications (group 2), or complete syndesmosis (group 3).A total of 222 (81%) patients were in group 1, 37 (14%) in group 2 and 15 (5%) in group 3. There was no significant difference in incidence between AO type 44-B and type 44-C fractures (p=0.89). Severe calcification or synostosis occurred in 21 patients (19%) in whom a syndesmotic positioning screw was used and in 31 (19%) in whom a syndesmotic positioning screw was not used (p=0.70). No significant differences were found between the groups except for a greater reduction in mean dorsiflexion in group 2 (p=0.004).

Discussion

This is the largest study on distal tibiofibular synostosis, and we found that synostosis is a frequent complication of surgery for a fracture in the ankle. Our findings suggest that synostosis of the distal tibiofibular syndesmosis in general does not warrant treatment.

INTRODUCTION

Fractures of the ankle are common and many have an associated partial or complete injury of the distal tibiofibular syndesmosis.[1-5] This may ossificate with the development of distal tibiofibular synostosis.[6-8] Little has been reported about the clinical consequences of a synostosis. Only small series have been reported with a short follow-up[1-4,6-8] and one larger cohort with 230 patients followed up for a mean of 14 years (6 weeks to 44 months).[5] We report the incidence, symptoms and clinical relevance of a distal tibiofibular synostosis resulting from the surgical treatment of a fracture of the ankle in a large group of patients with a long follow-up.

Patients and Methods

This is retrospective cohort study of all patient who underwent surgical treatment for an isolated AO type 44-B or C fractures of the ankle9 between 1995 and 2007 at the Medical Centre Haaglanden. We identified the patients by reviewing all the radiographs of those who underwent this treatment during this time (n=564) in our clinic, which is a level 1 trauma centre. Exclusion criteria were open fractures, epiphyseal fractures, isolated medial malleolar fractures, pathological fractures, pilon fracture, prior fracture of the same ankle, polytrauma and patients aged < 18 years at the time of trauma or those ages > 75 years at the time of follow-up. Also, patients who developed severe osteoarthritis (OA) leading to an arthrodesis or total ankle arthroplasty were excluded. The patients who were included were contacted by letter, followed by attempts to contact them by telephone. If contact information was missing or outdated, recent information was acquired from the patients' general practioner. Finally, 274 patients with a mean follow-up of 9.7 years (6 to 18) were included in the study (Fig. 1). All patients were reviewed in the clinic, where a physical examination was conducted (SMV) and the range of movement of the ankle was recorded, an validated questionnaires of the American Orthopaedic Foot and Ankle Society (AOFAS),10-12 American Academy of Orthopaedic Surgeons (AAOS)13,14 and a visual analogue score (VAS) for pain (0 to 10, best to worse) were completed. In accordance with the AOFASS scoring system, we measured the maximum dorsiflexion in both ankles, and the difference was registered as the limitation of dorsiflexion. In addition, contemporary radiographs were performed in order to assess the presence of OA of the ankle joint and whether there was calcification or synostosis at the level of the syndesmosis.

Distal tibiofibular ossification revealed on the non-weight-bearing radiographs was graded into one of three groups. Group 1 had no or minor calcification of the distal interosseous membrane, group 2 had severe calcification of the interosseous membrane or syndesmosis and group 3 had a complete synostosis (Fig. 2). This classification was recorded by two experienced independent observers (RD, SMV) who were blinded

to patient information except for date of birth and name. A trauma surgeon (JMH) compared the blinded assessments and in the event of disagreement, agreement was reached by consensus. The characteristics of the patients according to the classification for calcification at the distal tibiofibular syndesmosis are shown in Table 1.

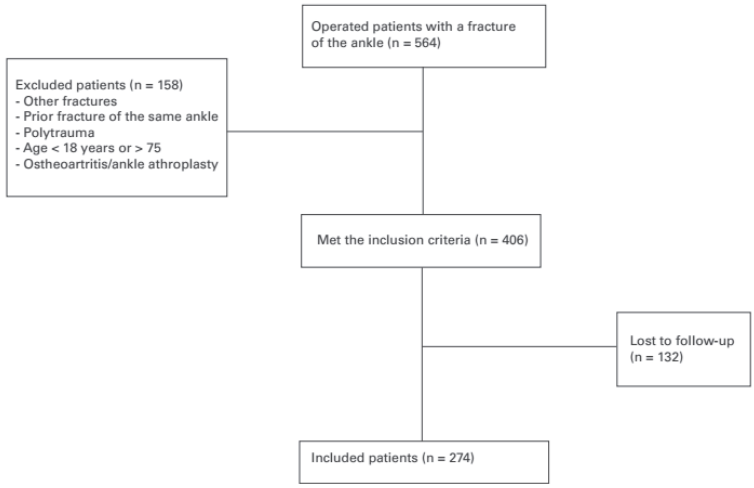

Figure 1: Consolidated Standards of Reporting Trials (CONSORT) flow diagram of the study.

Figure 2: Anteroposterior and lateral radiographs of the ankle to illustrate the classification grades of calcification at the distal tibiofibular syndesmosis. Group 1; no or minor calcifications, group 2; severe calcifications, group 3; complete synostosis.

Table 1: Patient characteristics according to classification of the presence of calcification at the distal tibiofibular syndesmosis. Data are presented as total number (%) unless otherwise stated.

	Group 1 (222)	Group 2 (37)	Group 3 (15)
Male	104 (47)	14 (38)	6 (40)
Female	118 (53)	23 (62)	9 (60)
Smoking	76 (34)	6 (16)	3 (20)
Non-smoking	146 (66)	31 (84)	12 (80)
Diabetes	30 (14)	6 (16)	1 (7)
Mean BMI (17.9-45.8)	28	28	27
Mean age (yrs, 27-75)	54	55	54
AO type B	160 (72)	27 (73)	10 (67)
AO type C	62 (28)	10 (27)	5 (33)
Unimalleolar fractures	99 (45)	18 (49)	5 (33)
Bimalleolar fractures	81 (36)	11 (30)	3 (20)
Trimalleolar fractures	42 (19)	8 (22)	7 (47)
Syndesmotic screws	92 (41)	17 (46)	4 (27)

BMI=Body Mass Index

Statistical analysis. Data were analysed using the Statistical Package for the Social Sciences v 20.0 or higher (SPSS-IBM), Armonk, New York). Continuous data were recorded as the mean with standard deviation and the median with the interquartile range. An unpaired two-sided t-test was used to compare the AOFAS scores between different groups. Categorical data (presence of ossification) were compared using a chi-squared test and Fisher's Exact test. A p-value <0.05 was considered statistically significant.

RESULTS

No or minor calcifications occurred in 222 patients (81%) (Table II, group 1). Severe calcifications appeared in 37 (14%, group 2) and a synostosis developed in 15 patients (5%, group 3). There was no significant difference in the incidence in AO type 44-B and C fractures (p=0.89, chi-squared test). The use of syndesmotic screws was not significantly related to the development of synostosis. Severe calcification or synostosis occurred in 21 patients (19%) in whom syndesmotic screws were used, and in 31 patients (19%) in whom they were not used (p=0.44, chi-squared test).

There were no significant differences in the AOFAS, AAOS and VAS-pain between the three groups (Table III). The median AOFAS score was worse in group 2 (85 vs 95 in group 1 and 3, respectively), but this was not significant (p=0.26, unpaired t-test), and this difference was not seen in the AAOS score. The mean dorsiflexion was 20° in the injured ankle and 25° in the uninjured ankle (0° to 40°) for the whole cohort. Subgroup

analysis of this parameter is shown in Table III. A significant difference in dorsiflexion and limitation of movement was found in group 1 compared with group 2 (p=0.004, unpaired t-test).

Table 2: Occurrence of calcifications or synostosis of the distal interosseous membrane or syndesmosis. Data are presented as total number (%) unless otherwise stated.

	Patients	AO-44B	AO-44C	p-value*
Group 1 (no or minor calcification)	222 (81)	160 (81)	62 (81)	0.768
Group 2 (severe calcification)	37 (14)	27 (14)	10 (13)	0.740
Group 3 (synostosis)	15 (5)	10 (5)	5 (6)	0.89

*Chi-squared test

Table 3: Long-term outcome parameters related to calcifications or synostosis of the distal interosseous membrane or syndesmosis

	Median AOFAS score (IQR)	Median AAOS score (IQR)	Mean VAS-pain (range)	Mean limitation of dorsiflexion (°) (range)
Group 1 (no or minor calcification)	95 (81-100)	95 (84-95)	1.6 (0-8)	4.9 (0-40)
Group 2 (severe calcification)	85 (75-95)	92 (82-98)	1.4 (0-4)	7.7 (0-40)
Group 3 (synostosis)	95 (91-100)	96 (91-98)	1.4 (0-6)	2.7 (0-10)
Overall	94	94	1.5	5.1
P-value	0.26	0.38	0.38	0.009

AOFAS: American Orthopaedic Foot and Ankle Society; IQR: Interquartile Range, AAOS: American Acadamy of Orthopaedic Surgeons, VAS: Visual Analogue Scale.

DISCUSSION

The distal tibiofibular syndesmosis plays a key role in the stability and movement of the ankle.[5,15] In order to achieve dorsiflexion, the fibula moves proximally by a rotational movement with widening of the mortise. The wider anterior part of the talus drives the syndesmosis outward and fills the mortise Increasing rigidity of the syndesmosis because of a synostosis should, theoretically, therefore impair dorsiflexion and interfere with the function of the ankle.[5]

However, few studies have discussed function after the development of a synostosis after surgery to the ankle.[5,7,8,12] The incidence of synostosis in non-operatively treated fractures of the ankle has also not been reported.

The only other long-term follow-up study published was by Albers et al[5] in 1996. They described nine patients with a distal tibiofibular synostosis following a fracture of the ankle from a database including 230 patients treated surgically. The incidence of synostosis was 2% after Weber B and 12% after Weber C fractures.[16] They compared patients using a modified ankle score which included a subjective and objective score with a

maximum of 100 points. After a mean follow-up of 14 years, patients with and without a synostosis had comparable mean functional scores (91 vs 92; 71 to 100). This suggested that a synostosis was associated with few symptoms. In 2009, Hou et al[8] reported a series of eight patients with a synostosis. The mean limitations of dorsiflexion was 8° (4° to 13°) in ankles with a synostosis. In agreement with our study, both reports concluded that there is no indication to treat a synostosis.

We found that, after exclusion of those patients who developed OA of the ankle, 19% of the patients operatively treated for an isolated ankle fracture developed severe calcification or synostosis of the distal tibiofibular syndesmosis. This was not associated with symptoms or decreased function compared with those without a synostosis. The only significant difference was a greater limitation of movement in those with severe calcification. This was not reflected by a significant difference in pain or outcome. It is possible that the measurement of limitation of dorsiflexion is too imprecise to draw conclusions.

We acknowledge the weaknesses in this retrospective, observational study. Many patients were lost to follow-up despite offers to contact them. The retrospective nature of the study contributes recall bias. It is, however, the largest study on distal tibiofibular synostosis. We found that synostosis is a relatively frequent complication of fractures of the ankle which are treated surgically. Although it reduced the range of ankle movement, it did not affect the functional outcome.

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Medium-sized posterior fragments in AO Weber-B fractures, does open reduction and fixation improve outcome? The POSTFIX-trial protocol, a multicenter randomized clinical trial.

CHAPTER11

ABSTRACT

Background

Guidelines for treatment of the posterior fracture fragment in trimalleolar fractures are scarce and show varying advices. Did the increasing size of the posterior fragment seem to relate to worse outcome in the past, nowadays this has changed to the amount of dislocation of the posterior fragment post-operatively. Despite many retrospective cohort studies and some prospective cohort studies, no consistent guideline could be derived from the current literature.

Methods

The POSTFIX-study is designed as a multicenter randomized clinical trial to analyse the effects of anatomical reduction and fixation of the posterior fragment in AO 44-B3 fractures with medium-sized posterior fragment. A total of 84 patients will be included and online allocated to either anatomical reduction and fixation of the posterior fragment via the posterolateral approach (n = 42) or no fixation of the posterior fragment (n = 42). The concomitant fractured medial and lateral malleoli are treated according to the AO-principles. Functionality of the ankle as measured by the AAOS-questionnaire (American Association of Orthopaedic Surgeons) 1 year post-operatively was set as primary outcome. Main secondary outcome measures are the AAOS-questionnaire 5 years postoperatively and osteoarthritis as measured on plain radiographs 1 year and 5 years post-operatively. The Olerud and Molander score, the AOFAS-score, the VAS-pain, the Euroqol-5D and Range of Motion by physical examination will also be evaluated during the follow-up period.

Discussion

The POSTFIX-trial is the first high quality multicenter randomized clinical trial worldwide to analyse the effects of anatomical fixation of the posterior fragment in trimalleolar fractures. New guidelines on anatomical reduction and fixation of the posterior fragment can in future be based on the results of this trial.

BACKGROUND

The optimal treatment of ankle fractures with involvement of the posterior malleolus remains a subject of debate. Despite a large amount of literature on the role of the posterior malleolus in a so-called trimalleolar fracture, there are no clear guidelines for its treatment. Its size was taught to be the leading indicator for the need of fixation of the fragment[1,2]. Most orthopaedic surgeons consider a posterior malleolar fracture fragment larger than 25 to 33% of the joint surface an indication for fixation. Interestingly, after careful evaluation of the available literature[3-8], there does not seem to be solid substantiation of this assumption. Theories about the relation between the size of the posterior fracture fragment and outcome are partially based on biomechanical studies. First, a large posterior fragment was thought to lead to posterior instability and therefore to worse outcome on the long term. Several cadaveric ankle studies however, showed different cut off values ranging from 25 to 33% of the involved articular surface[9,10]. Other studies could not prove the theory of posterior instability in cadaveric ankles[11-14]. Later cadaveric studies suggested a shift of contact pressure pattern in case of a posterior malleolar fracture and therefore the early induction of increased in post-traumatic osteoarthritis[15,16]. Several retrospective cohort studies showed no clear relation between fragment size and functional outcome. Jaskulka et al. and Langenhuijsen et al. found a worse long-term outcome (follow-up 5.7 and 6.9 years) in fragments larger than 5 and 10% of the involved articular surface respectively[3,5]. Broos et al. found a worse outcome after 1 year in patients with posterior fragments larger than 33% of the involved articular surface[6]. De Vries et al. found no relation between size and functional outcome but he suggested a worse functional outcome in case of a posterior malleolar fracture dislocation[4]. More recently two large retrospective cohort studies on the influence of joint congruency in posterior malleolar fractures were published. The first was performed by Xu et al., who studied 102 trimalleolar fractures with a mean follow up of 2.8 years[8]. There was no relation between fragment size and radiological or functional outcome (AOFAS). However, they found a worse functional outcome if a persisting tibiotalar step-off was present after open reduction and internal fixation. Therefore they advised to anatomically restore the articular surface, especially when fragment size involves than 25% of the joint surface[8]. Drijfhout et al. performed a retrospective cohort study of 131 trimalleolar fractures with a mean follow-up of 7.3 years[7]. Functional outcome was worse in trimalleolar fractures with a medium-sized (5–25%) or large (>25%) posterior fragment compared to small fragments (<5%). A postoperatively persisting step-off ≥1 mm of medium-sized or large posterior fragments showed to be the most important predictor for the development of osteoarthritis[7]. Restoration of the tibiotalar articular surface therefore seems essential in medium-sized and large fragments. As shown, no consistent advice is found in the literature as to which fragment size of the posterior

malleolus should be internally fixed. Currently, according to AO guidelines[17] fixation of posterior fragments is indicated if there is a displaced fragment larger than 25% of the involved articular surface or if instability is persistent after reduction of the lateral injury[17] Traditionally, reduction of these larger fragments is performed indirectly, followed by percutaneous screw fixation in anterior-posterior direction. It is often challenging to achieve an anatomical reduction and fixation of smaller fragments using the percutaneous method. Recently, direct exposure of the posterior tibia via a posterolateral approach, followed by open reduction and fixation with screws in posterioranterior direction or an antiglide plate, is advocated by several authors[18-21]. This approach, with the patient in prone position, allows good visualization of the fracture, articular anatomical reduction, and solid fixation. Another advantage is that even small posterior fragments can be addressed. Several case series published favourable results; few major wound complications, good functional outcomes, and rarely a need for reoperation[22,23]. To test the hypothesis that anatomical reduction and fixation of medium-sized posterior fragments via the posterolateral approach is meaningful, this multicenter randomized clinical trial was designed. As far as we know, this is the first randomized controlled trial on fixation of the posterior fragment in trimalleolar fractures worldwide.

METHODS/DESIGN

Aim of the study

Anatomical reduction and fixation of medium-sized posterior malleolar fractures leads to a stable and anatomical fixation[22,23]. In this study, we hope to prove that anatomical reduction and fixation of medium sized posterior fragments leads to less osteoarthritis and better functional outcome in patients having a trimalleolar fracture. Study design and setting This study comprises a multicenter randomized controlled clinical trial in three teaching hospitals in the Netherlands, evaluating functional outcome using the AAOS foot and ankle questionnaire after 1 year in AO-44B3 trimalleolar fractures with a medium-sized (5–25%) posterior fragment.

Patients will be randomized between; 1. Open reduction and fixation with additional fixation of the posterior malleolus via the posterolateral approach or 2. Open reduction and fixation without fixation of the posterior fragment. Two level-1 traumacenters (MCH Westeinde, Haga ziekenhuis) and one level-2 traumacenter (Bronovo hospital) participate, which are all centers in The Hague. The study will be open for inclusion from 2015 till 2019, the follow up will be completed in 2024. The Medical Ethics Committee South West Netherlands approved of the study protocols (protocol number 15-040). The study is registered at ClinicalTrials.gov (Number NCT02596529).

Study population

All patients presenting at the emergency department with an AO-44B3 trimalleolar fracture with a medium sized (5–25%) posterior fragment are asked to participate in the study. The initial decision on inclusion is based on review of pre-operative radiographs since this best resembles daily practice. The pre-operative X-rays are judged by 2 observers to confirm eligibility for the study. Fragment size is measured on plain lateral radiographs at tibiotalar joint level. A computed tomography scan is made in order to assess intra-articular fragments and correlation with pre-operative X-rays and posterior fragment size. The inclusion criteria are: age between 18 and 75 years, trimalleolar AO-44B3 fracture with medium sized (5–25% of the distal tibial articular surface) posterior fragment and first ankle fracture of affected side. Excluded are multitraumatized patients (ISS > 16), patients with multiple fractures or open fractures, ankle fracture of same side in medical history, with pre-existent disability or mobility problems (need of walking gait), where follow-up takes place in another hospital and with insufficient understanding of the Dutch language. A detailed list of in- and exclusion criteria is presented in Table 1.

Table 1: inclusion and exclusion criteria

Inclusion criteria	
1.	>18 and <70 years at time of inclusion
2.	AO 44-B3 fracture with medium-size posterior fragment
3.	First ankle of affected side
Exclusion criteria	
1.	Severely traumatized patients (ISS≥16)
2.	Multiple fractures
3.	Ankle fractures of the same ankle in the history
4.	Patients with pre-existent mobility problems
5.	Pre-existent disability
6.	Patients with follow-up in another hospital
7.	Insufficient understanding of the Dutch language

Recruitment, informed consent and randomization

Patients are first seen at the Emergency Department and will receive the study information from the attending surgeon or surgical resident. All patients will be informed about the potential risks and complications of both fix and non-fix management of the posterior malleolus. If the patient is eligible for inclusion (based on fragment size measured on plain lateral X-ray) and willing to participate, the research coordinator includes the patient within 1 week. All participants provide written informed consent. After inclusion, participants are allocated to one of the two randomisation groups by an

online randomization program in blocks of 6 or 8 patients. A flow-chart of inclusion and randomization is shown in Fig. 1. Blinding is not possible because the two different soft tissue approaches in the treatment protocols indicate which type of surgical fixation is performed.

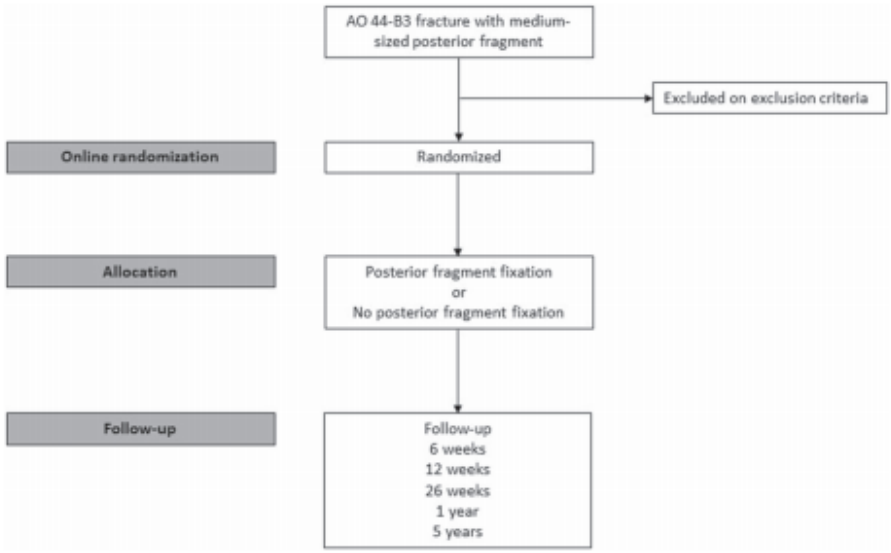

Figure 1: Flow-chart of inclusion and follow-up.

Treatment protocol

All operative interventions are performed by experienced surgeons familiar with both treatment protocols and fixation techniques. Pre-operatively 1 gram Cefazoline® prophylaxis is administered. Dependent form surgeon's preference, patients will be operated with a thigh tourniquet. In case of non-fixation of the posterior fragment, patients are operated in supine position. The lateral malleolus is fixed with two lag screws and/or lateral plate fixation. The medial malleolus is fixed with two cancellous screws or tension band wiring. In case of allocation to the fixation-group, the participant is operated in prone position. The posterolateral approach is used for fixation of both the lateral malleolus and the posterior fragment. The posterior fragment is fixed with lag screws or a buttress or antiglide plate. The lateral and medial malleolus are fixed in the same manner as in the first group. After fixation the syndesmosis is tested by a bone hook or external rotatory stress under fluoroscopic control. If the syndesmosis is unstable, two trans syndesmotic positioning screws are placed. Non-weightbearing mobilization is instructed for 6 weeks after operation. After 6 weeks gradual weight-bearing mobilization is allowed and physiotherapy is started. Low-molecular weight heparin 2850 international units was administered daily as long as patients are immobilized in cast.

End points and follow-up

The primary outcome of this study is the functional outcome after 1 year assessed by the AAOS (American Association of Orthopaedic Surgeons) Foot and Ankle score. Secondary outcome parameters include functional outcome measured with the AOFAS-questionnaire (American Orthopaedic Foot and Ankle Society) and with the Olerud and Molander functional score and osteoarthritis on plain radiographs 1 and 5 years postoperatively. Pain measured on a Visual Analogue Scale (VAS-pain), range of motion in the upper ankle joint (dorsal and plantarflexion) measured using a goniometer and general health measured using the Euroqol-5D are assessed at each visit. The total study period for a participant is 5 years. The entire study will be performed in approximately 10 years. An overview of all measurements during the follow-up period is provided in Table 2. Patients visit the outpatient clinic at 6 weeks, 12 weeks, 26 weeks, 1 year and 5 years after surgery. Deviations of the treatment protocol will be reported. Sample size In this study functional outcome as measured by the AAOS score will be used as the primary outcome parameter. Up to now the minimal clinically important difference has not been determined and published for the AAOS score. Recently, a Cochrane Review suggested a difference of 10 points to be clinically relevant[24] .

Table 2: Measurements during follow-up

	Postoperative	6 weeks	12 weeks	26 weeks	1 year	5 year
X-ray	X	X			X	X
CT-scan	X					
Olerud and Molander		X	X	X	X	X
AAOS				X	X	X
AOFAS				X	X	X
Euroqol-5D		X	X	X	X	X
VAS-pain		X	X	X	X	X
Range of Motion			X	X	X	X

For the sample size calculation we adopted this 10 point difference, with a standard deviation of 15 points and a significance level of 5%. To achieve 80% power, group samples of at least 36 patients are needed. To account for 15% drop-out, group samples of 42 patients are needed (84 in total). Statistical analysis The analysis will be performed on the basis of the intention-to-treat principle. Baseline characteristics (age, gender, fragment size, dislocation posterior fragment etc.) of the study groups will be described using summary statistics. Continuous outcome measures (Olerud and Molander ankle score, VAS-pain, AAOS, range of motion) will be reported as mean and standard deviation and will be compared between the treatment groups by an unpaired t-test. Multiple

imputation for missing data will be performed. Linear mixed models will be used to compare the functional outcome of the two groups during the follow-up.

Data will be analyzed using the "Statistical Package for the Sciences" version 22.0 or higher. Statistical testing will be 2-tailed and a p-value <0.05 will be used as threshold for statistical significance.

DISCUSSION

This study seeks answers to the question whether or not open anatomical reduction and fixation of medium-sized posterior malleolar fractures via a posterolateral approach leads to better functional outcome than when the fragment is left untouched. Since the treatment involves two different surgical procedures with different scars from which the treatment can be deduced, randomisation status will not be blinded. Also post-operative X-rays will show different implants and therefore partial blinding in the postoperative treatment phase will not be possible. For the pre-operative measurement of posterior fragment size and therefore patient selection, we use the Picture Achieving and Communication System (PACS) which is standard in all participating hospitals. Two observers measure the fragment size in PACS on plain X-ray. However, in a discussion amongst clinicians the preferred device for posterior fracture fragment was recently debated[25,26]. The most widely used and currently most reproducible one, is the method described above in PACS, which we use for this study. Functional outcome is measured with three questionnaires. The Olerud and Molander ankle score is best available for short term functional outcome and therefore used to evaluate during the first post-operative year. The AAOS ankle questionnaire is best available functional outcome score on long term and therefore used to evaluate 1 and 5 years post-operatively. The AOFAS ankle questionnaire is build up from a questionnaire and a limited range of motion and therefore also used to evaluate 1 and 5 years post-operatively. The first patient was included in January 2014. We expect to include the last patient in 2018. Latest follow-up visit to our outpatient clinic and the conclusion of the data-acquisition will therefore be in 2023.

CONCLUSION

The POSTFIX-trial is the first multicenter randomized clinical trial worldwide to analyse the effects of open anatomical fixation of the posterior fragment in trimalleolar fractures. New guidelines on anatomical reduction and fixation of the posterior fragment can in future be based on the results of this trial.

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S.M. Verhage

General discussion
and future perspectives

CHAPTER12

GENERAL DISCUSSION AND FUTURE PERSPECTIVES

Since Coopers' description of the trimalleolar fracture in 1822, many publications have discussed and analyzed the challenges and pitfalls of treatment of posterior malleolar fractures. Although more and more literature on the topic becomes available, there is still a lively debate about the diverse aspect of treatment of posterior malleolus fracture. The aim of this thesis was to gain more knowledge about several aspects of treatment of posterior malleolar fractures, including the decisional process, operative approaches, and short- and long-term results. And subsequently to provide evidence based guidance in treatment strategies, whenever possible.

Diagnostics

The initial radiographic examination of the injured ankle includes a true anteroposterior, mortise, and lateral view. The presence of a posterior malleolar fracture is usually obvious on lateral radiographs. Historically, decision-making on treatment of trimalleolar fractures involves determination of the fragment size on plain radiographs. However, measurement of the exact size of the posterior fragment on radiographs is very difficult (**Chapter 2)**. Moreover, the exact fracture morphology like medial extension and central depression with intra-articular loose fragments can be easily missed on plain X-rays. Over the last decades, CT-scanning became widely available and is more frequently performed in ankle fractures. This diagnostic modality leads to a better understanding of the fracture pattern and potentially to other decisions on fracture treatment[1]. Some authors advocate a 3D-CT-scan to measure the involved articular surface of the whole fragment and not only the involved anterior to posterior distance[2-4]. Recently, two posterior fragment fracture classifications were described in detail by two authors[5-7]. Posterior malleolar fractures may be classified as extraincisural fragments (type 1 according to Bartonicek, 8%), single posterolateral fragments (type 2, 52%), posterolateral fragments with posteromedial extension (type 3, 28%) and large, posterolateral triangular fragments (type 4, 9%)[6]. The severity of fracture is higher with increasing type in the classification of Bartonicek. The size of the posterior fragment is deemed of lesser importance than previously thought[6,8]. Involvement of the fibular notch at level of the distal tibia (incisura fibularis), or the presence of depressed loose interarticular joint fragments seems to be of greater therapeutic relevance than the size of the fragment itself and the amount of the involved fractured articular surface alone. Up till now, no cohort studies have related the CT-scan based fracture classification to functional outcome. Use of CT-scan in case of posterior fragment fractures however, gains popularity and is in my opinion essential in better understanding of the fracture pattern, which again is relevant for both decision-making and preoperative planning.

Indications for fixation

Traditionally, it is advised to fixate the posterior malleolus fragment if its size exceeds 25-33% of the involved articular surface or in case of persistent anterior-posterior instability after fixation of the lateral and medial malleoli. However, substantiation of this tradition is thin, since high-quality studies regarding the functional outcome of operatively treated trimalleolar fractures are scarce. Most published studies on this topic are outdated retrospective cohort studies[9-13]. They primarily describe results on functional outcome and development of osteoarthritis in relation to fragment size and in relation to the operative or conservative treatment of the posterior fragment. Limitations of these studies are the retrospective design and heterogeneous use of (sometimes outdated and non-validated) functional outcome questionnaires. The indication for fixation of the posterior fragment in the studied patients was based on plain X-rays. Different sizes are mentioned in different studies (from 5% to 33%) without a clear consensus or threshold from which size posterior fragments should be fixated[8-10,14].

With the introduction of CT-scans more attention is paid to the fracture pattern, specifically to involvement of the incisura, medial fracture extension, step-off and gap, and intra-articular or intercalary fragments. Literature from the last ten years shows a tendency towards a more frequent preference for anatomical reduction, even in case of fragments smaller than 25-33%. This often implies open reduction and fixation. Although extraincisural fractures (type 1 according to Bartonicek) can be treated nonoperatively, operative treatment of type 2 to 4 fractures might aim at reconstruction of the posterior tibial plafond, the fibular notch, and the integrity of the posterior tibiofibular syndesmosis. However, our study amongst orthopaedic trauma surgeons shows that currently there still is a large practice variation in the Netherlands (**chapter 4**).

Approaches for fixation

Different approaches to the posterior malleolus of the ankle are described in literature. Most commonly used is the percutaneous anterior approach with screw placement from anterior to posterior. In this procedure, after open reduction and fixation of the fibula, the posterior fragment should reduce by ligamentotaxis, if necessary with use of a percutaneously AP-placed reduction clamp. But closed anatomical reduction of the posterior fragment can be difficult due to possible loose interfragmentary fragments that may prevent the anatomical reduction. Also, smaller fragments are difficult to reduce by ligamentotaxis alone and fixate with an AP-screw. Clinical studies presented in this thesis show non-anatomical reduction to occur in a large part of the percutaneous anterior to posterior fixated fragments. Two other common approaches are the posterolateral and posteromedial approach, which are both open approaches[15-17]. The advantage of an open approach over a percutaneous approach lies in the higher success rate of anatomical reduction[18]. The posterolateral approach is frequently used for fixation of the

posterior malleolus fragment and is described in detail in this thesis **(Chapter 8).** Good visualization of the anatomical fracture reduction and fixation of both the posterior fragment and the fibula are possible through one posterolateral incision. The posteromedial approach is comparable to the posterolateral approach, but this approach is only useful when the location of the fracture is more to the medial aspect of the ankle, or when large medial extension from a posterior malleolar fracture exists[17]. Currently, in only three publications the radiological or functional results of percutaneous approach are compared with those of the posterolateral approach[18-20]. These studies showed step-off (>1 or >2mm) rates of 8 to 17 % respectively for the posterolateral approach. Step-off (>1 or >2mm) rates in case of the percutaneous approach were significantly higher (17% to 73%). A limitation of two of these studies[19,20] was that the comparison results of postoperative step-off were based on plain X-ray measurements instead of on CT-scan. No studies compared both approaches to no fixation at all. In **chapter 9** we showed that percutaneous reduction followed by 'A-to-P' fixation does not lead to better radiological results than no fixation of the posterior fragment at all in posterior malleolar fractures larger than 5% involved intra articular surface. Open reduction and internal fixation via the posterolateral approach leads to better radiological results when compared to percutaneous fixation and no fixation. Strength of this study is that this study is the only study to describe the radiological outcome of no fixation at all, percutaneous fixation and the open posterolateral approach followed by internal fixation. Limitation of this study is the fact that radiological results are measured on postoperative X-rays instead of CT-scan due to the unavailability of CT-scans.

Factors affecting functional outcome trimalleolar fractures

In the past, several studies conclude worse functional outcome for trimalleolar fractures compared to unimalleolar or bimalleolar fractures[11-13]. Our data support this statement, which is described in **chapter 9**. In this study, bi- and trimalleolar fractures had worse functional outcome compared to isolated fibular fractures. Isolated medial malleolar fractures showed relatively poor outcomes. Fibular fractures in combination with posterior malleolar fractures without medial malleolar fracture showed relatively good functional outcome compared to 'true' trimalleolar fractures[21]. In our other studies, a fragment size larger than 5% was associated with a significant increase of development of osteoarthritis and worse functional outcome (**chapter 5**). Radiological and functional outcome are comparable for fragments of 5-25% and larger than 25% of the involved articular surface. Besides size of the posterior fragment, persisting post-operative step-off of the tibiotalar articular surface after fixation was found to be the most important independent risk-factor for development of osteoarthritis. Correcting the intra-articular step-off seems to be the only surgical parameter that can be positively influenced and could lead to a reduction of development of posttraumatic osteoarthritis. Osteoarthritis

and increased BMI were the only two independent risk factors for worse functional outcome (**chapter 6**).

Distal tibiofibular synostosis is another regularly seen post-traumatic complication of lower-leg fractures. Distal tibiofibular synostosis is thought to worsen functional outcome due to stiffness of the ankle joint as result from bony fusion[22]. This thesis describes a large cohort of ankle fractures with respect to the development of distal tibiofibular synostosis. Development of synostosis postoperative of any grade did not lead to functional impairment in our cohort of ankle fracture patients, although we did find that the range of motion was impaired compared to the contralateral healthy ankle. No relation was found between severity of ankle injury and development of synostosis. Strength of this study is the relative large numbers of included malleolar fractures. Limitations the large number of lost-to-follow-up and the retrospective design of the study.

Future perspectives

In the past literature, a lot of attention was given to the relation between the size of the posterior fragment and the functional outcome. This thesis suggest that the size of the posterior fragment is only one of the factors that contributes to the functional outcome. To decide whether a posterior fragment should be anatomically reduced and fixated a CT-scan of the ankle is advised for a better understanding of the fracture pattern. Up to know more and more CT-scans are performed in daily practice without proven implications for treatment. New studies have to prove the additional value of CT-scans in both preoperative and postoperative evaluation.

Two studies regarding the fixation of the posterior malleolus have been designed and are currently performed in the Netherlands **(**the POSTFIX and POSTFIX-C trials**, chapter 11)**. In these studies, a preoperative CT-scan of the injured ankle will be performed to understand and classify the fracture pattern. Since anatomical reduction is the most important predictor for development of posttraumatic osteoarthritis, evaluation of reduction must take place through postoperative CT-scan. Therefore, a postoperative CT-scan is performed in all participants. Also, the role of syndesmotic stability after fixation of the posterior malleolus will be evaluated in the POSTFIX-C study. With a stable fixation of the posterior malleolus, additional syndesmotic positioning screw is most probably not necessary in fibular fractures proximal of the syndesmosis due to the posterior tibiofibular ligament which is attached to the posterior malleolus. These well-designed randomized clinical trials should give us the answer if fixation of smaller fragments through a posterolateral approach leads to better radiological and functional outcome.

Clinical implications

In summary, to fuel the ongoing debate on the best treatment of posterior malleolus fracture fragments, and to provide some guidance in treatment strategies for the posterior malleolus fracture, the author of this thesis concludes to the following clinical implications of the previously described research:

- In case of a posterior malleolus fracture diagnosed on radiographs, a CT-scan is strongly advised for treatment decisions and preoperative planning.
- Posterior fragments should be classified in the future according the Bartonicek classification in order to compare functional outcome and different morphology of these fragments.
- Open reduction and internal fixation of the posterior malleolus is also recommended in fragments smaller than 25% of the involved articular surface.
- An anatomical reduction of the posterior fragment is essential in providing from development of osteoarthritis and therefore functional outcome.
- Fixation of the posterior malleolus can be best performed through open reduction via the posterolateral approach.
- Development of distal tibiofibular synostosis after ankle fractures does not lead to poor functional outcome.

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Summary

CHAPTER13

SUMMARY

Malleolar fractures are frequently seen at the Emergency Departments of hospitals. A substantial part of these fractures involves the posterior malleolus, a so called trimalleolar fracture. The optimal treatment of the posterior malleolus fracture is the main subject of this thesis.

Diagnostic modalities that help classify trimalleolar fractures are evaluated in **chapter 2**. Different classification systems have been described in literature and it is unclear if the current diagnostic modalities are accurate enough in the detection of trimalleolar fractures. In the ideal situation, a classification system has a good interobserver agreement, is easy in use and has implications for treatment. An interobserver study was performed with three of the most used classification systems: the Weber, the AO and the Lauge-Hansen classification. Also the interobserver agreement for presence of a posterior fracture fragment and the intraclass coefficient for size estimation of the posterior fragment were determined. A moderate agreement was found for the classification systems according to Weber (K=0.49), AO (K=0.45) and Lauge-Hansen (K=0.47). Interobserver agreement on the presence of a posterior fracture fragment was substantial (K=0.63). Estimation of the size of the posterior fragment showed moderate agreement (ICC=0.57).

Although more and more literature has become available on the topic, many questions about the treatment of the posterior malleolus fracture persist. To evaluate the current state of treatment modalities known from previous studies a literature review was performed and described in **chapter 3**. Two main questions were answered in this chapter: WHEN and HOW has the posterior fragment to be fixated? According to the literature the size of the posterior fragment itself does not hand a solid indication for fixation of the posterior fragment. Persisting posterior step-off in the tibiotalar joint however, seems to be an important predictor for developing posttraumatic osteoarthritis and therefore worse functional outcome. An anatomical reduction is therefore essential for radiological and functional outcome. Although only limited literature is available regarding the topic how the fragment should be fixated, open reduction and internal fixation via the posterolateral approach seems superior over percutaneous anterior to posterior screw fixation, because of better visibility of both the fracture and the joint. But these results need to be confirmed in a prospective comparative trial.

The current state of treatment of the posterior malleolar fracture in the Netherlands is described in **chapter 4.** An online survey amongst 151 Dutch trauma- and orthopaedic surgeons was performed. It consisted of three sections; a general section presenting eight questions about the general experience and preferences in fixation of the posterior malleolus of the surgeons. Second, a section presenting six different preoperative cases including the X-rays and CT-scans, regarding the indication for fixation of the posterior fragment. In the third section, questions about reduction quality and about the need

for reoperation in nine cases, presented with their postoperative X-rays and CT-scans, were asked. According to the results of our survey there is great variation in treatment strategies if only the size of the posterior fragment is taken into account. Second, an open posterolateral approach is not preferred over a percutaneous anterior to posterior approach among the respondents. A percutaneous approach and an open posterolateral approach are somewhat equally distributed. Third, most discussion in treatment preference exists for Bartonicek type 3 fractures (with an additional posteromedial fragment) and in Bartonicek type 2 fractures with medium-sized posterior fragments. Reoperation after initial treatment was considered by 33-38% of the respondents in case of a postoperative step-off of more than 1mm.

In **chapter 5** a retrospective cohort study of 131 patients with an operatively treated trimalleolar fracture is presented. This study was performed to evaluate the influence of fragment size on functional outcome and development of posttraumatic osteoarthritis. Mean follow-up was 6.9 (range 2.5-15.9) years. Patients were divided into groups depending on size of the fragment, small (<5%, n = 20), medium (5-25%, n = 86), or large (>25%, n = 25), and presence of step-off after operative treatment. Development of posttraumatic osteoarthritis was significantly more common in ankle fractures with medium fragments compared to small fragments (medium 48%, small 16%; p=0.02) and in large fragments compared to small fragments (large 54%, small 16%; p=0.006). No difference in functional outcome or development of posttraumatic osteoarthritis is found between medium and large fragments. In the group with medium and large posterior fracture fragments, a persistent postoperative step-off ≥1 mm showed a significantly higher incidence of posttraumatic osteoarthritis compared to anatomically reduced fractures (61% versus 41%, p=0.02). Fixation of the posterior malleolus (in addition to the medial and lateral malleolus) did not influence the incidence of posttraumatic osteoarthritis, compared to fixation only of the lateral and medial malleolus. A postoperative step-off persisted in 42% of the fixated posterior fracture malleolus fragments versus 45% in the group without fixation. No significant difference in functional outcome was found between the three analyzed groups in this study.

A retrospective cohort of 169 patients with a mean follow-up of 6.3 years was described in **chapter 6.** This study was designed to determine predictors for development of posttraumatic osteoarthritis and worse functional outcome in trimalleolar fractures. A persistent postoperative step-off larger than 1mm was found in 65 patients (39%) and osteoarthritis was present in 49 patients (30%). To identify risk factors for a poor functional outcome, linear regression analyses and subsequent multivariable analysis were performed. Higher age and postoperative step-off >1mm were independent, significant risk factors for development of osteoarthritis. Osteoarthritis and BMI were independent, significant risk factors for worse functional outcome. Size was not a risk factor for worse functional outcome nor development of osteoarthritis. Next to BMI, a correction of an

intra-articular step-off is the only risk factor that can be positively influenced by (surgical) interventions. It is therefore advised to anatomically correct any intra-articular step-off of intra-articular posterior malleolar fragments in order to reduce the risk of developing osteoarthritis and, consequently, the risk of worse functional outcome after long-term follow-up.

Different fixation methods for fixation of the posterior malleolus have been described in literature. Traditionally, the posterior fracture fragment is reduced through ligamentotaxis and fixated percutaneously from anterior to posterior. Recently, fixation through open reduction and internal fixation via the posterolateral approach is gaining more and more popularity. This study was performed in order to evaluate the radiological results and the complication rate of fixation via the posterolateral approach. Also, a brief description of this approach is given in **chapter 7**.

A total of 52 patients were included in this study with a mean posterior fragment size of 27% (range 10-52%). All posterior fragments were fixated via a posterolateral approach. In 12 patients (23%) the posterior fragment was fixated with lag screws only. The other 40 patients were treated with a buttress plate. A radiologically determined anatomical reduction (step-off smaller than 1mm) was achieved in all patients. The retrospective design and the measurement of postoperative step-off on X-ray instead of CT-scan present two limitations to this study. According to the results of this study, open reduction and internal fixation via the posterolateral approach leads to an anatomically reduced posterior malleolus fracture fragment and stable fixation, even in AO Weber-C fractures without placement of syndesmotic positioning screws.

Postoperative reduction results after closed reduction and fixation of the posterior fragment through percutaneous anterior to posterior screw fixation and an open reduction via the posterolateral approach are evaluated in **chapter 8.** A study group of 180 patients with a posterior fragment larger than 5% of the involver articular surface was postoperative radiographically analyzed on postoperative gap and step-off by three observers. Twenty-five posterior fragments had been fixated percutaneously from anterior to posterior (group 1) and 51 had had open reduction and internal fixation through a posterolateral approach (group 2). In 104 patients the posterior malleolus was not fixated (group 3). The average size of the posterior fragment was 34% in group 1, 27% in group 2 and 16% in group 3. A postoperative step-off >1mm was found in 40% (group 1), 9% (group 2) or 34% respectively (group 3). The presence of a postoperative step-off was significantly more frequent in the 'A to P' screw fixation and the no-fixation groups compared to 'ORIF' group (both p=0.001). There was no significant difference in incidence of step-off between the group 1 ('A to P') and group 3 (no-fixation). Based on these results we concluded that fixation of the posterior malleolus through an open posterolateral approach leads to better radiological results as compared to percutaneous 'A to P' screw fixation or no fixation at all.

The largest published cohort of ankle fractures with long-term follow-up is described in **chapter 9.** A total of 243 operated patients with a mean follow-up of 9.6 years were evaluated for clinical outcome at the outpatient clinic. Significant better outcomes were found in unimalleolar (isolated fibular) compared to bimalleolar (a combination of fibular and medial) fractures (AOFAS 97 vs 91, p= 0.035; AAOS 97 vs 90,p= 0.026; dorsiflexion restriction 2.8° vs 6.7°,p= 0.003). Functional outcomes of fibular fractures with an additional posterior fragment were similar to those of isolated fibular fractures. There was no significant difference in isolated fibular fractures with or without additional deltoid ligament injury. However, significant differences were found between unimalleolar and trimalleolar (a combination of lateral, medial and posterior) fractures (AOFAS 97 vs 88, p< 0.001; AAOS 97 vs 90,p= 0.003; VAS-pain 1.1 vs 2.3p< 0.001; dorsiflexion restriction 2.9° vs 6.9°,p< 0.001). No functional differences were found between bimalleolar and trimalleolar fractures. Development of posttraumatic osteoarthritis occurred mainly in trimalleolar fractures with a posterior fragment larger than 5% of the involved intra-articular surface. Only a small part of these posterior malleolar fractures had been operatively treated.

Chapter 10 describes the largest cohort of postoperative distal tibiofibular synostosis in current literature in order to evaluate the effect of synostosis on functional outcome. Distal tibiofibular synostosis is a common seen complication in ankle fractures and leads theoretically to functional impairment due to decreased mobility between the distal tibia and fibula. A total of 274 patients were analyzed. Of them, 52 patients showed severe calcifications or a complete synostosis. All patients were classified into groups with either no or minimal calcifications (group 1, 81%), severe calcifications (group 2, 14%) or complete synostosis (group 3, 5%). The use of syndesmotic positioning screws did not lead to increased development of synostosis. No significant differences were found in functional outcomes or limitation of dorsiflexion between the three groups. A distal tibiofibular synostosis did not lead to worse functional outcome in our study.

This thesis is about the optimal treatment of the posterior malleolus in trimalleolar fractures. Although more and more studies are published on the topic, well designed randomized clinical trials are missing. Therefore, a multicenter randomized clinical trial is designed and the protocol is described in **chapter 11.** This trial is currently performed in the Netherlands and the results can be expected soon.

Overall conclusion

Persistent postoperative step-off of the posterior fragment in trimalleolar fractures is the most important predictor for development of posttraumatic osteoarthritis and therefore for worse functional outcome. An anatomical reduction and fixation of posterior fragments is therefore essential and can probably be performed best, and in a safe way, through an open posterolateral approach.

Nederlandse samenvatting

CHAPTER14

NEDERLANDSE SAMENVATTING

Enkelfracturen worden regelmatig gezien op de spoedeisende hulp afdeling. Een aanzienlijk deel van enkelfracturen betreft fracturen met een tertiusfragment, de zogenaamde trimalleolaire fracturen. De optimale behandeling van het tertiusfragment in trimalleolaire fracturen is het onderwerp van dit proefschrift.

De diagnostiek van trimalleolaire fracturen wordt besproken in **hoofdstuk 2**. In de literatuur zijn verschillende classificatiesystemen om een trimalleolaire fractuur te classificeren beschreven. Het is echter onduidelijk of de huidige diagnostiek in staat is om trimalleolaire fracturen adequaat te diagnosticeren en daarmee classificatie goed mogelijk te maken. In de ideale situatie heeft een classificatiesysteem een goede interobserver overeenkomst, is eenvoudig in gebruik en heeft gevolgen voor de behandeling. In een interobserver studie werden de drie meest gebruikte classificatiesystemen voor enkelfracturen, de Weber-, AO- en Lauge-Hansen, met elkaar vergeleken. Tevens werd de interobserver overeenkomst voor aanwezigheid van een tertiusfractuur en de intraclass coëfficiënt voor de grootte van het tertiusfractuurfragment berekend. Alle drie classificatiesystemen (Weber K=0.49, AO K=0.45, Lauge-Hansen K=0.47) toonden een matige overeenkomst. Voor de aanwezigheid van een tertiusfractuur werd een redelijke interobserver overeenkomst gevonden (K=0.63). De bepaling van de grootte van het tertiusfragment resulteerde in een matige overeenkomst.

Hoewel recent steeds meer literatuur over dit onderwerp is gepubliceerd, bestaan er nog steeds veel vragen over de behandeling van de tertiusfractuur. In een literatuur review wordt de huidige behandeling geëvalueerd **(hoofdstuk 3)**. Twee vragen staan in dit hoofdstuk centraal: wanneer en hoe moet het tertiusfragment worden gefixeerd? De grootte van het tertiusfragment is volgens de huidige literatuur niet de enige indicator voor fixatie van het fragment. Postoperatieve intra-articulaire tibiotalaire step-off is een belangrijke voorspeller voor de ontwikkeling van posttraumatische artrose en daardoor ook voor slechte functionele uitkomst. Anatomische repositie is daarom essentieel voor de radiologische en functionele uitkomst. Over de beste methode van fixeren van het tertiusfragment is slechts weinig literatuur beschikbaar. Uit de spaarzame literatuur lijkt een open reductie en interne fixatie vanuit posterieur superieur te zijn aan een percutane anterieur-posterieure schroeffixatie. Hoogstwaarschijnlijk komt dit door een goede expositie van de fractuurdelen en uitstekende visualisatie van het tibiotalaire gewricht. Deze bevindingen moeten echter bewezen worden in prospectieve studies.

De huidige behandeling van het tertiusfragment in trimalleolaire fracturen in Nederland wordt beschreven in **hoofdstuk 4**. Een online enquête werd afgenomen bij 151 (orthopedische) traumachirurgen in Nederland. De vragenlijst bestond uit 3 delen. Als eerste een algemeen deel met acht vragen over de ervaring van de chirurg en voorkeur van benadering. Als tweede werden zes preoperatieve casussen gepresenteerd met

behulp van röntgenfoto's en CT-scans. Hierbij werd de vraag gesteld of fixatie van het tertiusfragment geïndiceerd was. Als laatste werden negen postoperatieve casussen gepresenteerd met twee vragen; namelijk of de reductie acceptabel was en of de osteosynthese gereviseerd diende te worden. De resultaten van deze survey toonde een grote variatie in behandeling van de fracturen als alleen de grootte van het tertiusfragment in acht wordt genomen. Ten tweede wordt een open posterolaterale benadering ongeveer even vaak gebruikt als een percutane anterieure benadering. Beide benaderingen hebben in ongeveer 50% van de respondenten de voorkeur. De meeste verschillen van inzicht over de behandeling bestonden bij Bartonicek type 2 fracturen (met posteromediale uitbreiding) en Bartonicek type 3 fracturen met middelgroot tertiusfragment. 33-38% van de respondenten overwoog een reoperatie te verrichten bij een persisterende postoperatieve step-off van meer dan 1 mm.

Hoofdstuk 5 beschrijft een retrospectieve cohort studie van 131 patiënten met een operatieve behandeling van een trimalleolaire fractuur. Het doel van deze studie was om de invloed van fractuurfragmentgrootte op de functionele uitkomst en de ontwikkeling van posttraumatische artrose te onderzoeken. Gemiddelde follow-up was 6.9 jaar (range 2.5-15.9). De patiëntenpopulatie werd opgedeeld afhankelijk van de grootte van het tertiusfragment in; kleine fragmenten (<5%, n=20), middelgrote fragmenten (5-25%, n=86) of grote fragmenten (>25%, n=25). Tevens werd de aanwezigheid van postoperatieve step-off bepaald. Deze studie toonde een significant hogere frequentie van posttraumatische artrose in de middelgrote (middelgroot 48%, klein 16%, p=0.02) en grote fragmenten (groot 54%, klein 16%, p=0.006) ten opzichte van kleine fragmenten. Er werd geen verschil gevonden in zowel functionele uitkomst als ontwikkeling van posttraumatische artrose tussen middelgrote en grote fragmenten. Een persisterende postoperatieve step-off van meer dan 1mm leidde tot een significant hogere incidentie van posttraumatische artrose in de groep met middelgrote en grote tertiusfragmenten (61% versus 41%, p=0.02). Fixatie van het tertiusfragment op zichzelf (in aanvulling op fixatie van laterale en/of mediale malleolus) had geen invloed op incidentie van posttraumatische artrose in vergelijking met trimalleolaire fracturen welke alleen fixatie van laterale en/of mediale malleolus ondergingen. 42% van de gefixeerde tertiusfragmenten had postoperatief een step-off van meer dan 1mm vergeleken met 45% in de groep van niet gefixeerde fragmenten. Een significant verschil in functionele uitkomst tussen de 3 verschillende groepen werd niet gevonden.

Hoofdstuk 6 beschrijft een retrospectief cohort van 169 patiënten met een gemiddelde follow-up van 6.3 jaar. Deze studie werd ontworpen om risicofactoren voor ontwikkeling van posttraumatische artrose of slechte functionele uitkomst te detecteren. 65 patiënten (39%) hadden een persisterende postoperatieve step-off groter dan 1mm. Posttraumatische artrose werd aangetoond in 49 patiënten (30%). Middels lineaire regressie en multivariabele analyse werden tweeonafhankelijke risicofactoren

voor slechte functionele uitkomst gevonden: Hogere leeftijd en postoperatieve step-off groter dan 1mm waren onafhankelijke significante risicofactoren voor ontwikkeling van posttraumatische artrose. Artrose en verhoogde BMI waren op hun beurt onafhankelijke significante risicofactoren voor slechte functionele uitkomst. Grootte van het tertiusfragment was geen risicofactor voor slechte functionele uitkomst of ontwikkeling van posttraumatische artrose. Correctie van een intra-articulaire step-off is, naast een verhoogde BMI, de enige risicofactor die (chirurgisch) gecorrigeerd kan worden. Daarom is correctie van de intra-articulaire step-off bij tertiusfragmenten sterk geadviseerd om het risico van ontwikkeling van posttraumatisch artrose te beperken, en daarmee het risico van slechte functionele uitkomst op lange termijn te reduceren.

In de huidige literatuur zijn verschillende fixatiemethoden voor het tertiusfragment beschreven. Een veel gebruikte methode van fixatie is gesloten fractuurrepositie en percutane schroeffixatie van anterieur naar posterieur. Tegenwoordig wint open reductie en interne fixatie via een posterolaterale benadering steeds meer aan populariteit. **Hoofdstuk 7** geeft een gedetailleerde beschrijving van deze techniek. In deze studie worden de radiologische resultaten en de complicaties van deze techniek in een cohort van 52 patiënten met een gemiddelde tertiusfragmentgrootte van 27% (range 10-52%) beschreven. Alle tertiusfragmenten werden gefixeerd via de posterolaterale benadering: 12 patiënten (23%) met posterieure schroeffixatie, 40 patiënten (77%) werden behandeld met een afsteunplaat op de posterieure tibia. Bij alle patiënten werd anatomische reductie (step-off < 1mm) bereikt (postoperatieve röntgenfoto). Het retrospectieve design en de meting van de postoperatieve step-off op een röntgenfoto in plaats van een CT-scan zijn de grootste beperkingen van deze studie. Deze studie laat zien dat open repositie en interne fixatie via de posterolaterale benadering tot een anatomische repositie en stabiele fixatie leidt, zelfs in het geval van een Weber C fractuur, zonder plaatsen van een stelschroef.

Hoofdstuk 8 beschrijft de radiologische resultaten na verschillende operatieve behandeling van trimalleolaire fracturen. De postoperatieve röntgenfoto's van werden beoordeeld op gap en step-off door 3 observers. In totaal namen 180 patiënten deel. Vijfentwintig tertiusfractuurfragmenten werden gesloten gereponeerd en vervolgens percutaan voor-achterwaarts gefixeerd (groep 1) en 51 tertiusfragmenten zijn na open repositie intern gefixeerd via de posterolaterale benadering (groep 2). In 104 patiënten werd het tertiusfragment niet gefixeerd (groep 3). De gemiddelde fragmentgrootte was 34% van het gewrichtsoppervlak in groep 1, 27% in groep 2 en 16% in groep 3. Een postoperatieve step-off groter dan 1mm werd gevonden in 40% (groep 1), 9% (groep 2) en 34% (groep 3) van de patiënten. Deze studie toonde een significant lagere frequentie van postoperatieve step-off in de ORIF groep vergeleken met de percutane fixatie of geen fixatie groep (beide p=0.001). Er werd geen significant verschil in incidentie van step-off gevonden tussen de percutane fixatie (groep 1) en de niet-fixatie groep (groep

3). Op basis van deze resultaten concluderen we dat open reductie en interne fixatie van het tertiusfragment via de posterolaterale benadering tot betere radiologische resultaten leidt vergeleken met percutane voor-achterwaartse fixatie of geen fixatie.

Het tot op heden grootste gepubliceerde cohort van enkelfracturen met lange termijn follow-up is beschreven in **hoofdstuk 9**. Een groep van 243 geopereerde patiënten met een gemiddelde follow-up van 9.6 jaar werd teruggezien op de polikliniek voor klinische evaluatie. De studie toonde significant betere uitkomsten in unimalleolaire (geïsoleerde fibulafracturen) vergeleken met bimalleolaire (combinatie van fibula en mediale malleolus fractuur) fracturen (AOFAS 97 vs 91, p=0.035; AAOS 97 vs 90, p=0.026; dorsaalflexiebeperking 2.8° vs 6.7°, p=0.003). Er was geen significant verschil in functionele uitkomst tussen fibulafracturen met of zonder een tertiusfragment. Tevens was er geen verschil in functionele uitkomst tussen geïsoleerde fibulafracturen met of zonder aanvullende mediaal bandletsel. Wel werden er significante verschillen gevonden tussen unimalleolaire en trimalleolaire (combinatie van laterale, mediale en posterieure fractuur) fracturen (AOFAS 97 vs88, p<0.001; AAOS 97 vs 90, p=0.003; VAS-pijn 1.1 vs 2.3, p<0.001; dorsaalflexiebeperking 2.9° vs 6.9°, p<0.001). Tussen bimalleolaire en trimalleolaire fracturen werden geen significante verschillen gevonden. Posttraumatische artrose werd met name gevonden in trimalleolaire fracturen met een tertiusfragment groter dan 5% van de voor-achterwaartse gewrichtsoppervlakte. Slechts een klein aantal van deze tertiusfragmenten werden gefixeerd.

In **hoofdstuk 10** wordt een groot cohort van postoperatieve distale tibiofibulaire synostoses beschreven. Synostose kan theoretisch tot een beperkte functie van het enkelgewricht leiden door verminderde mobiliteit tussen de distale tibia en fibula. In totaal werden 274 patiënten geanalyseerd voor deze studie. Van deze patiënten hadden 52 patiënten ernstige calcificaties of een volledige synostoses. Alle patiënten werden onderverdeeld in drie groepen met geen of minimale calcificaties (groep 1, 81%), ernstige calcificaties (groep 2, 14%) of een complete synostoses (groep 3, 5%). Het gebruik van syndesmose stelschroeven had in deze groep niet geleid tot een verhoogde ontwikkeling van synostoses. Er werden geen significante verschillen gevonden in functionele uitkomst of beperking van dorsaalflexie tussen de drie groepen. Een distale tibiofibulaire synostoses leidt niet tot slechte functionele uitkomst in deze studie.

Dit proefschrift beschrijft de zoektocht naar de optimale behandeling van het tertiusfragment in trimalleolaire fracturen. Hoewel recent steeds meer literatuur beschikbaar komt over dit onderwerp zijn er nog geen goede gerandomiseerde studies gepubliceerd. Daarom is een multicenter randomized controlled trial opgezet en het studieprotocol van deze studie is beschreven in **hoofdstuk 11**. Deze studie loopt momenteel in een aantal Nederlandse ziekenhuizen en de resultaten van deze studie worden binnenkort verwacht.

Conclusie

Persisterende postoperatieve step-off van het tertiusfragment in trimalleolaire fracturen is de belangrijkste voorspeller voor de ontwikkeling van posttraumatische artrose en daarmee voor slechte functionele uitkomst. Anatomische repositie en fixatie van het tertiusfractuurfragment is daarom essentieel in de behandeling van deze fracturen en kan waarschijnlijk het beste en veilig uitgevoerd worden via een open posterolaterale benadering.

APPENDICES

SCIENTIFIC PUBLICATIONS AND PRESENTATIONS

Publications

Verhage SM, Hoogendoorn JM. Fixatie van het tertiusfragment in trimalleolaire fracturen. (Dutch) *Nederlands Tijdschrift voor traumatologie, Oct 2012*.

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Verhage SM, Hoogendoorn JM, Krijnen P, Schipper IB. Variation in posterior fragment fixation in the Netherlands, a nationwide study. *(submitted)*

Verhage SM, Leijdesdorff A, Krijnen P, Schipper IB, Hoogendoorn JM. Open reduction and internal fixation of the posterior malleolus fragment via the posterolateral approach is radiologically superior to 'A to P' screw fixation. *(submitted)*

Oral presentations

Mediale malleolus prognostisch voor lange termijn uitkomst in 243 geopereerde enkelfracturen. *(Traumadagen 2012, Amsterdam, **Verhage SM**, Hoogendoorn JM)*

Mediale malleolus prognostisch voor lange termijn uitkomst in 243 geopereerde enkelfracturen. *(Wetenschapsmiddag MCHaaglanden, The Hague, **Verhage SM**, Hoogendoorn JM)*

Synostose na een geopereerde enkelfractuur leidt niet tot slechtere resultaten. *(Assistentensymposium Traumachirurgie 2013, Soestduinen, **Verhage SM**, Droog R, Hoogendoorn JM)*

Medial Malleolar fracture prognostic for long-term outcome in 243 ankle fractures. *(ECTES 2013, Lyon, **Verhage SM**, Hoogendoorn JM)*

Synostose na een geopereerde enkelfractuur leidt niet tot slechtere resultaten. *(Traumadagen 2013, Amsterdam, Droog R, **Verhage SM**, Hoogendoorn JM)*

Anatomical reposition of medium-sized posterior malleolar fractures lead to less osteoarthritis *(Assistentensymposium 2014, Soestduinen, **Verhage SM**, Drijfhout-van Hooff CC, Hoogendoorn JM)*

Synostosis as a complication in 274 malleolar fractures. *(EFORT 2014, London, **Verhage SM**, Droog R, Hoogendoorn JM)*

Anatomisch repositie van het tertiusfragment in trimalleolaire fracturen leidt tot minder artrose. *(Chirurgendagen 2014, Veldhoven, Drijfhout-van Hooff CC,* ***Verhage SM****, Hoogendoorn JM)*

Influence of fragment size and postoperative joint congruency on long-term outcome of posterior malleolar fractures. *(ECTES 2015, Amsterdam, Drijfhout-van Hooff CC,* ***Verhage SM****, Hoogendoorn JM)*

Open Reposition and fixation of the posterior malleolus via the posterolateral approach. *(ECTES 2015, Amsterdam,* ***Verhage SM****, Schipper IB, Hoogendoorn JM)*

Fixation of the posterior malleolus in trimalleolar fracture via the posterolateral approach is radiological superior to "A to P" percutaneous screw fixation. *(Wetenschapsmiddag HMC 2016,* ***Verhage SM****, Leijdesdorff A, Hoogendoorn JM)*

Open reduction and internal fixation of the posterior malleolus via the posterolateral approach is radiological superior to 'A to P' screw fixation. *(ECTES 2017, Boekarest,* ***Verhage SM****, Leijdesdorff A, Schipper IB, Hoogendoorn JM)*

Fixation of the posterior malleolus: functional and radiological outcomes after changing our operative strategy to the posterolateral approach. *(ECTES 2017, Boekarest,* ***Verhage SM****, Krijnen P, Schipper IB, Hoogendoorn JM)*

Instable ankle fractures in geriatric patients, do not operate! *(Traumadagen 2018,* ***Verhage SM****)*

Poster presentations

Relation between size of posterior fragment and development of osteoarthritis in 77 operated trimalleolar fractures *(Traumadagen 2012,* ***Verhage SM*** *et al.)*

Interobserver variance in classification of malleolar fractures *(Traumadagen 2012,* ***Verhage SM*** *et al.)*

Relation between size of posterior fragment and development of osteoarthritis in 79 operated trimalleolar fractures *(ECTES 2013,* ***Verhage SM*** *et al, nominated for best poster award)*

Anatomische repositie van middelgrote tertiusfragmenten leidt tot verminderde artrose. *(Wetenschapsmiddag MCHaaglanden 2013,* ***Verhage SM*** *et al)*

Interobserver variation in classification of malleolar fractures. *(ECTES 2015,* ***Verhage SM*** *et al.)*

Variation and agreement in the treatment of open lower limb fractures in the Netherlands. *(ECTES 2017,* ***Verhage SM*** *et al.*

Variation in posterior fragment fixation in the Netherlands, a nationwide study. *(Traumadagen 2018,* ***Verhage SM*** *et al.)*

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CURRICULUM VITAE

Sander Verhage was born on the 18th of April 1988 in Gouda, the Netherlands. After graduating from the Calvijn College in Goes in 2006, he studied Medicine at the Leiden University. In 2008, he took one year off in order to organize the introduction week for the Leiden University in the summer of 2009. He was a very active member of the Leiden University and took place in several student committees during his study like the lustrum committee (87th) of the University of Leiden and the Leiden University Fund.

During the last part of his study, he started his scientific work on trimalleolar fractures under supervision of dr. J.M. Hoogendoorn in 2011 in the Haaglanden Medical Center. His enthousiasm to continue the scientific work during his internships from medical school leads to this thesis. Several retrospective studies were performed by the author and 2 prospective studies were designed to keep the science going. In May 2014 he graduated from medical school whereafter he started working as a resident Surgery not in training at Haaglanden Medical Center in the Hague. In this period, the collaboration with Prof. Dr. I.B. Schipper started.

He started working as a resident Surgery in training (AIOS) in January 2015 under supervision of Dr. H.J. Smeets and Dr. S.A.G. Meylaerts. In 2015 and 2016 he was member of the scientific committee of the Haaglanden Medical Center. In 2017 he took one year off to work as a resident traumasurgery in Spitalzentrum Oberwallis, Visp, Switzerland under supervision of dr. T. Beck. In 2018 he continued his training as Surgery Resident in training in Haaglanden Medical Center. In January 2020, he will start his final training in Traumasurgery in the Haaglanden Medical Center and the Leiden University Medical Center.

Sander lives happily together with his wife Inge in the Hague, the Netherlands and is proud father of two beautiful children: Lauren and Aron.