Patient-reported outcome and fracture-related infection after ankle fracture surgery

Kristian Pilskog

Avhandling for graden philosophiae doctor (ph.d.)
Universitetet i Bergen
2023

UNIVERSITETET I BERGEN

Patient-reported outcome and fracture-related infection after ankle fracture surgery

Kristian Pilskog

Avhandling for graden philosophiae doctor (ph.d.)
ved Universitetet i Bergen

Disputasdato: 01.12.2023

År: 2023

Tittel: Patient-reported outcome and fracture-related infection after ankle fracture surgery

Navn: Kristian Pilskog

Trykk: Skipnes Kommunikasjon / Universitetet i Bergen

Scientific environment

The studies that make up this thesis are based on data from patients operated at the Department of Orthopedic Surgery at Haukeland University Hospital. The PhD training took place in the Department of Clinical Medicine, University of Bergen, Norway.

Main supervisor:

Professor Jonas Meling Fevang, MD, PhD

1. Clinical Insitute 1, Department of Clinical Medicine, Faculty of Medicine, University of Bergen
2. Chief of department, Consultant, Department of Orthopedic Surgery, Haukeland University Hospital

Co-supervisors

Professor Håvard Dale, MD, PhD[1,2]

Associate Professor Eivind Inderhaug, MD, PhD[1,2]

1. Clinical Insitute 1, Department of Clinical Medicine, Faculty of Medicine, University of Bergen
2. Consultant, Department of Orthopedic Surgery, Haukeland University Hospital

Acknowledgements

As a new resident I was asked to give a lecture on posterior malleolar fractures as part of the teaching at our department at Haukeland University Hospital. Through the preparations of my presentation, I read most of the papers published on the topic. This made me realize how there was no clear answer to whether the posterior malleolus fractures should be fixed during ankle osteosynthesis or not. Still, our department saw a dramatic shift in practice towards a posterior approach for treating ankle fractures with a posterior malleolus fracture, without sufficient available evidence to justify the change. These considerations inspired me to go into research. Not only to answer the question of fixation versus no fixation of the posterior malleolar fractures but to help strengthening the research field of orthopedic trauma surgery. This motivation was reinforced by being part of a department with surgeons and researchers of the highest quality.

Firstly, I would like to thank the patients for participating in the studies. Their flexibility and accommodating approach made the collecting of data feasible. They expressed an appreciation to help future patients.

Secondly, a warm thank you to my dear supervisors.
Thank you, Jonas Meling Fevang, for being my main supervisor. You are busy man, but your door is always open. Thank you for giving me endless opportunities and for believing in me. Your support is vital. I deeply appreciate our talks and discussions on life, research, orthopedic topics, medical health services and much more. You have an incredibly sharp mind and I have and still am learning a lot from you. Thank you for the excellent job you are doing for the department. I hope we will work on more projects in the future. Please share my great gratitude with your wife, Bjørg Tilde Fevang, as well.

Håvard Dale came in as a co-supervisor and helped me see the finish line. Thank you for considering me, believing in me, and wanting to join the project. Thank you for the honest reviews. I have learned to analyze, digest and cope with critique in a much better way. I appreciate our talks on life and on research. I am looking forward to the next projects on FRI.

I am honored to have had Eivind Inderhaug as my co-supervisor. Thank you for your dedication and the time spent helping me develop as a researcher and person. Your incredibly fast replies and reviews have kept me on track and helped me reach my goals. You are a role model as a scientific writer, communicator, researcher, and as a person – your kindness and inclusiveness are admirable. Thank you for the many talks in our office on life, work, coming projects and orthopedic research.

Several colleagues have helped me with this project. A special thank you to Teresa Brnic Gote who have examined most of the patients in Paper 1 and Paper 2. Your kindness and dedication are appreciated.

Thank you also to Heid Elin Johannessen Odland for your contribution. You go far beyond expectation both for your colleagues and your patients, thank you for being a great colleague and friend.

Thank you, Knut Andreas Fjeldsgaard, for believing in me and supporting me since I was a fresh resident. Thank you for always pushing me and helping me search for results and new knowledge.

A special thank you to Paula Sætre, Aina Thomine Apelthun, and Magnhild Kallekleiv for your help with administrating and contacting the study participants.

I want to thank my great colleagues at the Section for arthroplasty. We have a super environment and the support from Jan-Erik Gjertsen, Ove Furnes, Radenko Borojevic, Torbjørn Kristensen, Geir Hallan, Pål Høvding, and Sindre Myklatun Tveit is truly important to me. To stand on the research traditions of such giants is both humbling and motivating. Thank you for the discussions and help from all of you.

Thank you also to Jostein Skorpa Nilsen and Omar Thorstein Arnason. You are both incredible surgeons and role models in the operating theater. Your door is always open and with you help is always near. I appreciate the weekly talks we have on ankle fractures, orthopedic trauma, research projects, and all your tips and tricks on surgical skills when we operate together. Thank you, Jostein, for our good cooperation on PMFIX and other projects.

Thank you Stein Atle Lie and Anne Marie Fenstad, both statisticians at the Norwegian National Advisory Unit on Arthroplasty and hip fractures. Your advice and contribution are appreciated.

Lastly, I want to thank my family. To my parents for giving me a safe environment to grow up. For being role models in dedication to the tasks you undertake and for your support. To my brothers, Martin and Eivind, for your support and discussions. You are both role models in family life and your excellence at work.

To my dear children, Herman Filip, Eliah, and Esekiel. I love you and am so proud of all of you. I appreciate spending time and playing with you.

The biggest gratitude I will give my dear wife, Irina. Thank you for keeping up with me through the many hours of work and research. Thank you for giving me space and opportunity to fulfill this project. You are too generous with me. Your kindness and warmth to those around you is inspiring and clear to all. You have helped me become

a better person and father. Thank you for showing that putting our children and family first is what matters most.

Abbreviations

AITFL	Anterior inferior tibiofibular ligament
AO	Arbeitsgemeinschaft für Osteosynthesefragen
AOFAS	American orthopedic foot and ankle society ankle-hindfoot score.
AP	Anteroposterior
ANOVA	Analysis of Variance
ASA	American Society of Anesthesiologist classification
CDC	Centers for Disease Control and Prevention
CI	Confidence interval
CNS	Coagulase Negative Staphylococcus
CRP	C-reactive Protein
CRPSD	Center on Patient Reported Data in Helse Bergen
CT	Computed Tomography
EQ-5D	EuroQol 5 Domain questionnaire
ESR	Erythrocyte Sedimation rate
FRI	Fracture-related Infection
HUS	Haukeland University Hospital/Haukeland Universitetssjukehus
IOL	Interosseous ligament
IQR	Inter Quartile Range

MCS	Medial Clear Space
MCID	Minimal Clinically Important Difference
MOxFq	Manchester Oxford Foot Questionnaire
OA	Osteoarthritis
OMAS	Olerud Molander ankle score
OR	Odds Ratio
ORIF	Open Reduction Internal Fixation
OTA	Orthopedic Trauma Association
PA	Pronation Abduction
PER	Pronation External Rotation
PITFL	Posterior inferior tibiofibular fragment
PMF	Posterior Malleolus Fracture
PRO	Patient reported outcome
PROM	Patient reported outcome measure
RCT	Randomized controlled trial
REC	Regional Committee for Medical and Health Research Ethics
SA	Supination adduction
SD	Standard deviation

SDC	Smallest detectable change
SEFAS	Self-Reported Foot and Ankle Score
SER	Supination external rotation
SN	Sural nerve
SPN	Superficial peroneal nerve
SSI	Surgical site infection
TL	Transverse ligament
VAS	Visual analogue scale
WBC	White blood count
YLD	Years lived with disability

Abstract

Ankle fractures are the third most common fracture after proximal femoral fractures and distal radial fractures. They make up 10% of all fractures. Operative treatment is often needed to prevent complications such as stiffness, pain, and posttraumatic osteoarthritis. Depending on fracture pattern in the ankle, different approaches and methods of fixation are needed. Ankle fractures including the posterior malleolus of the distal tibia are known to have poor outcome. Indication for fixation and the best surgical approach to fix the posterior malleolus fracture (PMF) have been subject to debate and particularly in the last decade there has been an increase in publications and a flare-up in the discussion. Convinced that such treatment would give better outcome our department saw a dramatic shift in 2015 where almost every patient with a PMF was treated via a *posterior approach*. Surgical treatment of ankle fractures comes with the risk of complications. Time from injury to surgery, the duration of surgery and the postoperative period may affect the soft tissue and surgery may cause nerve injury or damage the skin. The most common complications are nerve injury, soft tissue problems and fracture-related infection. Addressing this, and defining such problems for diagnostic and research purposes, a new definition of fracture-related infection (FRI) has been published to improve clinical practice and enable comparison of infection rates between studies.

The aims of this thesis were:

i) to evaluate the patient-reported outcome of patients treated for ankle fractures with PMFs

ii) to assess the impact of time to surgery on patients with severe ankle fractures

iii) to estimate the rate of FRI in our cohort of patients treated surgically for ankle fractures

iv) to identify risk factors for the development of FRI

The first study compared patient-reported outcome in patients treated with a *posterior approach* to patients treated with a *traditional approach*. We found similar results between groups on Self-reported foot and ankle score (SEFAS), VAS of pain, and VAS of satisfaction. The group of patients treated with a posterior approach had more often received a temporary external fixation prior to definitive surgery, had a higher rate of high-grade osteoarthritis and had significantly longer time from injury to definitive surgery.

The second study examined the impact of time from injury to definitive surgery on patient-reported outcome of patients with severe ankle fractures (ankle fractures with a concomitant PMF). Patients surgically treated more than a week from injury had worse SEFAS and reported more pain than patients treated within a week from injury.

The third study examined the rate of FRI among all patients surgically treated for ankle fractures at our department in the period 2015-2019. A total of 87 (9%) of 1004 patients were diagnosed with FRI. The study also revealed several areas of improvement for our department in the assessment, diagnostics, and treatment of patients with FRI.

In the fourth study we evaluated risk factors for developing FRI. High patient age, current smoking, heart failure, and peripheral arterial diseasewere identified as independent risk factors. The combination of risk factors found in this study shows the need for a thorough, multidisciplinary, and careful approach when faced with ankle fractures in elderly patients.

Sammendrag på norsk

Ankelbrudd er det tredje mest vanlige bruddet som opereres etter håndleddsbrudd og hoftebrudd. Disse bruddene utgjør 10% av alle brudd. Operativ behandling er ofte nødvendig for å hindre utvikling av stivhet, smerte og artrose i ankelleddet. Avhengig av antall og type brudd i ankelen kan ulike tilganger og fiksasjonsmetoder brukes under operasjonen. Ankelbrudd der det i tillegg er et brudd i bakre malleol har dårlig prognose. Indikasjonen for fiksering og hvilken tilgang som er best for behandling av bruddene i bakre malleol har blitt diskutert i årtier. De siste 10-15 årene har en sett en særlig økning i publikasjoner og i debatten om emnet. I 2015 så vi en stor endring hos oss mot bruk av *bakre tilgang* på nesten alle pasienter med brudd i bakre malleol med mål om bedre resultater. Kirurgisk behandling av ankelbrudd involverer en risiko for komplikasjoner. Både tiden før og etter kirurgi samt selve kirurgien gir en risiko for at utfallet ikke blir slik en ønsker. Ventetid til operasjon kan påvirke bløtvevet og vanskeliggjøre operasjonen, kirurgi kan gi nerveskade og skade på hud. Den vanligste komplikasjonen etter kirurgi er infeksjon. Det er nylig publisert en ny definisjon av fraktur-relatert infeksjon (FRI). Få studier har publisert hyppigheten av FRI etter kirurgi for ankelbrudd.

Målene med denne avhandlingen var å evaluere pasient-rapporterte utfall hos pasienter behandlet for ankelbrudd med samtidig brudd i bakre malleol. Vi ønsket også å få en bedre forståelse av hvilke konsekvenser ventetid til operasjon har for pasienter med alvorlige ankelbrudd. Videre ønsket vi å undersøke hyppigheten av fraktur-relatert infeksjon (FRI) hos pasienter som har fått kirurgisk behandling hos oss. Til sist identifiserte vi risikofaktorer for utvikling av FRI og beregnet sannsynligheten for å få FRI etter kirurgi for ankelbrudd.

Den første studien sammenlignet pasient-rapporterte utfall hos pasienter som er behandlet med bakre tilgang med pasienter som fikk den tradisjonelle tilgangen. Vi

fant like resultater mellom gruppene ved Self-reported foot and ankle score (SEFAS), VAS for smerte og VAS for tilfredshet. Pasientene som ble behandlet med bakre tilgang ble oftere gitt en midlertidig ekstern fiksasjon, hadde høyere grad av posttraumatisk artrose og hadde signifikant lengre tid fra skade til endelig behandling.

Den andre studien undersøkte effekten av tid fra skade til endelig behandling på pasient-rapporterte utfall hos pasienter med alvorlige ankelbrudd (ankelbrudd som og har et brudd i bakre malleol). Pasienter som ble behandlet mer enn en uke etter skade hadde dårligere SEFAS og mer smerte enn pasienter behandlet innen en uke fra skade.

Den tredje studien undersøkte hyppigheten av fraktur-relatert infeksjon hos pasienter med ankelbrudd som var kirurgisk behandlet hos oss i perioden 2015-2019. Totalt ble 87 (9%) av 1004 pasienter diagnostisert med FRI. Studien avdekket også flere forbedringsområder for avdelingen vår med tanke på vurderingen av pasienter med mistanke om infeksjon, diagnostisering og behandling av pasienter med FRI.

I den fjerde studien identifiserte vi risikofaktorer for utvikling av FRI. Høy alder, røyking, hjertesvikt og perifer karsykdom ble funnet å være uavhengige risikofaktorer. Kombinasjonen av de ulike risikofaktorene viser behovet for en grundig tilnærming til eldre pasienter med ankelbrudd. Pasientene bør ved behov vurderes av leger fra flere fagområder for best mulig behandling.

List of Publications

Paper 1

Traditional Approach vs Posterior Approach for Ankle fractures Involving the Posterior Malleolus

Kristian Pilskog, MD , Teresa Brnic Gote, MSc , Heid Elin Johannessen Odland, MD1, Knut Andreas Fjeldsgaard, MD1, Håvard Dale, PhD, MD , Eivind Inderhaug, PhD, MD, and Jonas Meling Fevang, PhD, MD.

Foot & Ankle International, Sage, November 17, 2020, DOI: 10.1177/1071100720969431.

Paper 2

Association of Delayed Surgery for Ankle Fractures and Patient-Reported Outcomes

Kristian Pilskog, MD , Teresa Brnic Gote, MSc , Heid Elin Johannessen Odland, MD1, Knut Andreas Fjeldsgaard, MD1, Håvard Dale, PhD, MD , Eivind Inderhaug, PhD, MD, and Jonas Meling Fevang, PhD, MD.

Foot & Ankle International, Sage, February 20, 2022, DOI: 10.1177/10711007211070540.

Paper 3

Fracture-related infection: Prevalence and application of the new consensus definition in a cohort of 1004 surgically treated ankle fractures

Kristian Pilskog, MD, Pål Høvding, MD, Eivind Inderhaug, PhD, MD, Jonas Meling Fevang, PhD, MD, Håvard Dale, PhD, MD.

Injury, Elsevier, January 6, 2023, DOI: 10.1016/j.injury.2022.12.030.

Paper 4

Risk Factors for Fracture-related Infection After Ankle Fracture Surgery

Kristian Pilskog, MD, Pål Høvding, MD, Eivind Inderhaug, PhD, MD, Jonas Meling Fevang, PhD, MD, Håvard Dale, PhD, MD.

(Submitted)

Tabel of contents

Scientific environment **4**

Acknowledgements **5**

Abbreviations **9**

Abstract **12**

Sammendrag på norsk **14**

List of Publications **16**

1. Introduction **19**

1.1 Epidemiology of ankle fractures 19
1.2 Anatomy and biomechanics of the ankle joint complex 20
1.2.1 Overview *20*
1.2.2 The posterior malleolus *24*
1.3 Pathomechanics and injury mechanism 24
1.4 Classification of fractures 25
1.4.1 Anatomical classification *25*
1.4.2 AO/OTA Classification *26*
1.4.3 Danis-Weber classification *26*
1.4.4 Lauge Hansen classification *27*
1.4.5 Classification of posterior malleolus fractures *29*
1.4.5.1 Radiographs *29*
1.5 Diagnosis of ankle fracture 34
1.5.1 Clinical examination *34*
1.5.2 Radiology *35*
1.6 Treatment of ankle fractures and syndesmotic injuries 38
1.7 Outcome assesments after ankle fractures 41
1.7.1 Patient-reported outcome measures *41*
1.7.2 Clinical examination *43*
1.7.3 Radiographic assessment *43*
1.8 Complications after surgical treatment 45
1.8.1 Overview *45*
1.8.2 Fracture-related infection (FRI) *47*
2.0 **Background for studies** 53
2.1 Paper 1 .... *53*
2.2 Paper 2 .... *54*
2.3 Paper 3 .... *55*
2.4 Paper 4 .... *55*

3. Aims of the thesis **57**

4. Materials and methods **58**

4.1 Paper 1 58
4.2 Paper 2 63
4.3 Paper 3 68

5. Results **74**

5.1 Paper 1 74
5.2 Paper 2 75
5.3 Paper 3 78

5.4 Paper 4 ... 80

6. Discussion ... 81

6.1 Discussion of methods ... 81

6.1.1 Study design ... 81

6.1.1.1 Paper 1 and Paper 2 ... 83

6.1.1.2 Paper 3 ... 84

6.1.1.3 Paper 4 ... 84

6.2 General discussion of results ... 85

7 Conclusion ... 96

8 Future research ... 98

9 References ... 99

10 Appendices ... 129

1. Introduction

1.1 Epidemiology of ankle fractures

Globally there has been a 33.4% increase in number of fractures from 1990 to 2019.[1,2] The incidence of fractures is down 9.6% but the global population growth increases the number of fractures per year. Fractures affect the patients' lives and may result in absence from work, permanent impairment, disability, and they represent an increasing burden to the health care system.[2–4] Fractures of the lower limb (patella, tibia, fibula, or ankle) are globally the most common and are responsible for a rate of years lived with disability (YLD) of 190.4 per 100,000 population.[2] In comparison, hip fractures, which are known to have a high morbidity and mortality, have a YLD of 36.8 per 100,000 population.[2,5] Ankle fractures are the third most common fractures surgically treated after distal radius fractures and proximal femur fractures.[6] Ankle fractures constitute 10% of all fractures with an incidence of approximately 187 per 100,000 persons pr year.[7–9] The incidence is bimodal with a higher incidence in adolescence, predominantly men, and among older women.[6,10,11] The mean age of patients at time of injury is 55 years.[12] Overall there is an increasing incidence with age among women, but the incidence among men has a more even distribution through age groups.[9] Low energy, rotational mechanism of injury is the most common (68.2%), with patients falling from standing position.[9,10] Depending on the number of malleoli involved the fractures are termed uni-, bi- or trimalleolar. Seven percent of the ankle fractures are trimalleolar fractures.[12] A posterior malleolar fracture (PMF) is present in up to 46% of Weber B and Weber C fractures and 77% of Maisonneuve fractures.[13–15] Ankle fractures involving a PMF, and especially trimalleolar fractures, are known to have a poor outcome.[16–18] In the last decade the focus on treatment of ankle fractures and PMF has increased and a change in practice has taken place with the aim of improving outcomes and reducing complications. A shift towards the use of a posterior approach in these patients was also seen at our department at Haukeland University hospital and there was a need for practice evaluation. In this thesis, we wanted to evaluate our treatment of patients with ankle fractures, especially patients with PMF, and identify the true infection rate and its risk factors after ankle fracture surgery.

1.2 Anatomy and biomechanics of the ankle joint complex

1.2.1 Overview

The ankle joint consists of both bony and ligamentous structures. This complex connects the lower leg to the foot and allows interaction between them and the ground while walking, standing and other activities of daily living.[19] Stability of the ankle joint is provided by the mortise articulation of the fibula with the tibia, the syndesmosis, and the ligaments and muscles surrounding the ankle joint.

Motion of the foot and ankle relies on the multifaceted joint complex consisting of the transverse-tarsal (talocalcaneonavicular), talocalcaneal (subtalar), and tibiotalar (talocrural) joint.[19] The main motions of the foot and ankle are categorized as plantar- and dorsiflexion in the sagittal plane, adduction and abduction in the transverse plane and inversion and eversion in the coronal plane. The combination of these motions creates the three-dimensional supination and pronation.[19]

Figure 1- Radiograph of an ankle with the mortise marked with the yellow line. Radiographs from Department of Radiology, Haukeland University Hospital.

The distal fibula and the distal tibia form a mortise in which the talus of the hindfoot enters (Figure 1).[19,20] The distal tibial joint line is also known as the tibial plafond while the tibiotalar joint is the center for load bearing. The distal tibia and fibula constrain the talus making a hinge joint contributing to plantar- and dorsiflexion of the foot (Figure 2). During dorsiflexion, the talus externally rotates and is restricted by the medial and lateral malleoli.[21] The motion of the talus makes the fibula externally rotate, move laterally and posteriorly. The talus is narrow posteriorly and wide anteriorly making the ankle joint more stable in full dorsiflexion.[19]

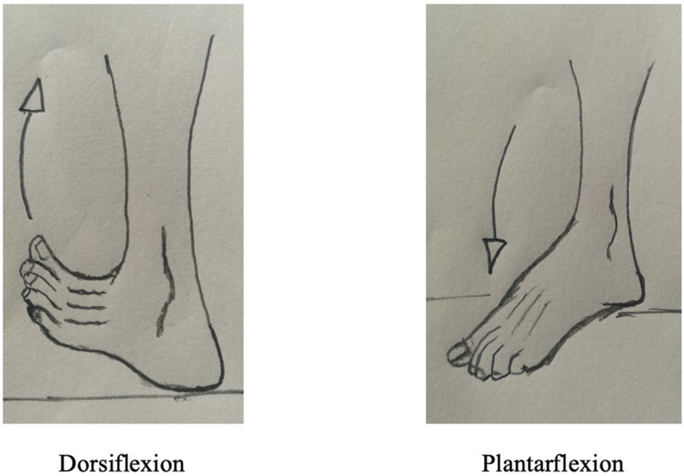


Figure 2 - Illustration of dorsiflexion and plantarflexion. Drawings by K. Pilskog.

An important joint contributing to stability between the distal fibula and tibia is the inferior tibiofibular joint, sometimes included as part of the tibiotalar joint.[19] In this joint the distal fibula lies in curvature on the lateral part of the tibia named the fibular incisura or fibular notch.[22,23] The subtalar joint allows inversion and eversion of the foot and ankle. The transverse tarsal joint (Chopart's joint) shares a common axis of motion with the subtalar joint and is therefore part of the same functional unit contributing to eversion and inversion motion of the foot.[19]

The bony structures are stabilized and connected by three groups of ligaments: the lateral ligaments (anterior talofibular ligament, calcaneofibular ligament and posterior talofibular ligament), the deltoid ligaments on the medial side of the ankle and the tibiofibular syndesmosis that connects the distal epiphysis of the tibia and fibula (posterior inferior tibiofibular ligament (PITFL), interosseous ligament (IOL), anterior inferior tibiofibular ligament (AITFL).[20] The proximal continuation of the IOL between the fibula and tibia is called the interosseous membrane(Figure 3-5).

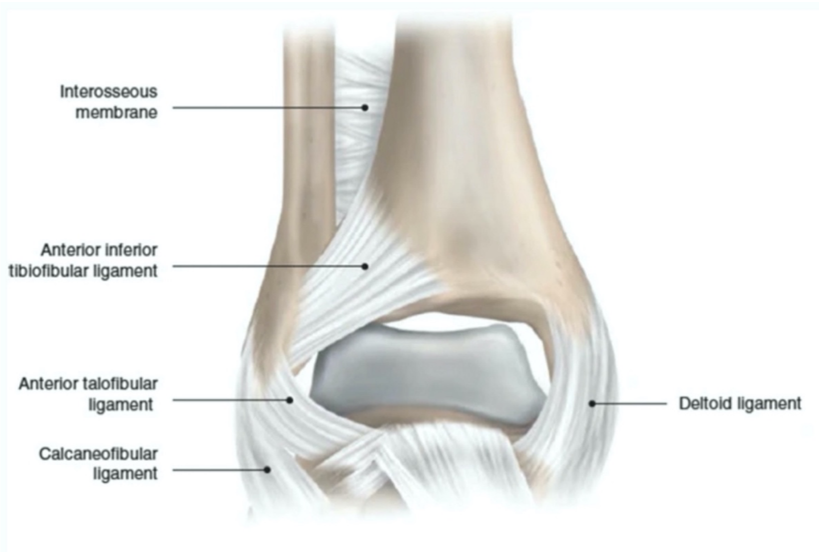


Figure 3- Anterior view of the ankle, overview of ligaments. Figure 2-4 are taken from D'Hooghe, P., Cruz, F. & Alkhelaifi, K. Return to Play After a Lateral Ligament Ankle Sprain. Curr Rev Musculoskelet Med 13, 281–288 (2020). . Re-used with permission through the Creative Commons Attribution 4.0 International License (Figure 3-5).

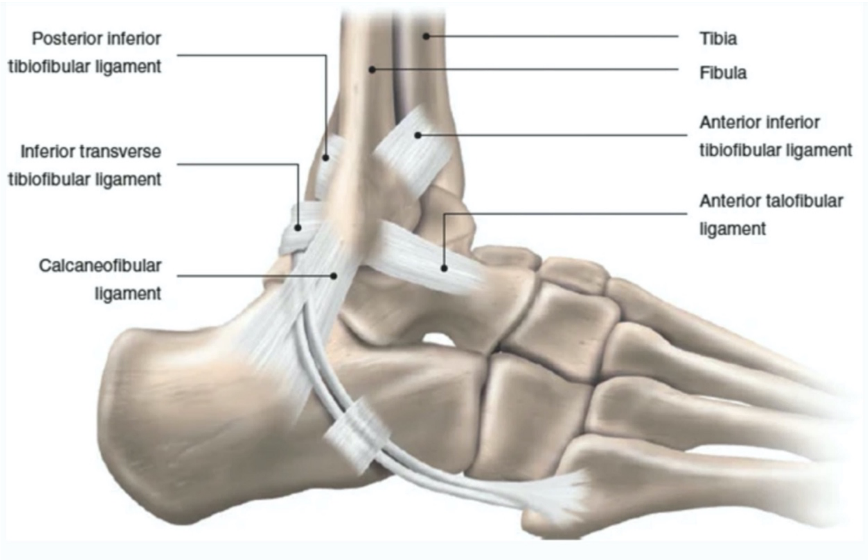


Figure 4- Lateral view of ankle, overview of ligaments

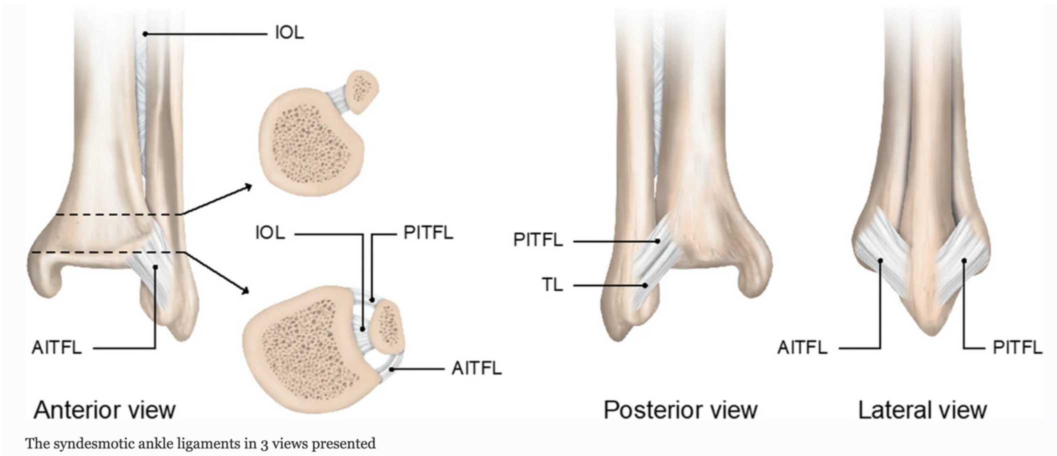


Figure 5 - The syndesmotic ankle ligaments. AITFL – Anterior inferior talofibular ligament, PITFL – Posterior inferior talofibular ligament, IOL – interosseus ligament, TL – Transverse ligament.

The lateral ligaments limit varus stresses and reduce rotation and inversion of the ankle joint. The medial part of the ankle joint is supported by the deltoid ligament which resists external rotation, eversion, and valgus stresses of the joint.[19,21] The tibiofibular syndesmosis limits widening and motion in the inferior tibiofibular joint. It thus contributes to stability of the mortise. [19,20] These ligaments are often involved in ankle fractures and eversion injuries.[19,20,24–26]

1.2.2 The posterior malleolus

The tibial plafond has a horizontal articular surface in the coronal plane and is concave in the sagittal plane. The anterior rim of the distal tibia lies cranial to the posterior rim.[13] On lateral radiographs the angle between the line connecting the anterior and posterior border of the distal tibia and the axis of the tibia shaft is approximately 84.0 +/- 8 degrees.[27] The posterior articular part of the distal tibia is called the posterior malleolus (Figure 6).[12,20] A prominent bony posterior tubercle is located at the lateral part of the posterior distal tibia. The tubercle forms the posterior half of the fibular notch. Medially the tubercle is separated from the medial malleolus (colliculus posterior) by the groove of the posterior tibial tendon.[20,28] The PITFL originates from the tubercle and the posterior surface of the distal tibia. It is trapezoid and attaches on the posterior margin of the lateral malleolus. [28] A separate horizontal bond of ligaments originates from the very rim of the distal tibia and attaches to the lateral malleolus distal to the PITFL. These fibers are named the transverse ligament (Figure 4).[20]

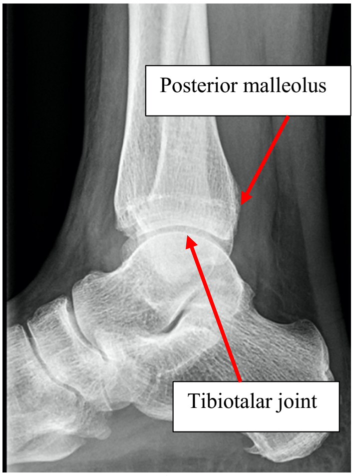


Figure 6 - Lateral radiograph of the ankle joint

1.3 Pathomechanics and injury mechanism

The degree of injury is related to the energy of trauma. Ankle fractures can be caused by both low and high-energy mechanisms. Low energy mechanisms are falling or stumbling on flat ground, icy or wet surface often resulting in rotational injuries of the ankle.[10,11] High-energy mechanisms may be fall from heights, motor vehicle accidents and extreme sport incidents (parachuting). In high-energy injuries some degree of axial trauma in addition to rotational forces are involved, resulting in a different fracture pattern and soft-tissue injury than in low energy injuries. Fractures of the ankle may occur in one or more of the lateral, the medial , or the posterior malleoli.[20] Avulsion fractures from the anterior tubercle of the distal tibia (Tubercle of Chaput) or anterior part of the lateral malleolus (Tubercle of Wagstaff) are also common with a reported incidence of 25.8% in ankle fractures.[20,29]

Due to the many joints of the ankle joint complex, injuries changing the anatomy and position of the medial, lateral, or posterior malleoli and thus the position of the talus, have clinical implications for normal gait.[24,30,31] A one millimeter lateralization of the talus may lead to a shift in contact areas inducing pain and later posttraumatic osteoarthritis.[32]

Injuries to the syndesmosis occur because of external rotational forces from the talus on the distal fibula. The talus pushes and externally rotates the fibula away from the tibia. Firstly, the AITFL ruptures and as the rotation continues the IOL and the PITFL rupture. Alternatively, avulsion of the Wagstaff or Chaput fragments may occur with an intact AITFL. Similarly, a PMF with an intact PITFL can occur in supination external rotation (SER) and pronation external rotation (PER) injuries as described, in the following, under Mason Type 3 fractures.[33]

1.4 Classification of fractures

Classification of ankle fractures varies depending on which structures one wishes to focus on.

1.4.1 Anatomical classification

Anatomical classification distinguishes ankle fractures depending on the location of the fracture: Isolated lateral malleolus fractures and isolated medial malleolus fractures are both unimalleolar. Bimalleolar ankle fractures are fractures of two malleoli. The most common combination is fractures of both the lateral and medial malleolus. Combined fractures of the lateral and posterior malleolus are also frequent.

1.4.2 AO/OTA Classification

A universal fracture classification is designed by the AO foundation in collaboration with the Orthopedic Trauma Association (OTA, AO/OTA classification).[34] The Swiss study group, "Arbeitsgemeinschaft für Osteosynthesefragen" (German for "working group for bone fusion issues") or AO society, founded 1958, transformed into the AO foundation in December 1984. The AO foundation has defined and constructed a classification system for all fractures.[35] Depending on the level of the fibula fracture, isolated fractures of the distal fibula are defined as 44A1 (infrasyndesmotic), 44B1 (transsyndesmotic) or 44C1 (suprasyndesmotic).[34] Further subclassification is added when a medial and/or posterior malleolus fracture is involved. Ligamentous injuries also contribute to the classification.

Fractures at the proximal end of the fibula are commonly termed Maisonneuve fractures and are classified as AO/OTA 44C3.[34,36] Maisonneuve fractures are considered to include deltoid ligament injury or medial malleolus fractures, and syndesmosis ligament injury. With the current literature available these fractures are considered unstable requiring operative treatment.[14,15,36]

1.4.3 Danis-Weber classification

The most commonly used classification system for ankle fractures is the Danis-Weber classification, or just Weber classification, which focuses on the level of the fibula fracture and its relation to the syndesmosis (Figure 7).[37] The classification is based on plain radiographs of the ankle. Infrasyndesmotic fractures are termed Weber A. Isolated Weber A fractures are usually stable and may be treated non-operatively. Weber B are fibula fractures at the level of the syndesmosis (intrasyndesmotic).

These fractures may be stable if the deep deltoid ligament is intact and may then be treated non-operatively.(REF) Surgical treatment is necessary in Weber B fracture with complete rupture of the deltoid ligament. Weber C fractures have the fracture line cranially to the syndesmosis (suprasyndesmotic). Weber C fractures are considered unstable and require surgical treatment due to concomitant deltoid ligament and syndesmosis rupture.

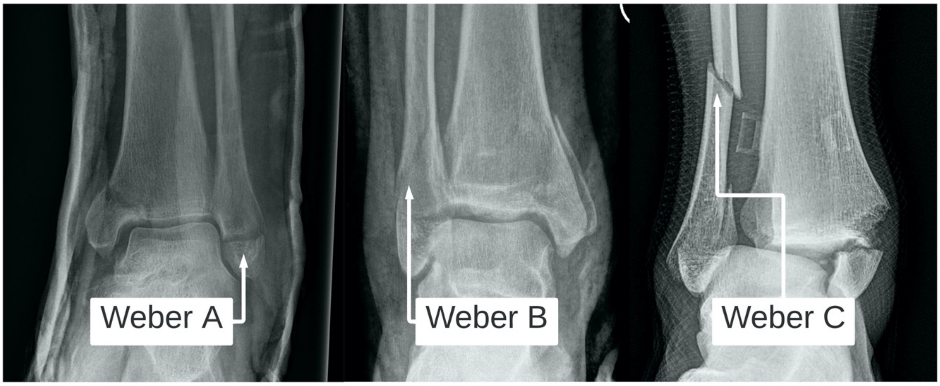


Figure 7 - Weber classification

1.4.4 Lauge Hansen classification

Lauge-Hansen was a Danish physician who wished to create a classification system based on patho-mechanism of the injury, and not solely radiographs. [38] By applying rotational forces on human ankle cadavers he discovered different fracture patterns. He used dissection for applying his system and classified the fractures into four categories with 13 subgroups. The most common classes are the supination-external rotation (SER, 60% of the fractures) and pronation-external rotation (PER) where the fibula fracture correlates to the Weber B (SER) and Weber C (PER) fractures, respectively.

The first word of each category describes the foot's position at the time of injury and the second word describes the rotation of the talus compared to the tibia. Supination stretches and endangers the lateral ligaments. In pronation the medial ligaments are stretched and in danger of injury.

The four categories are:

Supination-Adduction (SA)

1. Transverse fracture of the distal fibula
2. Vertical fracture of the medial malleolus

Supination-External Rotation (SER)

1. AITFL injury
2. Oblique fracture of the lateral malleolus
3. PITFL injury or PMF
4. Medial malleolus fracture or deltoid ligament injury

Pronation-External Rotation (PER)

1. Medial malleolus, transverse, fracture or deltoid ligament injury
2. AITFL injury or Chaput fracture
3. Oblique fracture of the lateral malleolus, suprasyndesmotic
4. PITFL rupture or PMF

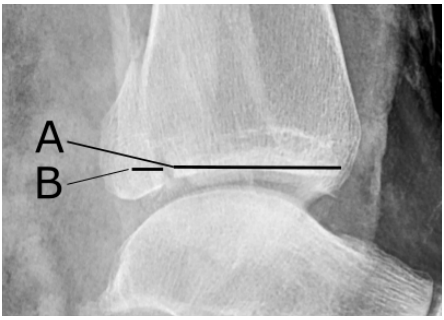
Pronation-Abduction (PA)

1. Medial malleolus fracture or deltoid ligament injury
2. AITFL injury
3. Transverse or comminuted fibula fracture, proximal to the tibiotalar joint.

1.4.5 Classification of posterior malleolus fractures

1.4.5.1 Radiographs

The size of the fragment as part of the distal tibial articulate surface has been



measured on lateral radiographs to guide treatment (Figure 8). Grondahl and Souligoux were the first to classify the PMFs in 1913. Grondahl divided them into "proper fractures of the posterior lip, fractures of the posterolateral corner of distal tibia, and fractures consisting of cortical avulsion from the dorsal surface of the tibia".[16,39] Souligoux distinguished between avulsion fractures from the posterior tubercle, avulsion of the entire posterior rim of the distal tibia, and a conical PMF of the entire posterior rim with varying size of articular surface on the fragment.[16,40]

Later Ashurst and Bromer classified the PMFs as "small, medium and large".[16,41] From a study with only eight cases Nelson and Jensen grouped fractures of the posterior malleolus into "classic fractures" when involving more than one-third of the articular surface on lateral radiographs.[42] Fractures involving less than one-third of the articular surface were termed minimal fractures. They recommended screw fixation of the classic fracture type. The 33% joint-involvement has since been used as a yardstick for fixation of PMFs.[17,43–46] In the last decade there has been an increasing number of studies challenging this cut-off.[12,47]

In 1987 the AO-classification grouped the PMFs into three types: extra-articular, small fragment of the articular surface, and large fragment of the articular surface.[48] Two years later, Urs Heim used the AO-classification and further specified five types of PMF of which two were extra-articular and three intra-articular.[44]

Later studies have shown that one cannot truly understand the morphology and size of the PMF on plain radiographs.[12,49,50] To better understand fracture patterns and to guide choice of treatment, classification based on fracture patterns of the PMF on CT has been published (Figure 9).[12,33,51]

1.4.5.2 Classification based on CT imaging

Haraguchi-classification

Haraguchi et al. published a classification system in 2006.[51] Based on axial CT images of 57 patients with ankle fractures, the PMFs were classified into three categories.

Type I are triangular fragments of the posterior malleolus (Volkmann's triangle) which involve the fibular incisura.[52–54]

Type II are similar fragments as Type I but with extension of the fracture line to the medial malleolus. These fractures are termed transverse medial extension fractures. Haraguchi also includes fractures that involve the entire medial malleolus i.e. extend into the anterior colliculus.

Type III are small shell fragments involving the posterior rim of the distal tibia but do not involve the fibular notch or the distal tibial cartilage.

This classification has, however, been criticized for not having a treatment recommendation and it is not based on severity and does not relate to clinical outcome.[55] It is also based on solely axial, unidimensional, images and not on 3D-morphology which the two following classifications are.

Bartoníček and Rammelt-classification

Bartoníček and Rammelt published their classification in 2015 after CT examination of 141 consecutive patients with ankle fractures.[12] The different types are intended to be a scale of increasing injury severity. The magnitude of dislocation of the talus, the height of the posterior fragment, the cross-sectional area of the fragment, and the extent of notch involvement increase across the classification groups.[12,16]

Type 1 are shell like fragments without involvement of the fibular notch. Approximately 8% of PMFs are Type 1.

Type 2 are posterolateral fragments involving a quarter to one third of the fibular notch. They make up 52% of PMFs.

Type 3 are two-part fragments involving the posterolateral corner of the tibia and a fragment that extends to the posterior colliculus of the medial malleolus. Type 3 constitutes 28% of PMFs.

Type 4 are large posterolateral fragments that involve up to 50% of the fibular notch. Approximately 9% of PMFs are Type 4.

Bartoníček and Rammelt differentiate between fractures extending to the anterior colliculus and fractures extending to the posterior colliculus. Haraguchi et al included the anterior colliculus in their Type II fractures, while Bartoníček et al. set a line between the center of the fibular notch and the intercollicular groove. Fractures posterior to the line are classified as PMF. Fractures extending anterior to the intercollicular groove or fractures that involve more than 50% of the fibular notch are defined as tibial pilon fractures. This classification was recommended in a newly published (Dec. 2022) review due to its treatment recommendation and wider use than the Mason & Molloy classification (below).

Mason and Molloy-classification

Mason and Molloy in 2017 published a new CT based classification of PMF to enhance the understanding of these fractures.[33] Their aim was to integrate injury patterns of the PMFs with pathomechanisms. They presented three fracture pattern groups related to the anatomy of the ankle and mechanism of injury.[33]

Type 1 are extraarticular, shell type fractures. These avulsion fractures occur due to the pull of the PITFL and transverse ligament on the cortex of the distal posterior tibia. The injury mechanism is rotational forces on the foot with an unloaded talus. The syndesmosis was found to be disrupted in 100% of the patients with Type 1 PMF in their study.

Type 2A fractures are triangular fragments from the posterior tubercle of the tibia that extend into the fibular notch. The injury mechanism is rotational forces on a loaded talus while the ankle is in neutral position.

Type 2B fractures involve both a posterolateral fragment and a posteromedial fragment. The posteromedial fracture is sustained as the talus continues to rotate within the ankle mortise with the same injury mechanism as for Type 2A. The syndesmosis was disrupted, as in need of fixation, in 49% of cases with Type 2A or 2B. Mason et al. found that the posterior syndesmosis was disrupted in a considerable proportion of these patients.

Type 3 are transverse, in the coronal plane, fractures involving the whole posterior plafond. They occur due to axial load on a plantarflexed talus. The syndesmosis was ruptured in 20% of the patients. The PITFL was intact in all cases as the distal fibula and PITFL moved posteriorly with the PMF.

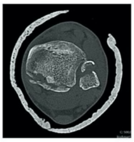
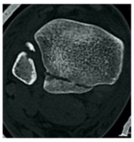
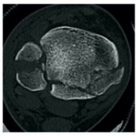
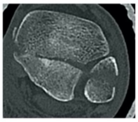
CT illustration	Description	Mason & Molloy type	Bartoníček	Haraguchi
	Posterior rim avulsion fracture without fibular notch involvement	1	1	3
	Posterolateral with involvment of fibular notch	2A	3	1
	Posterolateral with extention to the medial malleolus	2B	2	2
	Large posterolateral, triangular shaped, fragement	3	4	

Figure 8 - Overview of CT classifications of posterior malleolus fractures. Images from Department of Radiology, Haukeland University Hospital. [12,47,51]

1.5 Diagnosis of ankle fracture

All patient evaluation starts with a thorough anamnesis including the course of events causing the injury and past medical history. The goal is to narrow down and find possible injuries in preparation for the following clinical examination and radiology.

1.5.1 Clinical examination

A good clinical examination starts with inspection of the injured ankle. Signs of injury are swelling, malposition of the ankle or foot, hematoma, bruises, and wounds. Signs of open fractures must be documented and treated with prophylactic antibiotics. Any deformity showing a dislocation fracture must be addressed with quick and prompt reduction of the ankle. Figure 10 presents a radiograph of a fracture with dislocation of the ankle. Palpation is used to find fractures, concomitant injuries and investigate distal neurovascular status. The Ottawa ankle rules are used to decide the need for radiographs in an outpatient clinic when presented with an ankle injury.[56]

Figure 9 - Radiograph of an ankle with a dislocation fracture. Picture from Department of Radiology, HUS.

Radiographs must be requested if there is pain or tenderness at either malleolus in addition to one of the following criteria:

- Tenderness at the posterior edge of the distal 6 cm of the lateral or medial malleolus
- The patient is unable to bear weight both at the time of injury and on arrival at the outpatient clinic or emergency department

In case of a dislocation fracture or clear clinical signs of fracture one does not need the Ottawa ankle rules to justify radiology.

1.5.2 Radiology

1.5.2.1 Radiographs

Plain radiographs are the primary modality for assessment of ankle injuries with suspected fractures. The projections taken are anteriorposterior (AP), Mortise and lateral views of the ankle (Figure 12).

Figure 10 - Standard radiographs of the ankle

Anteroposterior (AP) view is used for identification of fractures of the fibula and the medial malleolus. Soft-tissue swellings may also be visible. Mortise view are radiographs taken with 15 degrees internal rotation of the leg and with the foot in plantigrade position. This projection is used to assess the congruity of the tibiotalar join and potential widening of the syndesmosis. Lateral view is used to discover PMFs, dislocation or subluxation of the talus, and talus dome injuries.

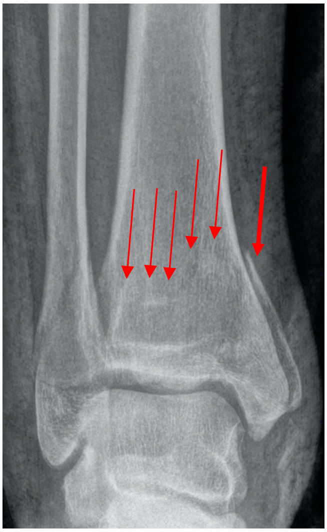


Figure 11 - AP radiograph showing a visibile medial extending PMF (arrows). The fleck sign marked with the thickest arrow.

Posterior malleolar fractures are present as part of both SER-IV, PER-III, and PER-IV fractures.[38] PMFs are most often visible on lateral radiographs, but with medial-extension they may also be visible on AP-radiographs often with fleck sign (Figure 13).[57] Plain radiographs with measurement of the posterior malleolar fracture on lateral radiographs have been the traditional assessment of posterior malleolar fractures until recently. However, Meijer et al. found that orthopedic surgeons overestimate the articular involvement of a PMF by a factor of 1.8 on plain radiographs compared to 3D-CT images.[49] Interobserver agreement was found to be 0.61. The diagnostic accuracy of measurements on lateral radiographs was only 22% in their study.

1.5.2.2 Computer tomography (CT)

Bartonicek et al [12] concluded that it is impossible to assess the size, shape, and morphology of the posterior malleolar fracture on lateral radiographs. They concluded that for correct assessment and preoperative preparation of these fractures

CT is needed. Martin Weber also recommended CT for trimalleolar fractures in his case study from 2004 because of the possible involvement of the posteromedial part of the dorsal distal tibia[57]. The need for CT is further underlined by the studies of Mason, Molloy and collegues.[28,33,47,58,59]

1.5.2.3 Intraoperative assessment

After fixation of fractures in the lateral and/or medial malleolus the tibiofibular syndesmosis is tested for stability with the Cotton test or external rotation at the surgeon´s discretion**.**[60] The syndesmosis is also tested after fixation of a PMF.

1.6 Treatment of ankle fractures and syndesmotic injuries

The ankle is often visualized as a ring consisting of both bones and ligaments.[61] If the ring is broken in only on place the ankle is considered stable and can be treated non-operatively. If the ring is broken at two or more places, the ankle is unstable and operative treatment is needed.

Isolated Weber A and Weber B fractures are fractures that may be treated non-operatively with the foot in a below the knee cast for three to six weeks.[62] New studies have further nuanced how fractures of the lateral malleolus are treated. The authors show that Weber B fractures with partial injuries to the deltoid ligament, where the deep deltoid ligament is intact, can be treated non-operatively.[63,64]

Operative treatment of the ankle fractures follows the AO-principles.[65] In the case of a PMF patients are operated upon in a prone position. A posterolateral and, if needed, posteromedial direct approach is used.[59] The posterolateral skin incision is approximately midline between the lateral border of the achilles tendon and posterior border of the lateral malleolus. Careful dissection down to the fascia is needed to avoid injury to the sural nerve and the nerve is usually found medial to the incision. Ankle joint debridement may be performed before the PMF is anatomically reduced. Fixation of the fragments is performed with plates and screws (Figure 14), 2.4-3.5 mm screws or a small-fragment plate are commonly used. Fibular fractures may be reduced and fixed through the posterolateral incision or by a separate lateral incision

screw fixation of a PMF via a posterior appraoch depending on the fibular fracture type (i.e., diaphyseal Weber C fractures). Medial malleolus fractures are addressed in a separate direct medial or posteromedial approach.[59] Fibular plates may be applied posteriorly or laterally on the fibula depending on fracture morphology and location.

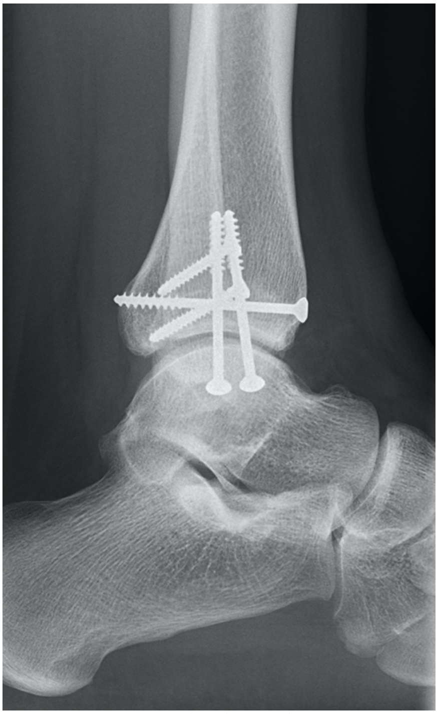


Figure 13 - Lateral radiograph illustrating an AP-screw fixation of the PMF.

Patients with an isolated fibular fracture or bimalleolar fractures (lateral and medial malleolus) are treated in a supine position. The lateral and, if present, the medial malleolus fracture are treated with ORIF through a direct lateral and direct medial incision. At the operating surgeon's choice, a concomitant PMF may be indirectly reduced and fixed with an AP screw (Figure 15).[66] Newer studies have also shown that larger PMFs, especially posteromedial fragments, may be addressed from a medial-posteromedial approach.[59] This is also possible with the patient in supine position.

Fibula fractures are fixed with interfragmentary compression screws, standard one-third tubular plates, standard locking plates, or anatomical locking compression plates (LCP) depending on fracture type, bone quality and comminution of the fracture.

Regardless of the approach used for ORIF, after fracture fixation the tibiofibular syndesmosis is tested for stability.[60] If instability is found, syndesmosis fixation may be performed with either one quadricortical screw, two tricortical 3.5 mm screws or a suture button.[24,67–69] Screw- or plate fixation of a PMF has been shown to reduce the need for additional fixation of the syndesmosis.[47,70–72]

Patients with poor arterial blood supply or with poor soft tissue status may be treated with a fibular nail, tibio-talar-calcaneal nail or with external fixation.[73–76] Using these devices may reduce the soft tissue trauma and may prevent postoperative wound problems such as infection.

Mobilization using partial weightbearing supported by crutches is allowed for the first six weeks. In cases of syndesmosis fixation patients are allowed foot touch weight bearing for the first six weeks and thereafter partial weight bearing for further six weeks. Full weight bearing is allowed from 12 weeks in the latter cases. If the syndesmosis is stabilized with a quadricortical screw or two 3.5 mm tricortical screws many departments routinely remove the screws at 12 weeks postoperatively during a planned operation at the outpatient clinic.[77] Newer studies support the retention of the 3.5 mm screws if the patients do not have complaints from the ankle.[26,78]

1.7 Outcome assesments after ankle fractures

Several ways of evaluating the treatment outcome are available. Most orthopedic clinical trials use patient reported outcome as their primary outcome assessment. In addition, clinical examination of the patient is performed to evaluate range of motion (ROM), nerve injuries, signs of hardware discomfort, and soft tissue problems including infection.

1.7.1 Patient-reported outcome measures

In 2009 the FDA defined patient-reported outcome as “any report of the status of a patient’s health condition that comes directly from the patient without interpretation of the patients' response by a clinician or anyone else”.[79] Patient-reported outcome measures (PROMs) are questionnaires collecting information from the patients themselves such as data regarding symptoms, functional status, mental and physical status, and health-related quality of life. The introduction of PROMs is partly due to a shift away from the subjective considerations of the orthopedic surgeon to the subjective experience *of the patient*.

Internationally the use of PROMs has several motives. Initially they are used to evaluate effectiveness of treatments.[80] Also, PROMs are used in comparing health-care providers, prioritizing patients for surgical procedures, foundation for clinical decision making, and evaluating policies.[81–85]

Each PROM has categories of questions (domains) with several questions (items) within each category. There are two main types of PROMs: generic and condition specific PROMs. Generic PROMs capture information about the patient’s general health and include concepts that enable comparison of different population groups and different conditions.[85] Hence, they have greater application on a superior level of decision making.[86] Examples of generic PROMs are EQ-5D, from the EuroQol Group,[87,88] and RAND-36 developed by the RAND corporation in the USA. A Norwegian, validated, version of RAND-36 is available.[89] There are eight domains that constitute the mental and physical components of RAND-36: Physical functioning, role limitations due to physical health, role limitations due to emotional problems, energy/fatigue, emotional well-being, social functioning, pain, and general health.

Condition specific PROMs focus on elements of health related to a specific disease, injury, treatment, group of patients or a specific organ/part of the body. In the setting of ankle fractures, several specific PROMs are available even though none are fully validated on all measurement properties.[90] The American Orthopedic Foot and Ankle Society (AOFAS) has developed four rating systems for conditions in the foot and ankle. The AOFAS Ankle-Hindfoot scale is one of the most commonly used PROMs.[91] However, it is not validated for ankle fractures, and its use has been heavily criticized.[92–94] Also, it consists of both patient and physician reported items. Olerud-Molander Ankle Score (OMAS) is the most frequently used PROM for ankle fractures and is one of the few PROMs validated for use in an ankle fracture population.[95,96]. The Manchester-Oxford Foot Questionnaire (MOxFQ) is available in Norwegian and has recently been used in ankle fracture settings even though it is not validated for this patient population.[68,90,97]

Self-Reported Foot and Ankle Score (SEFAS) is a Swedish questionnaire derived from a questionnaire developed by the New Zealand Arthroplasty register for evaluation of ankle joint replacement surgery.[98,99] Cöster et al. modified the questionnaire, named it SEFAS, and validated their version.[99–103] SEFAS has 12 questions with five levels each ranging from 0 (worst) to 4 (best). Total score therefore ranges from 0 to 48 points, where higher score represents normal function.[99] Median normative value of SEFAS for men are 48 and for women 47, and the MICD has been described by Cöster et al. to be a change of 5 points.[101,102] The domains covered are pain, function – including limitation of function, and ankle specific questions. The items include questions on pain, limping, walking and use of orthopedic shoe inserts. A Norwegian translation is validated and available.[104] However, in their paper evaluating SEFAS and reporting their translation, Garratt et al., report a sum score of 12-60. They have given each question a value of 1-5, and not 0-4 as originally intended by Cöster et al.[99,102]

Visual analogue scale (VAS)

VAS is a scale on which the patient marks the level of pain or satisfaction corresponding to a number on a scale ranging from 0-100 or 0-10. The VAS is reported to be valid and reliable.[105,106] It is an easy and quick way of assessing function and status.[107]

1.7.2 Clinical examination

During and after treatment, the patients are assessed during a follow-up visit at the outpatient clinic. Patients are interviewed with focus on pain, possible complications, clinical development, and their experience since the last follow-up.

Clinical examination includes inspection of the skin, operation wounds, range of motion, muscular strength over the ankle joint, and nerve- and vascular status in the foot – distal to the injury or operated area. The timing and frequency of follow-up varies between hospitals.

1.7.3 Radiographic assessment

Thorough examination of the radiographs is performed evaluating fracture healing, fracture displacement, signs of hardware loosening or breakage, and possible signs of osteomyelitis. Postoperative radiographs are taken shortly after surgery to confirm satisfying fracture reduction and osteosynthesis, and to detect any complications requiring urgent reoperation. Most orthopedic departments also have radiographs taken at the six- and/or twelve-week follow-up visit.

Over the course of time patients may develop post traumatic osteoarthritis (OA). Grade of OA may be evaluated with different scales, depending on location. The Kellgren-Lawrence classification is commonly used for evaluation of OA of the tibiotalar joint (Figure 15).[24,108]

Kellgren-Lawrence classification of osteoarthritis	
Grade	Radiologic findings
0	No radiologic findings of osteoarthritis
1	Doubtful narrowing of joint space and possible osteophytic lipping
2	Definite osteophytes and possible narrowing of joint space
3	Moderate multiple osteophytes, definite narrowing of joint space, small pseudocystic areas with sclerotic walls and possible deformity of bone contour
4	Large osteophytes, marked narrowing of joint space, severe sclerosis and definite deformity of bone contour

Figure 14 - Kellgren Lawrence classification of osteoarthritis

1.8 Complications after surgical treatment

1.8.1 Overview

Operative treatment comes with a substantial risk of complications, including postoperative infection. Complication rate among patients 60 years or older were, in one study, reported to be 21.5% among which only 10.8% required further surgical intervention.[109]

Overall complication rates following ankle fracture surgery vary among studies from 1% to 32%.[109–111] Different complications may occur including syndesmotic malreduction,[112] fracture malreduction and malunion,[113] hardware discomfort,[114] nerve injuries,[115,116] posttraumatic osteoarthritis,[108,117,118] and, most commonly, postoperative infection.[110,119,120]

Ovaska et al. found malreduced syndesmosis and fibula shortening to be the most common reasons for reoperation.[121]

Nerve injury is a common complication after surgery. Approximately 11 cm proximal to the tip of the lateral malleolus the superficial peroneal nerve (SPN) exits the deep fascia of the anterolateral compartment and becomes a subcutaneous nerve.[122] The nerve crosses the fibula from posterior to anterior approximately 5-7 cm cranially to the distal tip of the fibula (Figure 17).[116] The nerve continues distal and ventral to the tibiotalar joint. It divides into a lateral (intermediate dorsal cutaneous) and medial (medial dorsal cutaneous) cutaneous branch supplying the lateral side of the leg, the dorsum of the foot and the dorsal parts of toe one to four. SPN is in danger of iatrogenic injury with the direct lateral approach to

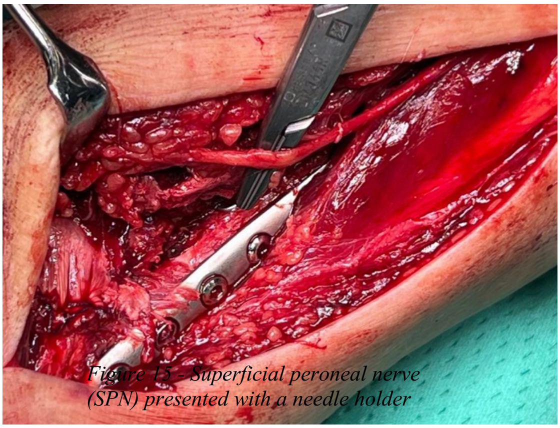


Figure 15 - Superficial peroneal nerve (SPN) presented with a needle holder

the distal fibula.[116,123,124] In a study of 56 patients with surgically treated ankle fractures, 21% had painful symptoms from an SPN injury. The sural nerve (SN) runs on the posterolateral side of the lower leg and innervates skin sensation on the lateral part of the ankle, heel, and foot. SN is also in danger of iatrogenic injury, especially via the posterolateral approach.[122,125–127] In the cranial part of the approach the sural nerve is closer to the achilles tendon while it is closer to the lateral malleolus in the distal part of the skin incision.

Posttraumatic osteoarthritis is one of the top causes of mobility-related disability and has been shown to be as severe as hip joint OA.[4] Posttraumatic OA accounts for 70-78% of all cases of ankle OA and 37% of these patients have had an ankle fracture.[108,128] Patients with posttraumatic ankle OA are younger (18-44 years old) than patients with primary ankle OA underlining the serious consequences of ankle fractures.[108,128] Primary ankle OA is rare, with a prevalence of only 7-9%.[128] The time from injury until posttraumatic OA is radiographically or clinically present, has been found to be as short as 12-18 months.[129] In a study of 102 patients treated for ankle fractures with an 18-year follow-up, 36% of the patients had Kellgren-Lawrence grade 3-4 ankle OA.[118] Weber C, concomitant medial malleolus fracture, fracture dislocation, malreduced syndesmosis, and overweight or obesity at time of injury are risk factors for developing posttraumatic OA.[117,118,130] In a large database study of over 57000 patients with operative treatment of ankle fractures 1% had ankle fusion or replacement surgery due to ankle OA.[110] Trimalleolar fracture was a risk factor for end stage osteoarthritis in the same material. Intraarticular step-off in the tibiotalar joint is known to be a risk factor for posttraumatic OA.[18]

1.8.2 Fracture-related infection (FRI)

After ankle fracture surgery the incidence of infection and wound dehiscence reportedly varies from 1.2% to 37.9% [131–133]. Undergoing an infection has severe consequences potentially ending in amputation for infection control.[134]

1.8.2.1 Risk factors

Several risk factors for developing FRI are described in the literature.

Higher age is a commonly described risk factor.[135–137] With increasing age, the prevalence of different comorbidities also increase.[138] Older patients are frail and may be cognitively impaired increasing the risk of falls and subsequent fractures.[136,139] Diabetes mellitus is one of the most important risk factors.[140] The disease alters bone metabolism, increases blood viscosity, and reduces tissue oxygenation. Thus, inflammatory reactions are slowed down and wound healing is altered, resulting in an increased risk of FRI.[141] Smoking is another important risk factor through tissue hypoxia.[142] Associated with smoking is peripheral artery disease (PAD) which also contributes to lower oxygenation distal to the arterial narrowing and thus soft tissue problems including FRI.[143,144] High-energy mechanism of injury and open fractures are additional risk factors forFRI due to the compromised soft tissue and direct path between bone and the surroundings.[140,145] Lastly, time from injury to surgery has been shown to be associated with developing postoperative infection after ankle fracture surgery.[146]

1.8.2.2 Pathogens

The most frequent pathogens are Staphylococcus aureus and Staphylococcus epidermidis (coagulase negative Staphylococcus, CNS).[134,147]

1.8.2.3 Defining Fracture Related Infection

The rate of infection varies depending on definition and population.[110,120,148] Different terms include deep and superficial infection, and surgical site infection (SSI).[119,145,148,149] FRI is one of the most challenging complications after ankle fracture and trauma surgery but its impact on patients has been difficult to compare due to the lack of an unequivocal definition of infection.[149–151] Only 2% of RCTs have described what they define as infection.[152]

Figure 16 - Picture of osteosynthesis of a fracture in the lateral malleolus with syndesmotic injury (left). Postoperative wound problem with excessive drainage showing a fracture-related infection (FRI). Picture with courtesy of Dr. Håvard Dale.

Based on the success of the work on PJI a new definition named Fracture-related Infection (FRI) was presented in 2017 by a consensus group of orthopedic surgeons, radiologists, microbiologists, pharmacists, and infection disease specialists.[152–154] The process of establishing the definition had three phases. Firstly, they had a modified Delphi process with exchange of ideas over e-mails, then they had face-to-face meetings for processing the ideas from phase 1 and voting on the resolutions, and lastly, they entered a publication phase.[152] The definition was updated in 2020.[155]

The consensus group had four themes for knowledge and standards when defining FRI:

- Classification: The definition should not be limited by time; it should define the presence of infection regardless of being termed acute or chronic.
- Location: it does not distinguish between superficial or deep infection. Fracture location also does not affect the definition. Again, presence of infection is the most important factor. Therefore, the depth of colonization may only be assessed from tissue samples from beneath the subcutis. Swabs taken from superficial wounds secretion or skin surrounding a wound are not adequate or recommended for diagnostics. They therefore recommend all FRI suspected wounds to be opened at revision surgery.
- Terminology: The consensus group do not use the terms osteitis, osteomyelitis, or deep infection. They describe them as difficult to separate from each other. Also, the destruction of bone/signs of osteomyelitis/osteitis is not present in early cases of FRI. Therefor the definition of fracture-related infection was introduced.
- Diagnostic criteria: The consensus group discussed clinical signs and results that are only present in FRI (confirms FRI, pathognomonic signs, or results) and results that suggest infection but require further investigation.

The consensus distinguishes between *confirmatory and suggestive criteria* of FRI (Figure 18).

Confirmatory criteria are the presence of fistulas, sinus formation, or wound breakdown with communication to bone or implant. The presence of purulent drainage or pus also confirms an infection. Further confirmatory criteria include phenotypically indistinguishable pathogens found by culture from at least two separate deep tissue/implant specimens - and the presence of microorganisms in deep tissue specimens, confirmed by histopathological examination.

Suggestive criteria include clinical signs of infection (redness, swelling, warmth and pain, fever), radiological signs, new-onset joint effusion, elevated serum inflammatory markers (WBC, CRP, ESR), and persistent, increasing or new-onset wound drainage. The suggestive criteria request a surgical exploration for confirmation of FRI. A positive culture from a single deep tissue/implant specimen is also considered a suggestive criterion which, in combination with other suggestive criteria, should give a high suspicion of FRI.[156]

The new definition was established to standardize future clinical reports and to improve the quality of future published research.

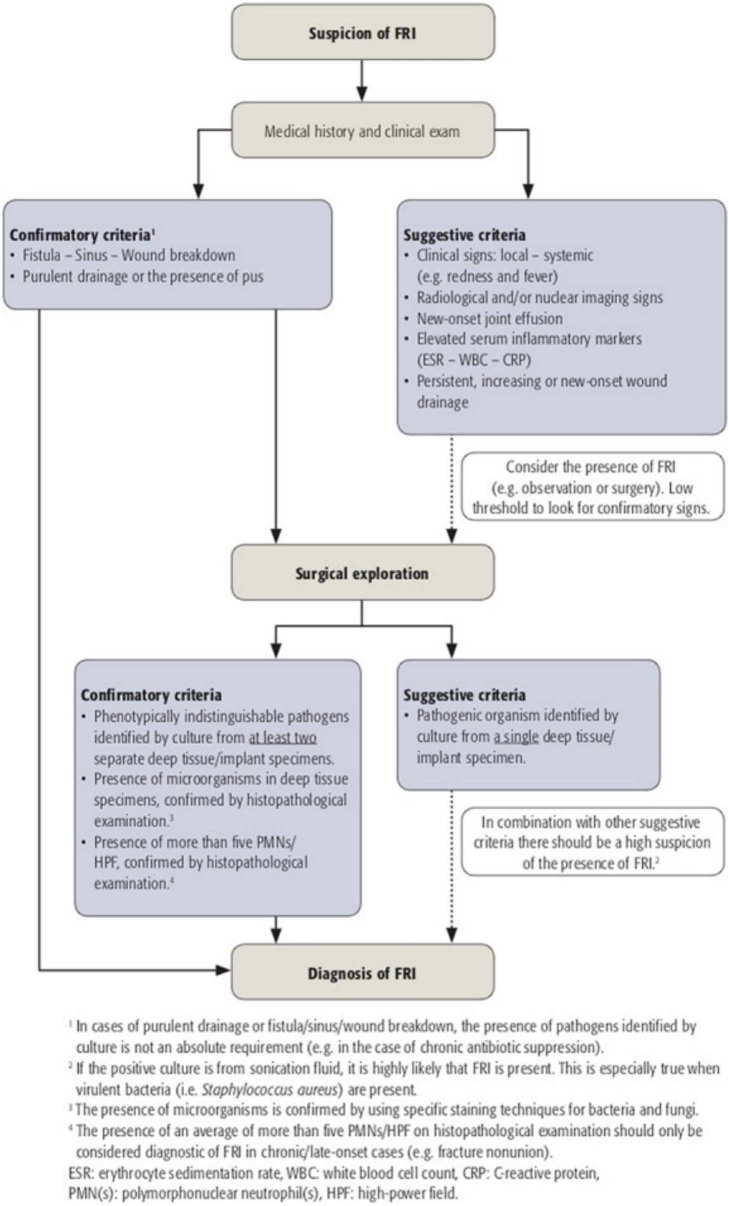


Figure 17 - Fracture-related infection[152]

Definition and flow-chart for diagnosis of Fracture-related infection. Figure from "Diagnosing Fracture-related Infection: Current Concepts and Recommendations", *Govaert GAM, Kuehl R, Atkins BL, Trampuz A, Morgenstern M, Obremskey WT, Verhofstad MHJ, McNally MA, Metsemakers WJ; Fracture-Related Infection (FRI) Consensus Group. J Orthop Trauma. 2020 Jan;34(1):8-17*

Adapted from: Fracture-related infection: A consensus on definition from an international expert group. WJ. Metsemakers, M. Morgenstern, M.A. McNally, T.F. Moriarty, I. McFadyen, M. Scarborough, N.A. Athanasou, P.E. Ochsner, R. Kuehl, M. Raschke, O. Borens, Z. Xie, S. Velkes, S. Hungerer, S.L. Kates, C. Zalavras, P.V. Giannoudis, R.G. Richards, M.H.J. Verhofstad

Injury,Volume 49 Issue 3 Pages 505-510 (March 2018, DOI: 10.1016/j.injury.2017.08.040[145]

2.0 Background for studies

2.1 Paper 1

Given the complexity of the ankle joint anatomy and PMFs (insert of the PITFL, involvement of both fibular notch and posterior margin of the tibia, joint involvement, posterior stability) one intuitively expects the posterior malleolus to significantly contribute to stability of the ankle and talus. However, biomechanical studies do not fully support these theories.[30,157] In a cadaver model Fitzpatrick et al. found that the talus was displaced anteriorly if a PMF involved 50% of the articular surface if there was a step-off or gap of two millimeters. Restoration of joint congruity did not completely normalize the pressure distribution in the tibiotalar joint.[157] Papachristou et al. found that the posterior quarter of the tibial plafond bears almost no load during normal, weighted, range of motion. Most of the loadbearing area was found in the middle two quarters of the articular surface.[30] Vrahas et al. found in a cadaver study that removing parts of the posterior malleolus did not lead to significant changes in peak contact stresses in the tibiotalar joint.[158] Bartoníček concludes that biomechanical studies cannot provide clear guidelines for clinical management of the PMFs probably because they do not fully reflect the in vivo conditions.[16]

Trimalleolar fractures are known to give poor clinical outcome.[159–161] As a result of poor prognosis and lack of clear guidelines these fractures have been the object of increased interest. Multiple studies have evaluated surgical approaches and postoperative results aiming for the correct indication and choice of intervention.[16–18,45,47,66] Closed, indirect reduction and, if needed, anteroposterior screw fixation of the PMF has been *the traditional approach* for fixating the PMF.[162] Despite lack of prospective studies of high quality the trend has turned towards the use of a *posterior approach* allowing open reduction and internal fixation (ORIF).[47,59,163] The reason being that this approach allows a more precise reduction of the PMF, even of fragments smaller than 25%-33% of the tibiotalar joint surface.[164] Incongruency and step-off in the tibiotalar joint are known to be associated with pain, osteoarthritis and a poor patient reported outcome.[165,166] In addition, the peroneus muscles are argued to give good soft tissue coverage when fixating the distal fibular fracture through the same posterolateral incision.[167] The PITFL attaches to the posterior malleolus and fixation of the PMF may therefore also reduce the need for further syndesmotic stabilization.[20,28,71,72,168] The posterior approach and fixation of the PMF have been shown to give good clinical outcome and few complications.[167,169]

Few studies have, however, reported on the comparative outcomes after use of the traditional approach versus the posterior approach for PMF fixation. Study 1 was conducted to address results after the change in practice towards treating these fractures with open reduction and fixation with a *posterior approach.* This way we aimed to achieve a better understanding of which treatment would benefit patients with trimalleolar ankle fractures more.

2.2 **Paper 2**

Surgery, including operations for ankle fractures, has various short- and long-term complications. Possible complications are soft-tissue problems, malreduction, hardware-related symptoms, pain, reduced range of motion, and fracture-related infections (FRI).[109,152,170–172] The correct timing of surgery and its impact on such complications is an ongoing debate. Schepers et al. found patients treated more than six days from injury to have a complication rate of 12.9%.[146] There might be several reasons for a delay of surgery; patient- or doctor delayed admission to hospital, need for additional computer tomography (CT) scans, or more commonly, preoperative soft-tissue challenges or scheduled treatment at a later point in time.[173–175] A temporary external fixator may be applied prior to definitive surgery.[176] The fracture may then be fixed and treated at a later point in time when the swelling is reduced, potentially lowering the risk of complications.[174] On the other hand, early, definitive surgery might prevent complications and allow early and faster rehabilitation.[177] There is a knowledge gap in the literature as to the effect of a delay in surgery on postoperative clinical outcomes.[177,178] From the work leading to Paper 1 we noticed that the time from injury till definitive surgery varied greatly between patients. In Paper 2 we therefore aimed to investigate whether a delay from time of injury to definitive operation has an impact on patient-reported outcome after operative treatment of severe ankle fractures compared to earlier surgery.

2.3 **Paper 3**

From the work with Paper 2 it was clear that the FRI rate was high in the current cohort, surgically treated for severe ankle fractures. Those results led us to examine the complication rates, particularly the FRI-rate in the ankle fracture population treated at Haukeland University Hospital. Postoperative infection after ankle fracture surgery, applying the FRI definition, has only been reported in a few studies.[140,152] FRI is one of the most common complications and have potentially severe consequences.[134] We therefore studied the FRI-rate among patients surgically treated for ankle fractures in the period of 2015-2019. We also assessed the application of the FRI consensus criteria on this patient cohort.

2.4 **Paper 4**

The risk of developing FRI is dependent on both patient- and surgery-related factors. Patients may be young and healthy, smoke cigarettes, have diabetes mellitus, be middle aged with a known opioid abuse, or older with various comorbidities including cardiovascular and peripheral vascular diseases.[179–182] These patients carry a different risk of developing complications including FRI. Also, the surgeon has to be aware of other potential surgery-related factors that add to the risk of infection, such as the time from injury to surgery, length of surgery, approach used, or devices used during surgery. When approaching a patient in the emergency room or at the outpatient clinic it is vital to know if the current patient has conditions increasing the risk of complications. Knowledge of risk factors is therefore important when planning the operation, to inform the patients about the following surgery, and the possible risk of infection. Several papers have studied the risk of SSI or deep infection after fracture surgery, but few have used the FRI consensus definition. In Paper 4 we therefore assessed the risk factors for developing FRI after ankle fracture surgery and calculated the probability of FRI depending on the absense or presence of risk factors.

3. Aims of the thesis

Overall aims

The aim of this PhD thesis was to evaluate different surgical treatment strategies for ankle fractures and to investigate the rate of fracture-related infection after ankle fracture surgery and address risk factors for infection, in patients treated at Haukeland University Hospital.

The specific aims of the papers included in the thesis were:

Paper 1

To compare the short-term PROMs and rate of complications in patients with ankle fractures including a PMF that were treated surgically with or without a posterior approach.

Paper 2

To investigate whether a delay from time of injury to time of definitive operation has an impact on patient-reported outcome after operative treatment for severe ankle fractures.

Paper 3

To report the prevalence of FRI and to discuss the applicability of the consensus criteria on patients operated for ankle fractures.

Paper 4

To identify risk factors for developing FRI after ankle fracture surgery.

4. Materials and methods

4.1 Paper 1

Design:

Level III - Retrospective case-control study.

Materials:

All patients treated in the period of January 2014 through December 2016 for ankle fractures with low energy mechanism of injury involving a PMF at Haukeland University Hospital in Bergen, Norway, were eligible for inclusion in the study.

Deceased patients, patients with follow-up at another hospital or in another country, patients with high energy mechanism, open fractures, former injury of the ipsilateral lower extremity of clinical importance, and non-compliant patients were excluded. Patients with cognitive impairment and severe alcohol- or drug abuse were considered non-compliant.

Patient selection, inclusion- and exclusion criteria are presented in Figure 19.

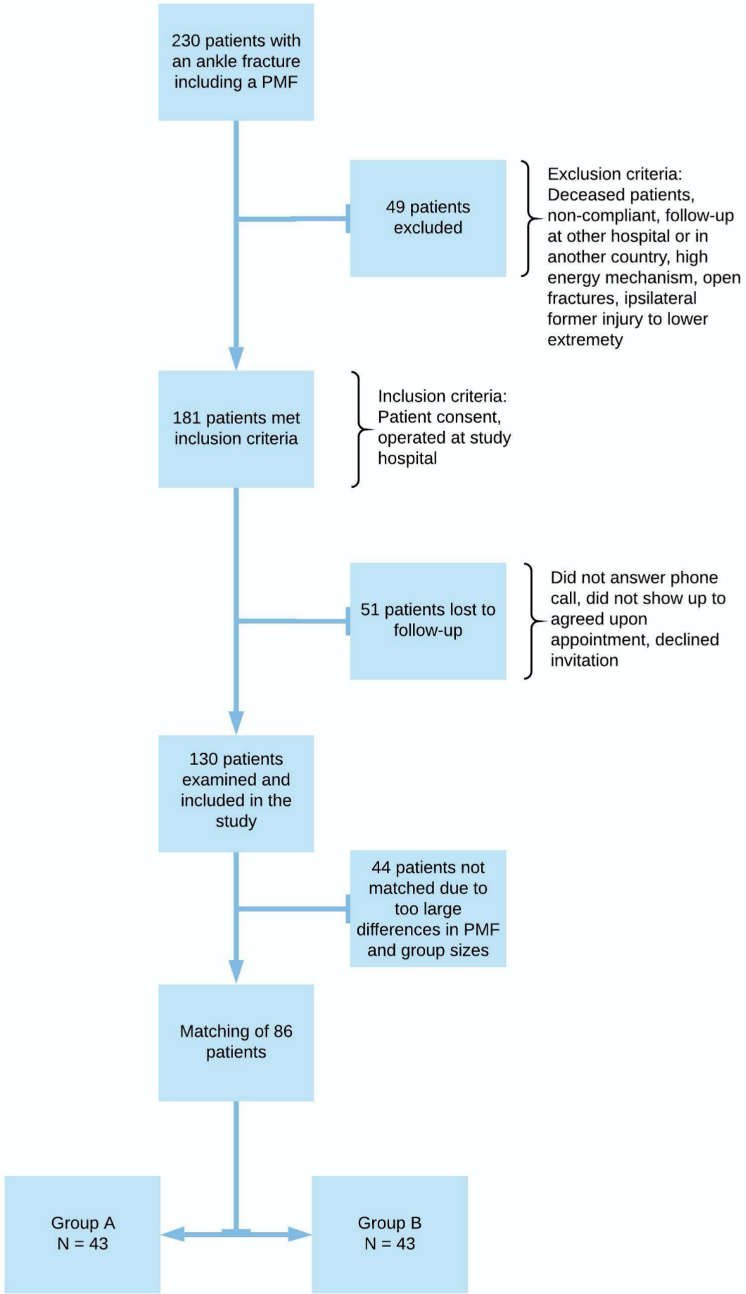


Figure 18 - Patient selection, inclusion, and exclusion criteria.

Methods:

A selective search through the operation planning system, Orbit version 5.11.2, was conducted based on Nordic Medico-Statistical Committee (NOMESCO) Classification of Surgical Procedures (NCSP) codes for bi- and trimalleolar fractures. Only patients with an ankle fracture with a concomitant PMF were included. Included patients were invited to a follow-up evaluation involving questionnaires, clinical examination, and radiographs.

Demographic data and information on injury- and fracture characteristics, time from injury to definitive operation, duration of operation and length of stay were collected from patient charts. Complications registered were nerve injury, reoperations, mechanical irritation from the implant, implant removal, surgical site infections, and non-infectious skin problems. Reoperation was defined as any new surgery due to malreduction of the fracture(s) or fixation of the syndesmosis after the primary operation.

Fracture classification was done according to the Weber and the Lauge Hansen classifications. The PMF size was measured as percentage of joint involvement of the anteroposterior length of the distal tibial articular surface on lateral radiographs of the ankle (Figure 20). Radiographs acquired at follow-up were examined by two of the authors, Odland and Pilskog. The Kellgren and Lawrence classification was used for grading of posttraumatic OA.

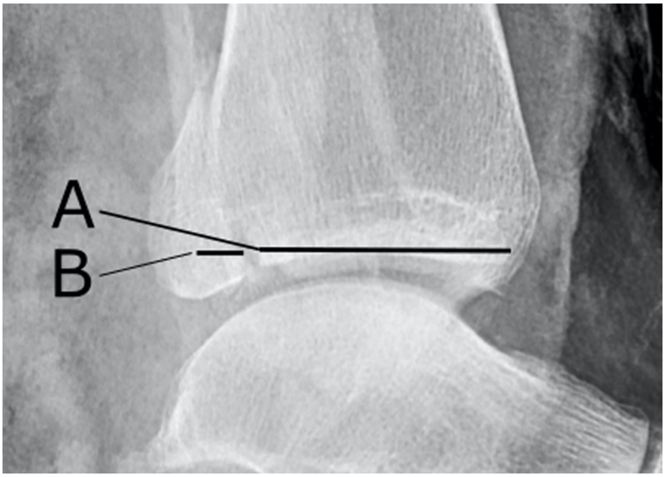


Figure 19 - Measurement of PMF-size. The size of the posterior malleolus fracture was measured as percentage joint involvement (B) of the anteroposterior length of the distal tibial articular surface (A +B) on lateral radiographs of the ankle ((B/(A + B)) *100 = % size of the distal tibial articulate surface).

Depending on the given treatment approach, patients were allocated to two groups; Group A: patients treated via a posterior approach, Group B: patients who received the traditional approach. A one-to-one matching according to the size of the PMF was performed to reduce bias on differences in PMF size when analyzing outcomes across Group A and Group B. A maximum ±2% size difference of the PMF was allowed for within each matched pair.

PROMs in the matched patients were compared. Sub analyses were performed for patients with fragments smaller than 25%, comparing those who had the PMF fixed in Group A to the patients in Group B that did not have the PMF fixed. Also, the results for matched patients with the PMF fixed, were compared.

Outcome:

Primary outcome:

PROM: Self-reported Foot and Ankle Score (SEFAS) at a minimum of one year postoperatively.

Secondary outcomes:

PROMs:

RAND-36 was used as a generic PROM

Patients reported VAS of Pain from 0 (no pain) to 10 (worst imaginable pain) describing the average of pain experienced the last two weeks prior to the follow-up appointment. VAS of Satisfaction was scored from 0 (very unsatisfied) to 10 (very satisfied) based on how satisfied the patients were with the result of the surgery and result after the injury.

Clinical examination

Range of motion (ROM) in passive dorsal- and active plantarflexion and heel raise distance for both the operated and the uninjured ankle was measured. Any differences between the sides were noted. Positive numbers denote better movement of the uninjured ankle and negative numbers denote better movement of the injured ankle. Dorsiflexion was performed with the foot being measured on top of a two-step stool with the knee flexed. While leaning forward the angle between the stool's top surface and the anatomical axis of the fibula was measured with a goniometer just before the heel left the surface. Plantarflexion was measured with the patient on an examination couch with straight knees and active plantar flexion of the foot. The angle between neutral position and the axis of the 5th metatarsal was measured with a goniometer. The heel raise test was performed with the patient standing on a stool performing a one leg heel raise. The distance between neutral and maximum height after heel raise was measured in centimeters.

Statistical analysis

Categorical variables were analyzed with Pearson's chi-squared test and non-parametric continuous variables were analyzed by Mann-Whitney-U test. Statistical significance was a priori set to a p-value of < 0.05. IBM SPSS v.24 (SPSS Inc., Chicago, IL) was used for data management and analysis.

Ethical considerations:

The Helse Bergen Data Protection Officer and Regional Committee for Medical and Health Research Ethics (REC) approved the project, 2016/1720. Informed consent was obtained from all patients before inclusion in the study.

4.2 Paper 2

Design:

Retrospective follow-up study. Level III Retrospective Case – control study.

Materials:

Patients with ankle fractures involving the posterior malleolus treated at Haukeland University Hospital from January 2014 through December 2016 were eligible for the study.

Deceased patients, patients with follow-up at another hospital or in another country, patients with high energy trauma mechanism, open fractures, former injury of the ipsilateral lower extremity of clinical importance, and non-compliant patients were excluded. Patients with cognitive impairment and severe alcohol- or drug abuse were considered non-compliant.

Patient selection, inclusion- and exclusion criteria are presented in Figure 21.

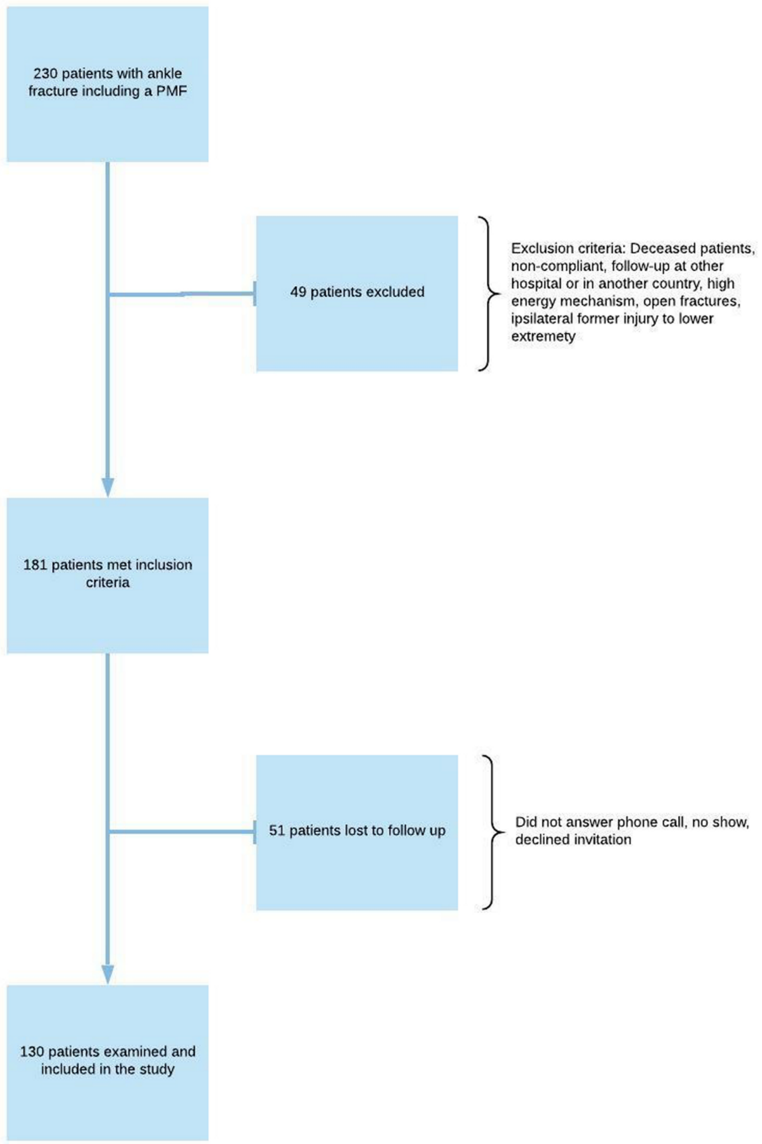


Figure 20 - Patient selection, inclusion- and exclusion criteria.

Methods:

A selective search through the operation planning system (Orbit version 5.11.2, Evry Healthcare Systems AB), was conducted based on Nordic Medico-Statistical Committee (NOMESCO) Classification of Surgical Procedures (NCSP) codes for bi- and trimalleolar fractures. Radiographs from the time of injury were examined and only patients with an ankle fracture that involved the posterior malleolus were included. All injuries were low energy mechanism fractures. Patient charts were reviewed for information concerning patient demographics, type of trauma, fracture characteristics, treatment given and complications. Eligible patients were invited to a follow-up visit that included clinical examination, radiographs, and patient-reported outcome measures (PROMs).

To assess the impact of surgical delay, patient reported ourtcomes were compared between patients treated with definitive surgery within a week from injury (0-7 days) and those treated later than a week from injury. To further examine the impact of time from injury to definitive surgery, the patients were stratified into three groups based on time from injury to definitive surgery; Group 1: within the same day, Group 2: within 1 to 7 days, and Group 3: later than 7 days after injury.

Outcome parameters:

Primary outcome:

Self-reported Foot and Ankle Score (SEFAS) at a minimum of one year postoperatively.

Secondary outcomes:

RAND-36 was used as a generic PROM.

Patients reported VAS of Pain from 0 (no pain) to 10 (worst imaginable pain) describing the average of pain experienced the last two weeks prior to the follow-up appointment. VAS of Satisfaction was scored from 0 (very unsatisfied) to 10 (very satisfied) based on how satisfied the patients were with the result of the surgery and result after the injury.

Clinical examination was performed as described in Paper 1.

Based on chart reviews, complications such as reoperations and revisions, nerve injuries, fracture related infections (FRI),[152] mechanical irritation from implants, and implant removal were registered. Reoperation was defined as any new surgery associated with the primary open reduction and internal fixation (ORIF), due to malreduction or failed syndesmotic fixation after primary surgery. Revision was defined as surgery performed due to FRI.

Fractures were categorized according to the Weber classification. Grade of posttraumatic OA was assessed from radiographs acquired at follow-up according to the Kellgren and Lawrence classification. The radiographic examination was performed by Odland and Pilskog.

Statistical analysis

IBM SPSS v.24 (SPSS Inc., Chicago, IL) and R (CRAN) were used for analyses. SEFAS was compared both between the group of patients treated within a week versus those treated after a week from injury, and between the three stratification groups (Definitive surgery at <1 day, 1-7 days and >7 days from injury). By controlling the histogram and normality of the residuals of the variables, the data were considered to have a normal distribution. Parametric tests were therefore used for analysis of these variables. The significance threshold for SEFAS was set at .05. The association of time from injury to definitive surgery on SEFAS was assessed using a linear model with adjustment for age, gender (female vs male) and American Association of Anesthesiologists (ASA) classification. Secondary patient-reported outcomes were tested with a Bonferroni correction at .05/3 = .017. Continuous variables for the three stratification groups were analyzed with the Analysis of Variance (ANOVA) with two degrees of freedom and with post hoc Bonferroni and Tukey HSD tests. One patient did not report RAND-36 and one did not report VAS of Satisfaction and these were consequently excluded from the analyses. Categorical variables were analyzed with Pearson's chi-squared test and between group differences were controlled for with the Bonferroni method for adjusting p-values while comparing column proportions. Continuous variables were analyzed with the students t-test for independent variables.

Ethical considerations:

The Helse Bergen data protection officer and regional committee for medical and health research ethics (REC) approved the project (REC ID 2016/1720). Informed, signed, consent was obtained from all patients prior to inclusion.

4.3 Paper 3

Design:

Retrospective cohort study

Materials:

Patient records of all patients surgically treated for ankle fractures at Haukeland University hospital in the period January 2015 through December 2019 were retrospectively assessed for signs of postoperative infection. Patients aged under 18 years at the time of primary surgery, those with bilateral injuries, and patients with follow-up at other hospitals were excluded.

Methods:

Patients were identified using the operation planning system, Orbit version 5.11.2 (Tieto Evry, Kristianstad, Sweden), based on Nordic Medico-Statistical Committee (NOMESCO) Classification of Surgical Procedures (NCSP) codes for uni-, bi- and trimalleolar fractures and infection complication diagnoses. Sectra software version 22.1 (Sectra AB, Linköping, Sweden) was used for radiograph examination. Patient records were thoroughly examined for information concerning postoperative signs of infection and wound problems.

Information indicating wound problems such as prolonged healing or dehiscence as well as clinical signs of infection, drainage or puss resulted in suspicion of infection. These patients were stratified to either have confirmatory criteria or suggestive criteria of FRI. Following the diagnostic algorithm published by FRI consensus group, patients were considered to have FRI when meeting either of the confirmatory criteria (Figure 1) [152,155]. Culture status (negative/positive) was evaluated thereafter.

Patients meeting the suggestive criteria were classified as having a FRI if they had one positive culture with virulent pathogens (Staphylococcus aureus (S. aureus), Staphylococcus lugdunensis (S. lugdunensis), Streptococci species, or gram-negative species), or phenotypically equal bacterial cultures in two or more bacterial samples. Although it is a coagulase negative staphylococcus, S. lugdunensis was included as a virulent bacterium due to similarities to S. aureus in causing infection [183,184]. Those who had suggestive criteria, but negative cultures, were classified as not having a FRI. Also, patients without bacterial sampling, not having received any antibiotic treatment and who did not develop any confirmatory criteria of FRI, were defined as not having a FRI. Patients with suggestive clinical signs of FRI treated without revision surgery were considered to have a good treatment outcome if the infection or soft tissue problems resolved and they were infection free 12 months after the initial treatment.

Revision surgery of patients with suspected FRI was performed by the surgeon on call. Both swab and tissue sampling were performed. We accepted two or more samples as sufficient in the current study. A single swab sample in the outpatient clinic or the operating room was considered insufficient.

Depending on the samples taken, the Department of microbiology at the study hospital use different agars for cultivation. Direct PCR is performed in cases with high suspicion of infection but negative cultures. Standard incubation time for swabs is two days. In suspected FRI, the incubation time was five days, early in the study period, but was later extended to 10 days for peroperatively taken bacterial samples, to identify slow growing bacteria with affinity for implants.

Patient selection and categorization of patients according to the FRI flow-chart and criteria is presented in Figure 22.

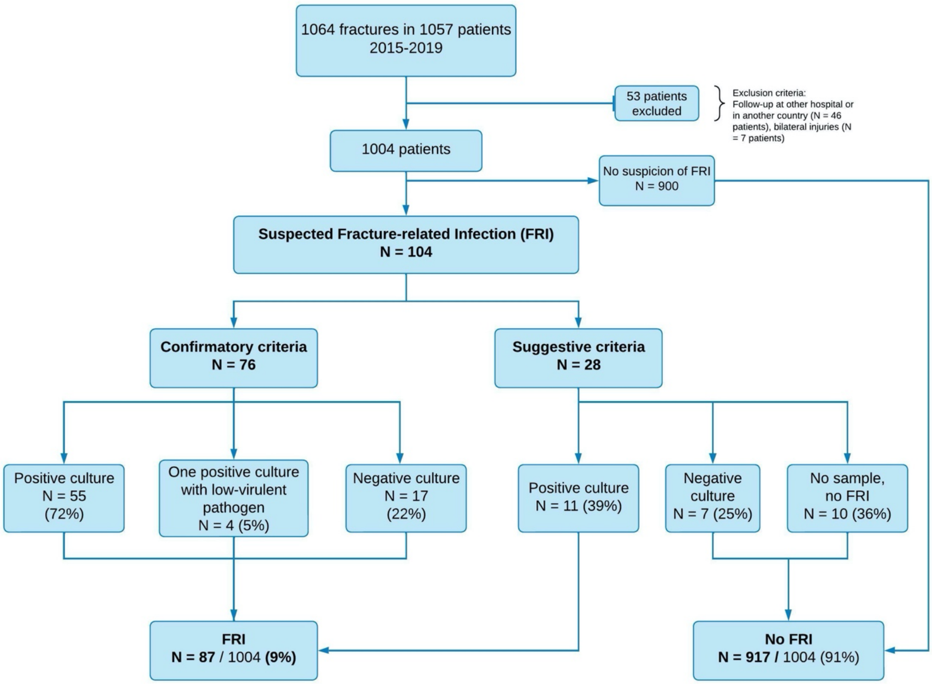


Figure 21 - Patient inclusion, patient with suspicion of FRI and categorization of patients according to the FRI criteria.

Outcome parameters:

Primary outcome:

Number of patients with FRI as defined by the consensus definition and algorithm.

Ethical considerations:

The paper is part of a larger project for follow-up of patients with complications after ankle fracture surgery. The project has approval by the Helse Bergen data protection officer and regional committee for medical and health research ethics (REC, REC reference 328437). Paper 3 does not involve acquisition of new data from the patients and therefore a new independent approval or written, informed consent from the patient, was not required.

4.4 Paper 4

Design:

Retrospective cohort study

Materials:

Medical journals of patients with operative treatment of ankle fractures at Haukeland University hospital in the period January 2015 - December 2019 were retrospectively assessed for signs of postoperative infection. Patients aged under 18 years at the time of primary surgery, those with bilateral injuries, and patients with follow-up at other hospitals were excluded.

Methods:

Orbit version 5.11.2 (Tieto Evry, Kristianstad, Sweden) was used for identification of patients using the operation planning system based on Nordic Medico-Statistical Committee (NOMESCO) Classification of Surgical Procedures (NCSP) and ICD-10 codes for uni-, bi- and trimalleolar fractures and infection complication diagnoses. Sectra software version 22.1 (Sectra AB, Linköping, Sweden) was used for radiograph examination. Patient records were thoroughly examined for information concerning postoperative signs of infection and wound problems.

Following the diagnostic algorithm published by FRI consensus group patients were considered to have FRI when meeting either of the confirmatory criteria (Figure 1) [152,155]. Patients meeting the suggestive criteria were classified as having a FRI if they had one positive culture with virulent pathogens (Staphylococcus aureus (S. aureus), Staphylococcus lugdunensis (S. lugdunensis), Streptococci species, or gram-negative species), or phenotypically equal bacterial cultures in two or more bacterial samples. Those who had suggestive criteria, but negative cultures, were classified as not having a FRI. Also, patients who did not develop any confirmatory criteria of FRI and where bacterial sampling was not performed, and not having received any antibiotic treatment were defined as not having had FRI.

Outcome parameters:

Primary outcome:

Risk factors for development of FRI after ankle fracture surgery.

Ethical considerations:

The paper is part of a larger project for follow-up of patients with complications after ankle fracture surgery. The project has approval by the Helse Bergen data protection officer and regional committee for medical and health research ethics (REC, REC reference 328437). Paper 4 does not involve acquisition of new data from the patients and therefore a new independent approval or written, informed consent from the patient, was not required.

5. Results

5.1 Paper 1

Among the 130 patients who met to a follow-up visit, patients from the *posterior* and *traditional group* were matched one to one according to the size of the PMF. The matching procedure rendered 86 patients, 43 patients in each of Group A and Group B.

The two groups of patients reported similar PROM results at follow-up (Table 1).

Table 1. Patient-reported Outcome Measures at Follow-up of Matched Patients.			
	Group A (N = 43), median (IQR)	Group B (N = 43), median (IQR)	P value
PROM			
SEFAS	36 (30-44)	40 (32-43)	0.2
RAND 36	73 (54-88)	81 (55-89)	0.6
VAS of pain	2 (1-4)	1 (0-3)	0.2
VAS of satisfaction	9 (7-10)	8 (7-10)	0.9

Table 1 - Patient-reported outcome in Group A and Group B, results at follow up. Median values with interquartile range (IQR) in parenthesis.

Complications

A total of 6 of 86 patients were treated for deep infection, 2 patients from Group A and 4 patients from Group B. Fewer patients reported hardware discomfort in Group A than in Group B (Table 1), $P < 0.1$. Non-infectious skin problems were more frequent among patients in Group A (Table 1). A total of 16 (19%) patients reported reduced sensation or paresthesia on the dorsum of the foot.

5.2 Paper 2

181 patients were eligible for inclusion of which 130 (72%) patients came to a follow-up visit at a mean 26 months (SD 9) months postoperatively. Eighty-six patients (66%) had definitive surgery within a week from injury and 44 patients (34%) were treated more than seven days from injury.

Stratification on time from injury to operation gave 44 patients in Group 1 (definitive surgery within the same day as the injury), 42 patients in Group 2 (definitive surgery on day 1-7 after injury, and 44 patients in Group 3 (definitive surgery later than seven days from injury (≥ 8 days).

A total of 41 patients received a temporary external fixator prior to definitive surgery, 7 patients in Group 2 and 34 patients in Group 3, $P = .1$. No patients in Group 1 got a temporary external fixator.

Outcomes at follow-up

When comparing patients treated within- versus after one week post injury, patients treated after a week from injury had worse scores for all PROMs, except RAND-36, than patients treated within a week from injury (Table 2).

Table 2. PROMs at Follow-up Stratified by Treatment Within or More Than 1 Week From Injury

	<= 7 days Mean (SD) (N = 86)	>7 days Mean (SD) (N = 44)	P value
SEFAS	38 (9)	34 (10)	0.01
RAND-36	74 (20)	71 (18)	0.4
VAS of Pain	2 (2)	3 (2)	<0.01
VAS of Satisfaction	8 (2)	7 (3)	0.02

Table 2 - PROMs at follow-up stratified by treatment within or after one week from injury.

General linear modeling (GLM) of SEFAS by time from injury to definitive surgery, as a continuous variable, adjusted for age, gender (female), and ASA classification showed that time to operation (*P = .002*) and female gender (*P = .001*) were associated with a lower SEFAS (Table 3).

Table 3. General Linear Model With Univariate Analysis of Variance of SEFAS With Time From Injury to Operation, Adjusted for Age, Gender (Female), and ASA Classification.a

Parameter	Beta	Std error	t	Significance level	95% CI	
					Lower Bound	Upper Bound
Time from injury to operation (days) as a *continuous variable* (*R*-squared = 0.153)						
Intercept	42.43	3.25	13.05	<0.001	35.99	48.86
Time from injury to operation (days) b	-0.45	0.15	-3.09	*0.002*	-0.73	-0.16
Gender (Female)	-5.79	1.73	-3.35	*0.001*	-9.22	-2.37
Age (Years)	0.08	0.05	1.56	0.12	-0.02	0.17
ASA classification	-2.13	1.43	-1.49	0.14	-4.96	0.69
Time from injury to operation (days) as a *categorical, ordinal variable* (three groups) (*R*-squared = 0.142)						
Intercept	37.72	3.48	10.85	<0.001	30.84	44.6
Time from injury to operation						
Group 1 (<1 day)	4.63	1.88	2.46	*0.015*	0.9	8.35
Group 2 (1-7 days)	4.41	1.89	2.34	*0.02*	0.67	8.15
Groups 3 (>7 days)	0c					
Gender (Female)	-5.48	1.74	-3.15	*0.002*	-8.92	-2.03
ASA classification	-2.55	1.44	-1.78	0.08	-5.39	0.29
Age (Years)	0.07	0.05	1.47	0.15	-0.03	0.17

Table 3 - General linear model with univariate analysis of variance of SEFAS with time from injury to operation, adjusted for age, gender (female), and ASA classification

a) Results of analyses with time to operation as both a continuous variable and a categorical, ordinal, variable.

b) The continuous variable of time from injury to operation was used in this analysis.

c) Reference group.

Complications

Comparing patients treated within a week from injury to those treated after a week from injury, similar frequencies of postoperative soft tissue problems (*P = .34*), FRI (*P = .83*), nerve injuries (*P = .12*), and reoperations (*P = .32*) were found.

FRI was present in 25 of 130 (19%) patients, but no difference was found between the three stratification groups.

5.3 Paper 3

The inclusion process left 1004 patients eligible for inclusion. A suspicion of infection was present in 104 (10%) patients.

Confirmatory criteria were met in 76 of the 104 (73%) patients and *suggestive criteria* were met in 28 (27%) of 104 patients. Fracture-related infection (FRI) was confirmed in 87 (9%) of 1004 patients (Table 4).

Confirmatory criteria

The most frequent *confirmatory criteria* were fistula, sinus tract formation, and wound breakdown. Bacterial samples were taken in all 76 patients with *confirmatory criteria*.

Suggestive criteria

Wound drainage was found in 27 of 28 patients with *suggestive criteria*. Bacterial sampling was performed in 18 of 28 patients with *suggestive criteria* but few had an adequate sampling method.

Table 4 - Distribution of confirmatory and suggestive criteria among the 104 patients with suspected Fracture-related Infection			
			n (%)
*Patients with confirmatory criteria, clinical signs, n = 76**			
	Fistula, sinus, wound breakdown		55 (72)
	Purulent drainage, pus		21 (28)
	Clinical signs of infection**		46 (61)
*Patients with suggestive criteria, n = 28**			
	Local clinical signs		7 (25)
	Systemic clinical signs (fever)		n.a.
	Other clinical signs	New-onset joint effusion	n.a.
		Wound drainage	27 (96)
	Histopathology		0
	Radiografic signs		1 (4)
	Serum inflammatory markers#	Erythrocyte Sedimation Rate (ESR)	2 (7)
		Leukocyte particle counct (LPC)	0
		Neurophile count	0
		C-reactive protein (CRP)	4 (14)

Distribution of confirmatory (clinical) and suggestive criteria among the 104 patients suspected of FRI. N.a. = not applicable. *A patient may have more than one confirmatory or suggestive criteria. **Clinical signs of infection: redness, warmth, swelling and pain. #For the serum inflammatory markers the number of patients with abnormal values are presented with percetages in parenthesis. Normal values: ESR <=20, LPC <=11 x10^9, Neutrophile count 1-8.5 x10^9, CRP <5.

Table 4 - Distribution of confirmatory and suggestive criteria. N.a. = not applicable. Continuous variables are presented with median values and range in parenthesis.

5.4 Paper 4

All variables which had significantly different distributions ($p < 0.05$) among patients with FRI and patients without FRI were included in binary logistic regression analyses to identify risk factors for developing FRI. Higher age at operation ($p = .002$), congestive heart failure ($p = 0.005$), PAD ($p < .001$), and current smoking ($p = .006$) were identified as risk factors for developing FRI (Table 5).

Time from injury to definitive surgery was not associated with development of FRI in the study population ($p = .95$) or in a sub-analysis of patients with dislocation fractures ($p = .73$).

Table 5 - Logistic regression model of risk factors for Fracture-related infection

	aOR (95% C.I.)	P-value
Female Sex	0.7 (0.4-1.1)	0.1
Age by 10 year interval	1.3 (1.1-1.5)	<0.001
Current smoking status	2.1 (1.2-3.5)	0.006
Congestive heart failure	4.7 (1.6-14.1)	0.006
Peripheral arterial disease	4.2 (1.8-10.1)	0.001

Table 1 - Logistic model of risk factors for Fracture Related infection. aOR - adjusted Odds Ratio. C.I. - Confidence interval

6. Discussion

6.1 Discussion of methods

6.1.1 Study design

All four papers are Level III, observational studies.[185,186] Paper 1 and Paper 2 are retrospective case-control studies and Paper 3 and Paper 4 are retrospective cohort studies.[186] The advantages of retrospective, observational studies are their low cost compared to randomized controlled trials (RCT), the easier feasibility, the immediate availability of patient data, and the opportunity to assess a range of risk factors and exposures. Other strengths of the current studies are the clear inclusion and exclusion criteria, and that the patients are from the same population. The type of fracture, ankle fractures with a PMF, is clearly defined and the population were treated in one hospital. However, there is a risk of recall bias and information bias. The information regarding mechanism of injury, soft tissue status, fracture type and past medical history is dependent on the quality of the patient journals. Patient and injury status may be variably reported, wrong, imprecise, or incomplete which may cause reduced internal validity.[186] For Paper 1 and 2 all the patients had a PMF and based on the patient demographics and fracture characteristics the groups are similar. However, there may be a bias in types of injury and PMF morphology. Being a one-institution study from a Level 1 trauma hospital may reduce the generalizability of the results as more serious injuries are allocated there. However, in Paper 1 and 2 the "exposure" is low energy, closed ankle fractures. In paper 3 and 4 all ankle fractures are included. We argue that these factors render a good external validity.

Matching

Matching is performed to reduce systematic differences of the background variables. We matched patients in Paper 1 to improve the comparison of Group A and Group B. The matching was based on the PMF size as the size of the fragment has been the argument for indication of fixation and is also a prognostic factor.[187,188] The most common variables for matching are age and sex, which were not matching variables in this study, but these were similar across groups in both Paper 1 and Paper 2.

Assessment of FRI

The diagnostic algorithm of FRI was not available at the start of the study period of Paper 3 and Paper 4. Therefore, the bacterial sampling was initially not at a satisfactory level. A limitation of Paper 3 and Paper 4 is therefore that we have assessed the FRI-rate, in part, with insufficient measures. Ideally one would perform a prospective study were the clinical confirmatory and suggestive criteria are accurately described and five bacterial samples taken with separate, non-contaminated instruments according to FRI protocol.[189] Alternatively, one could perform a retrospective study including patients from a period where the FRI criteria and accompanying sample protocol were in use at the department. This would most likely give an even more correct picture of the FRI rate and the clinical practice in our department. However, this was not possible for this study, but conducting the study certainly has increased our knowledge on FRI and has influenced the department's routines. Through this project we have, for instance, improved the quality of bacterial sampling in patients suspected of FRI.

Identification of risk factors for developing FRI

The presence of FRI is a dichotomous, categorical variable. Binary logistic regression was therefore used in the risk factor analyses with the presence or absence of FRI as outcome, and potential risk factors as independent variables.

Primary outcome

6.1.1.1 Paper 1 and Paper 2

SEFAS was chosen as the primary outcome as it was already in a Scandinavian language, Swedish, facilitating better cross-cultural adaptation. Also, it is a PROM reported solely by the patients, without interference from the physician unlike the much-used AOFAS questionnaire. A Norwegian version was not available at the start of Study 1 and Study 2. After consulting the Center on Patient Reported Data (CPRD) in Helse Bergen we therefore conducted a translation from Swedish to Norwegian.[190] The Norwegian version was controlled by two Swedish doctors that also were fluent in the Norwegian language. They verified the Norwegian and did a retranslation to Swedish. Any disagreements or comments were discussed with the main author, KP. The method was approved by the CPRD due to the closeness of the two languages. Garatt et al. later published and validated a translation of SEFAS.[104]

Later SEFAS has been used in studies of ankle fractures and found to be the best PROM for this patient group.[104] Nguyen et al. recently (2022) published a systematic review on the validation of PROMs for use in ankle fracture populations.[90] They conclude that there are no fully validated PROMs for this population. However, SEFAS is one of three questionnaires given a temporary recommendation for use until further evidence of validation is available.

One of the weaknesses of a PROM as a primary outcome is the potential for a ceiling or floor effect.[191] This occurs when at least 15% of the patients reports a top or bottom score[99] which makes evaluating differences and changes across individuals and groups difficult. A ceiling effect occurs if the groups being compared have a very left skewed distribution, which is common with the use of PROMs. Cöster et al. did not find any ceiling or floor effect when validating SEFAS for ankle, hindfoot and forefoot disorders.[192] However, Nguyen et al. found a floor effect of 22.4% in their review of SEFAS for ankle fractures.[90]

Cöster et al. reported the MCID to be 5 points.[99,192] We used this as a cut-off for clinical significance between groups prior to both Paper 1 and Paper 2. In the former paper both groups had a median of more than 5 points worse than the normative values found in the Swedish population.[102] Later Erichsen et al. translated and validated a Danish version of SEFAS.[193] They found a smallest detectable change (SDC) of 6.8 points while Garrat et al. published a SDC of 6.6 points. However, these cut-offs are calculated for evaluation of change and differences on an individual level. Unfortunately, there are no available validated values to decide between-groups differences. Papers have warned against using MCID for individuals on a group level as it may mislead the reader.[194] Future research must contribute to reducing this knowledge gap.

6.1.1.2 Paper 3

Few studies have reported results after ankle fracture surgery based on the new FRI definition. To identify the infection rate at our institution we chose FRI as the primary outcome of Paper 3.

6.1.1.3 Paper 4

The main outcome of paper 4 was risk factors for FRI after ankle fracture surgery. Risk factors for development of SSI after surgery for ankle fractures are formerly well described. However, for FRI there is a paucity in the literature. The natural step after defining the FRI rate at our institution was to identify the patients at risk of developing FRI.

6.2 General discussion of results

Patient-reported outcome

With the intent of improving outcome, our department in 2015 changed routines towards using a *posterior approach* with ORIF in the majority of cases, in the treatment of PMFs. Consequently, we were surprised to find similar PROM results for patients treated with fixation of the PMF and patients treated without fixation of the PMF. Still, our results are similar to former studies.[45,195–197]

We found a lower SEFAS and higher reported VAS of pain for patients treated with delayed surgery, similar to former studies.[146,198] The majority of patients who received an external fixator had definitive surgery more than seven days from injury. Patients treated with external fixator reported worse PROM than patients without a temporary external fixator. Also, patients with dislocation fractures treated later than seven days from injury reported six points lower mean SEFAS than those treated earlier. These findings suggest delayed surgery is not beneficial for patients with severe ankle fractures, supported by the GLM analyses. The mean difference in SEFAS between patients treated within or after seven days from injury was 4 points. This is a smaller difference than the MCID and SDC presented earlier in the thesis. However, as discussed previously, those cut-offs are intended for use on an individual level. Small differences in scores may indicate only a modest effect on an individual level but may be considered clinically relevant when used at the group level.[199] Our difference of 4 points is statistically significant and with the available literature we argue that our results also are clinically significant.

Patients with FRI in study 2 reported a mean 8 points lower SEFAS than those without ($P = 0.07$). Several authors have reported poor patient-reported outcome among patients with infection after ankle fracture surgery displaying the serious impact of this complication.[148,172,200–202]

The patients treated with a *posterior approach* had shorter time till follow-up than the patients treated with a *traditional approach* which may have affected the results. The latter patients may have had some degree of adaptation to their operated ankle and therefore reported better outcome. However, time to follow-up was similar between patients who had the PMF fixed and not. Also, the size of the PMFs which was fixed was larger than 30% indicating large injuries in both treatment groups of Paper 1. Patients with FRI in Paper 2 reported a mean 8 points lower SEFAS than those without (p = 0.07)

Approach and possible fixation of the PMF

Lately, several studies have shown that the size of the PMF is not the decisive factor for fixation or no fixation of the posterolateral fragment. Rather, an intraarticular step-off, presence of intercalated osteochondral fragments, PMF morphology, step-off in the fibular notch and subluxation of the talus are presented as the governing factors.[16,47,165,203–205] Mason and Molloy presented a prospective cohort study of 50 patients with ankle fractures with a PMF.[47] They recommend an algorithm of no fixation for Type 1 fractures but fixation of the syndesmosis, fixation of type 2A and 2B fractures with reduced need for syndesmosis fixation, and fixation of Type 3 fractures with no need for syndesmosis fixation. The study does not have a control group, but the patients are compared to a former study from the same research group, and they found improved outcome by following the new treatment algorithm.[47,159] In their study 28 of 50 patients had Type 1- or Type 3 fractures and most studies will support the algorithm considering those fractures.[162,164,168] However, this leaves 22 patients with Type 2A/B and based on our studies we are not convinced that the PROM results of 22 patients is sufficient documentation to completely change practice at our department. Patients with fixed PMF in Paper 1 did not have superior PROM results. Even though one must suspect a degree of heterogenicity among the fracture types, we argue that there still is a need for prospective studies with stronger statistical power and consequently stronger clinical impact. Especially for the medium-sized posterolateral fragments. Unfortunately, fracture patterns are not completely described in our patients due to the lack of CTs of the injured ankles in the study population. Plain radiographs are inadequate to fully understand the fracture pattern when faced with a PMF.[16,49,50] A preoperative CT is considered mandatory both as an assessment of the injury and for planning the surgery. Preoperative CTs are now standard procedure at our department for patients with ankle fractures with a PMF.

Our results show a reduced need for syndesmosis fixation in the group of patients treated with the *posterior approach*. Gardner, Miller, Baumbach and Tosun advise fixation of the PMFs as it reduces the need for additional fixation of the syndesmosis.[72,206–208] Tosun recommends fixation of all PMFs based on their results regarding the syndesmosis.

We found a lower rate of hardware complaints, implant removal and syndesmotic fixation among patients who were treated via a *posterior approach*. This supports the arguments for ORIF of the PMFs and is in line with other studies.[71,72,167,207]

Time from injury to definitive surgery

An important finding of this project was the significant difference in time from injury till definitive surgery between patients treated with a *posterior* and *traditional approach.* Also, most patients treated later than seven days from injury were treated with an initial, temporary external fixator prior to definitive surgery. The change in practice considering the use of a *posterior approach* and fixation of most PMFs was sudden and some of the surgeons were not familiar with the approach. External fixators may have been applied to delay definitive surgery until competent surgeons were available. The external fixators were also applied to perform final surgery when the soft tissue was ready and for better fracture reduction in the meantime. The external fixator may have given some degree of complacency, further postponing the definitive operation. Most of the preoperative soft tissue problems were found in patients treated later than seven days from injury. It is not possible to distinguish if these problems occurred due to the injury or the delay. Some patients had external fixators applied due to loss of reduction while in a cast. These types of fractures and subsequent treatments (cast, external fixator, and definitive surgery) have been shown to predispose to soft-tissue complications and longer time between injury and definitive treatment.[209] Gerlach found the size of the PMF (>22% of the distal tibial joint surface) to predict dislocation of ankle fractures while being immobilized with a temporary cast.[210] One could suspect worse injuries among the patients treated later than seven days from injury, but dislocation fractures and fracture classification had similar distribution across groups and these patients did not report worse PROM. Although patient demographics, mechanism of injury, rate of dislocation fractures, and fracture characteristics are similar across groups, the use of temporary external fixator was most frequent among patients who had definitive surgery more than seven days from injury. Therefore, we argue that the delay in surgery was not due to more severe injuries but rather the liberal use of external fixator. However, our results suggest this strategy did not improve patient-reported outcome at a median two years postoperatively. One must question if definitive operation could have been performed at the time of admission or when applying the external fixator. Both Naumann and Schepers have presented worse clinical outcomes in patients treated more than 6 days after injury.[133,146] Distinguishing between the use of external fixators and time till definitive surgery concerning the effect on PROM is difficult. But prompt and early surgery of the severe ankle fractures, where more than half of the patients had dislocation fractures, would reduce both the use of external fixators and time from injury till definitive surgery. We therefore recommend definitive surgery at time of admission for severe ankle fractures, if the soft tissue status allows it to be performed.[211]

The mean time till surgery for patients treated later than 7 days from injury was 12 days, almost two weeks after the injury. Surgery at such a late time can be challenging due to both soft tissue adherences and because the fracture has started to heal. Most of these patients were also treated via a posterior approach suggesting more demanding fractures. A more meticulous approach, more difficult fracture reduction and treatment may explain the longer duration of the operations. Operation time has been shown to be one of the few factors the surgeon can influence, to reduce the risk of complications.[178]

Complications

Arguments to prefer a *posterior approach* are to prevent postoperative intraarticular step-off and syndesmotic malreduction to reduce the risk of pain, stiffness, and posttraumatic OA.[212,213] We were therefore surprised to see a tendency of more high-grade osteoarthritis among patients treated with the *posterior approach*. These fractures were termed “severe ankle fractures” as they included the posterior malleolus. A recent review from 2022 showed that posttraumatic OA is associated with fracture classification and severity.[214] The authors of this review found that a third of severe ankle fractures were complicated with radiographic OA. In simpler fracture patterns the rate was one in four cases. In a study from 2021, Xu et al, found intercalated osteochondral fragments to be associated with the development of posttraumatic AO.[215] These fractures are often difficult to detect on lateral radiographs, again underlining the need for CT when assessing posterior malleolus fractures.

Nerve injuries were alarmingly high in paper 1 (20%). This calls for further awareness among the treating surgeons regarding the anatomy and course of the nerves and focus on the surgical approach to the fracture. Rbia found a prevalence of persistent neuropathic pain symptoms after ankle fracture surgery in 23% of 271 patients.[216] They identified age between 40-60 years, hypertension, dislocation fracture, and late complications (nonunion, posttraumatic arthritis, or osteochondral injury) as predictors of persistent pain or neuropathic symptoms.

Even though delayed surgery is a known risk factor for postoperative infection, the rate of FRI was similar across groups in Paper 1 and Paper 2.[146] Paper 2 found a 19% FRI-rate which is higher than most studies on postoperative infections after surgery for closed ankle fractures.[134,145,202] Saithna also reported a higher frequency of postoperative infection in patients treated later than 6 days from injury.[177] In paper 4, time from injury to definitive fracture surgery was not identified as a risk factor of FRI when analyzing all types of ankle fractures. Patients with and without FRI had on average seven days from injury till definitive surgery.

FRI

The infection rates found in our first two papers were 16% and 19% which is higher than that reported in most studies on postoperative infections after surgery for closed ankle fractures.[134,145,202] In paper 3 a total of 87 (9%) of 1004 patients were diagnosed with FRI following the algorithm presented by the consensus group.[152,153,217] Formerly only one paper is published on the rate of FRI in ankle fractures – Cooke et al. reported at rate of 15% among 1003 patients with open ankle fractures.[140] Among closed ankle fractures overall postoperative infection rates are lower, ranging from 1.4% to 12.9%.[110,148,202]

However, comparison across studies is difficult due to the different classifications used, where most studies use the CDC definition of SSI.[150] Sliepen et al. have shown that the FRI algorithm captures more patients with infection than the SSI definition.[218] Onsea et al. confirmed the FRI diagnosis in 480 (75%) of 637 patients with suspected infection after any fracture surgery. Comparatively, we confirmed FRI in 84% of our patients who had suspected infection after ankle fracture surgery in Paper 3. Follow-up time in Paper 3 and Paper 4 was nearly 5 years. With such a long follow-up time we are confident that all patients with FRI during the study period were detected.

Confirmatory criteria for FRI

Onsea et al. validated the diagnostic criteria of the consensus FRI definition.[156] In their study *confirmatory criteria* were present in 97.5% of patients diagnosed with FRI compared to 87% in our study.[156] Onsea reports a sensitivity of 97.5% in the presence of one *confirmatory criterion* and describes them as pathognomonic for FRI.[156] Fistula, sinus tract formation, or wound breakdown were present in 72% of our patients with confirmatory criteria but only in 49.8% of the patients in Onsea's study. Of the 50 patients in Paper 3 with adequate bacterial sampling taken without prior antibiotics, 11 (22%) of 50 patients had negative cultures, almost three times what Onsea et al (8.5%) found. We suspect the reason for this descripancy is that the number of samples taken from each patient was fewer than the recommended five separate, per operative, samples.[154,156,189] On the other hand, the sampling was not tampered with antibiotics which should give reliable culture results. The number of negative bacterial cultures among patients with adequately taken bacterial samples was higher than expected. Even so, we consider the ratio of positive/negative cultures as acceptable since developing an infection may lead to serious complications, even amputation.[198,219]

Suggestive criteria

Wound drainage was the most common *suggestive clinical sign* among our patients. The result is in great contrast to Onsea's findings where wound drainage was rare. Reasons for this difference could be several among which their inclusion of all types of fractures is important.[156] Furthermore, a single positive bacterial culture was found in two thirds of the patients with suggestive criteria and positive cultures, which is not adequate for the diagnosis of FRI. However, Onsea underlines that FRI should be highly suspected in case of a single positive culture in combination with clinical signs of infection. Clinical signs of infection (redness, warmth, swelling) were, however, only reported in 7 of our 28 patients with *suggestive criteria*. In the study of Onsea presence of one of these signs was associated with a sensitivity of 69.4% and a specificity of 84.1% for an FRI. They warn about interpreting these signs as “only” a superficial infection.

An important finding of Paper 3 is the lack of thorough examination, documentation, and adequate bacterial sampling among patients with suspected FRI, especially for patients with *suggestive criteria.* Based on this, there seems to be a need to improve daily practice regarding these patients. Due to the absence of a clear sampling protocol in the study period we accepted 2 or more bacterial samples as an adequate method in paper 3 and 4. However, both Hellebrekers and Dudareva have shown that at least 5 samples must be taken intraoperatively when treating a patient suspected of FRI to ensure a correct diagnosis.[189,220] Dudareva showed that having at least 2 of 5 specimens with indistinguishable pathogens identified with culture had a sensitivity of 68% and specificity of 87% for the diagnosis of FRI.[220] Also, only collecting 3 deep-tissue samples risked missing clinically relevant pathogens in possibly 1 in 10 cases. Temperature (fever) was not described in any patients with suggestive criteria and the type of wound drainage was often limited to “secretion” or “drainage”, and the duration of the clinical signs were often not described. Positive and negative findings should be described. Greenwald has discussed the difficulty of describing the presence of infection and found only a moderate interobserver agreement on this question in a study from 2002.[221] Better documentation and better bacterial sampling would improve the diagnostics and the treatment of our patients. When presented with a patient with suspicion of FRI a systematic assessment is essential, and the FRI algorithm facilitates such an approach.

Risk factors for developing FRI

Increasing age, heart failure, peripheral arterial disease (PAD), and current smoking were found to be risk factors for the development of FRI in our study. All of these are patient related. Interestingly, Audet et al. found patient characteristics to contribute more to patient-reported outcome than injury characteristics.[222] Comorbidities of the vascular system were also identified as risk factors in a large study by Szymski and colleagues in a recently published paper on FRI.[223] Patients with hypertension, heart failure and diabetes mellitus type II were at risk of developing FRI compared to the general population. Several studies have found DM to be one of the main risk factors for postoperative infection, especially in case of diabetes with hyperglycemia or complications such as neuropathy, retinopathy, and angiopathy [224–227] There was a low number of patients with diabetes mellitus in Paper 3 and 4 resulting in poor statistical power of the analyses, for this factor. Thus, diabetes mellitus not being identified as a risk factor in our study could be due to a too small number of outcomes and not to a de facto lack of association.

Lifestyle comorbidities such as obesity and diabetes mellitus are known risk factors for postoperative wound infection.[143,202,225,226,228,229] Schade et al. found an odds ratio (OR) of 2.6 (95% CI = 1.5-4.5; $P < .0001$) for early postoperative infection in patients with diabetes mellitus compared to patients without.[225]

Szymski et al. found 9.5 comorbidities pr case with FRI which underlines the multimorbidity of the patients.[223] We did find an increased rate of ASA 3 among the patients with FRI. It was however not significant as a risk factor in the binary regression model when analyzed in combination with the other risk factors which could be due to the strong influence of other individual risk factors for FRI. Also, in a larger study, the smaller risk factors would more likely be detected. ASA 3 or higher is also described in other studies as a risk factor for FRI.[225]

Smoking is closely associated with both cardiovascular disease, heart failure and PAD.[181,230,231] Even hypertension is a risk factor for PAD.[231] Therefore, the results and the literature underline the important role of not only the general practitioner, but also the orthopedic surgeon in helping patients with smoke cessation. Bullen argues that doctors of all specialties should offer advice on cessation, counseling, and nicotine replacement therapy.[181]

Dementia is known to be an important determinant of deteriorating physical status [137]. The low number of patients with dementia may have influenced the results of our study in which dementia as a risk factor for developing FRI was border significant with $p = 0.051$. Shivarathre et al. described dementia as a risk factor of postoperative wound problems in addition to diabetes mellitus, peripheral vascular disease, and smoking [224]. They found an odds ratio of 5.1 for wound problems in case of dementia.

Ziegler et al. recommends considering the use of fibular nails or minimal invasive techniques when treating elderly patients with ankle fractures.[232] Close contact casting is an alternative to surgery.[233] However, one of our patients was treated initially with casting to avoid soft tissue problems and infection. Due to loss of reduction this patient was treated with a minimal invasive technique, then a hindfoot nail, and ended with a below the knee amputation for infection control. All these options, and the patient presented, illustrate the difficulties in treating multimorbid patients.

The risk factors identified in Paper 4 as well as by other writers must be taken into account when evaluating indication for surgery. Must the patient be operated on and with which technique? Newer studies of isolated SERIV/Weber B lateral malleolus fractures suggest that fewer patients need operative treatment than what has been general practice the last decades.[63] Gougoulias and Sakellariou used weightbearing radiographs to assess stability of isolated SER/Weber B ankle fractures.[234] Applying this protocol they reduced the number of patients with SER-fractures considered unstable and in need of surgery from 45% to 3.7%.[234]

Identifying risk factors is important for giving balanced information to the individual patient about their risk of complications, in preoperative planning, and in the management of the patients. Also, modifiable factors must be addressed prior to surgery. The variety of risk factors found in this study demonstrates the need for a thorough, multidisciplinary, and careful approach when faced with ankle fractures in elderly patients.

7 Conclusion

Paper 1

- Clinical outcome of patients treated for ankle fractures involving the posterior malleolus did not improve by open reduction and fixation through a *posterior approach* compared to a *traditional approach* with indirect reposition and AP- fixation. Most of the patients with a traditional approach did not have fixation of the PMF.
- Patients from the *posterior approach* and the *traditional approach* groups who were matched according to the size of the PMF and who had the PMF fixed reported similar PROM results.
- The posterior approach with fixation of the PMF led to a reduced need for syndesmosis fixation.
- Patients treated with the *posterior approach* more often developed severe posttraumatic OA.

Paper 2

- Patients who waited more than a week for definitive surgery had a higher rate of soft tissue problems, reported more pain and poorer clinical outcomes.
- The patients who had delayed treatment more often were treated with a temporary external fixation before definitive surgery.
- In our study, the use of a temporary external fixation to prevent and resolve preoperative soft tissue problems did not prevent poorer clinical outcome two years after surgery.
- A delay of more than seven days till definitive surgery was not beneficial for the patient in our study.
- Patients with dislocation fractures reported better outcomes when definitively treated within one week from injury.

Paper 3

- In our study the prevalence of FRI, according to the consensus criteria, for patients with surgically treated ankle fractures was 9%.
- The routines of our department must be improved, and a systematical approach is needed when faced with a patient with the suspicion of infection.
- The FRI definition and algorithm facilitates such an approach.

Paper 4

- Increasing age, heart failure, peripheral arterial disease (PAD), and current smoking were found to be risk factors for the development of FRI in our study. Dementia was border significant with a p-value of 0.05.
- Identifying risk factors are important for information to the individual patient about their risk of complications, and for the orthopedic surgeons in preoperative planning and the management of the patients.
- Modifiable factors must be addressed prior to surgery.
- The combination of risk factors found in this study demonstrates the need for a thorough, multidisciplinary, and careful approach when faced with ankle fractures in elderly patients.

8 Future research

- We see the need for a randomized controlled trial of Mason & Molloy type 2A/B posterior malleolus fracture (fixation vs no fixation of the PMF). We have been granted NOK 3.3 million to conduct this study. The name of the study is PMFIX. It will be a multicenter study with 8 study centers in Norway.
- Development of MCID for between group differences for SEFAS in an ankle fracture population. Anchor questions are therefore included as part of the questionnaires in the PMFIX study.
- Evaluate the clinical necessity of syndesmosis fixation when the PMF is fixed.
- Clinical trial of augmentation of the AITFL in combination with PMF-fixation versus syndesmotic fixation.
- Fracture-related Infection is a relatively new term amongst orthopedic surgeons and the definition is sparsely used in ankle fractures. To better understand and to highlight this definition a study comparing patient-reported outcome in patients with FRI to patients without FRI after ankle fracture surgery is an interesting follow-up of Paper 3 and 4.
- For better evaluation of the rate of FRI at our department a prospective cohort study of the patients with FRI with a better methodology is also interesting.

9 References

1. Cauley, J. A. The global burden of fractures. *Lancet Healthy Longev* **2**, e535–e536 (2021).

2. Wu, A. M. *et al.* Global, regional, and national burden of bone fractures in 204 countries and territories, 1990–2019: a systematic analysis from the Global Burden of Disease Study 2019. *Lancet Healthy Longev* **2**, e580 (2021).

3. Polinder, S. *et al.* The economic burden of injury: Health care and productivity costs of injuries in the Netherlands. *Accid Anal Prev* **93**, 92–100 (2016).

4. Glazebrook, M. *et al.* Comparison of health-related quality of life between patients with end-stage ankle and hip arthrosis. *J Bone Joint Surg Am* **90**, 499–505 (2008).

5. Klop, C. *et al.* Mortality in British hip fracture patients, 2000–2010: A population-based retrospective cohort study. *Bone* **66**, 171–177 (2014).

6. Bergh, C., Wennergren, D., Möller, M. & Brisby, H. Fracture incidence in adults in relation to age and gender: A study of 27,169 fractures in the Swedish Fracture Register in a well-defined catchment area. *PLoS One* **15**, (2020).

7. Jensen, S. L., Andresen, B. K., Mencke, S. & Nielsen, P. T. Epidemiology of ankle fractures. A prospective population-based study of 212 cases in Aalborg, Denmark. *Acta Orthop Scand* **69**, 48–50 (1998).

8. Daly, P. J., Fitzgerald, R. H., Melton, L. J. & Llstrup, D. M. Epidemiology of ankle fractures in Rochester, Minnesota. *Acta Orthop Scand* **58**, 539–544 (1987).

9. Juto, H., Nilsson, H. & Morberg, P. Epidemiology of Adult Ankle Fractures: 1756 cases identified in Norrbotten County during 2009–2013 and classified according to AO/OTA. *BMC Musculoskelet Disord* **19**, (2018).

10. Elsoe, R., Ostgaard, S. E. & Larsen, P. Population-based epidemiology of 9767 ankle fractures. *Foot and Ankle Surgery* **24**, 34–39 (2018).

11. Court-Brown, C. M. & Caesar, B. Epidemiology of adult fractures: A review. *Injury* **37**, 691–697 (2006).

12. Bartoníček, J. *et al.* Anatomy and classification of the posterior tibial fragment in ankle fractures. *Arch Orthop Trauma Surg* **135**, 505–516 (2015).

13. Barton????ek, J., Rammelt, S., Tu??ek, M. & Na??ka, O. Posterior malleolar fractures of the ankle. *European Journal of Trauma and Emergency Surgery* **41**, 587–600 (2015).

14. Kašper, Bartoníček, J., Kostlivý, K., Malík, J. & Tuček, M. Maisonneuve fracture. *Rozhl Chir* **99**, 77–85 (2020).

15. Bartoníček, J., Rammelt, S., Kašper, Š., Malík, J. & Tuček, M. Pathoanatomy of Maisonneuve fracture based on radiologic and CT examination. *Arch Orthop Trauma Surg* **139**, 497–506 (2019).

16. Bartoníček, J., Rammelt, S., Tuček, M. & Naňka, O. Posterior malleolar fractures of the ankle. *European Journal of Trauma and Emergency Surgery* **41**, 587–600 (2015).

17. Drijfhout van Hooff, C. C., Verhage, S. M. & Hoogendoorn, J. M. Influence of Fragment Size and Postoperative Joint Congruency on

Long-Term Outcome of Posterior Malleolar Fractures. *Foot Ankle Int* **36**, 673–678 (2015).

18. Verhage, S. M., Krijnen, P., Schipper, I. B. & Hoogendoorn, J. M. Persistent postoperative step-off of the posterior malleolus leads to higher incidence of post-traumatic osteoarthritis in trimalleolar fractures. *Arch Orthop Trauma Surg* **139**, 323–329 (2019).

19. Brockett, C. L. & Chapman, G. J. Biomechanics of the ankle. *Orthop Trauma* **30**, 232 (2016).

20. Hermans, J. J., Beumer, A., De Jong, T. A. W. & Kleinrensink, G. J. Anatomy of the distal tibiofibular syndesmosis in adults: A pictorial essay with a multimodality approach. *J Anat* **217**, 633–645 (2010).

21. Michelsen, J. D., Ahn, U. M. & Helgemo, S. L. Motion of the ankle in a simulated supination-external rotation fracture model. *J Bone Joint Surg Am* **78**, 1024–1031 (1996).

22. Fojtík, P., Kostlivý, K., Bartoníček, J. & Naňka, O. The fibular notch: an anatomical study. *Surgical and Radiologic Anatomy* **42**, 1161–1166 (2020).

23. Bartoníček, J. Anatomy of the tibiofibular syndesmosis and its clinical relevance. *Surg Radiol Anat* **25**, 379–386 (2003).

24. Raeder, B. W. *et al.* Better outcome for suture button compared with single syndesmotic screw for syndesmosis injury: five-year results of a randomized controlled trial. *Bone Joint J* **102-B**, 212–219 (2020).

25. Williams, B. T. *et al.* Ankle Syndesmosis. *Am J Sports Med* **43**, 88–97 (2015).

26. Schepers, T. Acute distal tibiofibular syndesmosis injury: a systematic review of suture-button versus syndesmotic screw repair. *Int Orthop* **36**, 1199–1206 (2012).

27. Kellam, P. J. *et al.* Symmetry and reliability of the anterior distal tibial angle and plafond radius of curvature. *Injury* **51**, 2309–2315 (2020).

28. Jayatilaka, M. L. T. *et al.* Anatomy of the Insertion of the Posterior Inferior Tibiofibular Ligament and the Posterior Malleolar Fracture. *Foot Ankle Int* 107110071986589 (2019) doi:10.1177/1071100719865896.

29. Birnie, M. F. N., van Schilt, K. L. J., Sanders, F. R. K., Kloen, P. & Schepers, T. Anterior inferior tibiofibular ligament avulsion fractures in operatively treated ankle fractures: a retrospective analysis. *Arch Orthop Trauma Surg* **139**, 787–793 (2019).

30. Papachristou, G., Efstathopoulos, N., Levidiotis, C. & Chronopoulos, E. Early weight bearing after posterior malleolar fractures: An experimental and prospective clinical study. *Journal of Foot and Ankle Surgery* **42**, 99–104 (2003).

31. Kortekangas, T. *et al.* Effect of syndesmosis injury in ser IV (Weber B)-type ankle fractures on function and incidence of osteoarthritis. *Foot Ankle Int* **36**, 180–187 (2015).

32. Lloyd, J., Elsayed, S., Hariharan, K. & Tanaka, H. Revisiting the concept of talar shift in ankle fractures. *Foot Ankle Int* **27**, 793–796 (2006).

33. Mason, L. W., Marlow, W. J., Widnall, J. & Molloy, A. P. Pathoanatomy and Associated Injuries of Posterior Malleolus Fracture of the Ankle. *Foot Ankle Int* **38**, 1229–1235 (2017).

34. Meinberg, E., Agel, J., Roberts, C., Karam, M. & Kellam, J. Fracture and Dislocation Classification Compendium—2018. *J Orthop Trauma* **32**, S1–S10 (2018).

35. Meinberg, E. G., Agel, J., Roberts, C. S., Karam, M. D. & Kellam, J. F. Fracture and Dislocation Classification Compendium-2018. *J Orthop Trauma* **32**, S1–S170 (2018).

36. Bartoníček, J., Rammelt, S. & Tuček, M. Maisonneuve Fractures of the Ankle: A Critical Analysis Review. *JBJS Rev* **10**, (2022).

37. B.G., Weber, V. H. H. B. Classification of ankle fractures. *Die Verletzungen des oberen Sprung-gelenkes.* (1972).

38. Lauge., H. N. Ankelbrud I. Genetisk diagnose og reposition. *Diss. Munksgaard, Kbhn 1* (942).

39. Grondahl, N. B. Fractura marginalis posterior tibiae og andre bruddkomplikationer ved ankelbrudd. *Norsk Mag F Laegevidensk* **11**, 737 (1913).

40. Souligoux. Des fractures du cou-de-pied. *Tribune Med* **47**, (1913).

41. ASHHURST, A. P. C. & BROMER, R. S. CLASSIFICATION AND MECHANISM OF FRACTURES OF THE LEG BONES INVOLVING THE ANKLE: BASED ON A STUDY OF THREE HUNDRED CASES FROM THE EPISCOPAL HOSPITAL. *Archives of Surgery* **4**, 51–129 (1922).

42. Nelson, M. & Jensen, N. The treatment of trimalleolar fractures of the ankle. *Surg Gynecol Obstet* 509–514 (1940).

43. Mingo-Robinet, J., López-Durán, L., Galeote, J. E. & Martinez-Cervell, C. Ankle fractures with posterior malleolar fragment: Management and results. *Journal of Foot and Ankle Surgery* **50**, 141–145 (2011).

44. Heim, U. F. A. Trimalleolar fractures: Late results after fixation of the posterior fragment. *Orthopedics* **12**, 1053–1059 (1989).

45. Langenhuijsen, J. F., Heetveld, M. J., Ultee, J. M., Steller, E. P. & Butzelaar, R. M. J. M. Results of ankle fractures with involvement of the posterior tibial margin. *J Trauma* **53**, 55–60 (2002).

46. Evers, J. *et al.* Size matters: The influence of the posterior fragment on patient outcomes in trimalleolar ankle fractures. *Injury* **46**, S109–S113 (2015).

47. Mason, L. W., Kaye, A., Widnall, J., Redfern, J. & Molloy, A. Posterior Malleolar Ankle Fractures: An Effort at Improving Outcomes. *JB JS Open Access* **4**, e0058 (2019).

48. Muller, M. E. , N. S. , K. P. , & S. J. The comprehensive classification of long bones. . *Springer* 54–63 (1987).

49. Meijer, D. T. *et al.* Guesstimation of posterior malleolar fractures on lateral plain radiographs. *Injury* **46**, 2024–2029 (2015).

50. Mason, L. W., Marlow, W. J., Widnall, J. & Molloy, A. P. Pathoanatomy and Associated Injuries of Posterior Malleolus Fracture of the Ankle. *Foot Ankle Int* **38**, 1229–1235 (2017).

51. Haraguchi, N. Pathoanatomy of Posterior Malleolar Fractures of the Ankle. *The Journal of Bone and Joint Surgery (American)* **88**, 1085 (2006).

52. Ludloff, K. Zur Frage der Knöchelbrüche mit Heraussprengung eines hinteren Volkmannschen Dreiecks . *Zentralbl Chir* **53**, 390–391 (1926).

53. Heim, D., Niederhauser, K. & Simbrey, N. The Volkmann dogma: A retrospective, long-term, single-center study. *European Journal of Trauma and Emergency Surgery* **36**, 515–519 (2010).

54. Felsenreich, F. Untersuchungen über die Pathologie des sogenannten Volkmannschen Dreiecks neben Richtlinien moderner Behandlung schwerer Luxationsfrakturen des oberen Sprunggelenkes. *Archiv für orthopädische und Unfall-Chirurgie, mit besonderer Berücksichtigung der Frakturenlehre und der orthopädisch-chirurgischen Technik 1931 29:1* **29**, 491–529 (1931).

55. Terstegen, J. *et al.* Classifications of posterior malleolar fractures: a systematic literature review. *Archives of Orthopaedic and Trauma Surgery 2022* **1**, 1–40 (2022).

56. Stiell, I. Ottawa ankle rules. *Can Fam Physician* **42**, 478–480 (1996).

57. Weber, M. Trimalleolar fractures with impaction of the posteromedial tibial plafond: implications for talar stability. *Foot Ankle Int* **25**, 716–727 (2004).

58. Vosoughi, A. R., Jayatilaka, M. L. T., Fischer, B., Molloy, A. P. & Mason, L. W. CT Analysis of the Posteromedial Fragment of the Posterior Malleolar Fracture. *Foot Ankle Int* **40**, 648–655 (2019).

59. Gandham, S., Millward, G., Molloy, A. P. & Mason, L. W. Posterior malleolar fractures: A CT guided incision analysis. *Foot* **43**, (2020).

60. Van den Bekerom, M. P. J. Diagnosing syndesmotic instability in ankle fractures. *World Journal of Orthopaedics* vol. 2 51–56 Preprint at https://doi.org/10.5312/wjo.v2.i7.51 (2011).

61. Lampridis, V., Gougoulias, N. & Sakellariou, A. Stability in ankle fractures: Diagnosis and treatment. *EFORT Open Rev* **3**, 294 (2018).

62. Kortekangas, T. *et al.* Three week versus six week immobilisation for stable Weber B type ankle fractures: randomised, multicentre, non-inferiority clinical trial. *The BMJ* **364**, (2019).

63. Gregersen, M. G. & Molund, M. Weightbearing Radiographs Reliably Predict Normal Ankle Congruence in Weber B/SER2 and 4a Fractures: A Prospective Case-Control Study. *Foot Ankle Int* **42**, 1097–1105 (2021).

64. Gregersen, M. G., Fagerhaug Dalen, A., Nilsen, F. & Molund, M. The Anatomy and Function of the Individual Bands of the Deltoid Ligament—and Implications for Stability Assessment of SER Ankle Fractures. *Foot Ankle Orthop* **7**, (2022).

65. AO Foundation.

66. O'Connor, T. J. *et al.* "A to P" Screw Versus Posterolateral Plate for Posterior Malleolus Fixation in Trimalleolar Ankle Fractures. *J Orthop Trauma* (2015) doi:10.1097/BOT.0000000000000230.

67. Andersen, M. R., Frihagen, F., Hellund, J. C., Madsen, J. E. & Figved, W. Randomized trial comparing suture button with single syndesmotic screw for syndesmosis injury. *Journal of Bone and Joint Surgery - American Volume* **100**, 2–12 (2018).

68. Ræder, B. W. *et al.* Randomized trial comparing suture button with single 3.5 mm syndesmotic screw for ankle syndesmosis injury: similar results at 2 years. *Acta Orthop* **91**, 770–775 (2020).

69. den Daas, A., van Zuuren, W. J., Pelet, S., van Noort, A. & van den Bekerom, M. P. J. Flexible stabilization of the distal tibiofibular syndesmosis: clinical and biomechanical considerations: a review of the literature. *Strategies Trauma Limb Reconstr* **7**, 123–129 (2012).

70. Behery, O. A., Narayanan, R., Konda, S. R., Tejwani, N. C. & Egol, K. A. Posterior Malleolar Fixation Reduces the Incidence of Trans-Syndesmotic Fixation in Rotational Ankle Fracture Repair. *Iowa Orthop J* **41**, 121 (2021).

71. Miller, A. N., Carroll, E. A., Parker, R. J., Helfet, D. L. & Lorich, D. G. Posterior Malleolar Stabilization of Syndesmotic Injuries is Equivalent to Screw Fixation. *Clin Orthop Relat Res* **468**, (2010).

72. Gardner, M. J., Brodsky, A., Briggs, S. M., Nielson, J. H. & Lorich, D. G. Fixation of posterior malleolar fractures provides greater syndesmotic stability. *Clin Orthop Relat Res* **447**, (2006).

73. Giordano, V. *et al.* Nailing the fibula: alternative or standard treatment for lateral malleolar fracture fixation? A broken paradigm. *Eur J Trauma Emerg Surg* **47**, 1911–1920 (2021).

74. Chalak, A. *et al.* Ilizarov Ankle Arthrodesis: A Simple Salvage Solution for Failed and Neglected Ankle Fractures. *Indian J Orthop* **56**, 1587–1593 (2022).

75. Wawrose, R. A. *et al.* Temporizing External Fixation vs Splinting Following Ankle Fracture Dislocation. *Foot Ankle Int* **41**, 177–182 (2020).

76. Baker, G., Mayne, A. I. W. & Andrews, C. Fixation of unstable ankle fractures using a long hindfoot nail. *Injury* **49**, 2083–2086 (2018).

77. Andersen, M. R., Frihagen, F., Madsen, J. E. & Figved, W. High complication rate after syndesmotic screw removal. *Injury* **46**, 2283–2287 (2015).

78. Rammelt, S. & Obruba, P. An update on the evaluation and treatment of syndesmotic injuries. *European Journal of Trauma and Emergency Surgery* **41**, 601–614 (2015).

79. Patient-Reported Outcome Measures: Use in Medical Product Development to Support Labeling Claims | FDA. https://www.fda.gov/regulatory-information/search-fda-guidance-documents/patient-reported-outcome-measures-use-medical-product-development-support-labeling-claims.

80. Research, U. S. D. of H. and H. S. F. C. for D. E. and, Research, U. S. D. of H. and H. S. F. C. for B. E. and & Health, U. S. D. of H. and H. S. F. C. for D. and R. Guidance for industry: patient-reported outcome measures: use in medical product development to support labeling claims: draft guidance. *Health Qual Life Outcomes* **4**, 79 (2006).

81. Black, N. Patient reported outcome measures could help transform healthcare. *BMJ* **346**, (2013).

82. The Impact on Life questionnaire: validation for elective surgery prioritisation in New Zealand prioritisation criteria in orthopaedic surgery - PubMed. https://pubmed.ncbi.nlm.nih.gov/27356249/.

83. Dawson, J., Doll, H., Fitzpatrick, R., Jenkinson, C. & Carr, A. J. The routine use of patient reported outcome measures in healthcare settings. *BMJ* **340**, 464–467 (2010).

84. Price, A. *et al.* The Arthroplasty Candidacy Help Engine tool to select candidates for hip and knee replacement surgery: development and economic modelling. *Health Technol Assess* **23**, 1 (2019).

85. Churruca, K. *et al.* Patient-reported outcome measures (PROMs): A review of generic and condition-specific measures and a discussion of trends and issues. *Health Expect* **24**, 1015 (2021).

86. Churruca, K. *et al.* Patient-reported outcome measures (PROMs): A review of generic and condition-specific measures and a discussion of trends and issues. *Health Expect* **24**, 1015 (2021).

87. The EuroQol Group. EuroQol - a new facility for the measurement of health-related quality of life. *Health Policy (New York)* **16**, 199–208 (1990).

88. Brooks, R. EuroQol: the current state of play. *Health Policy (New York)* **37**, 53–72 (1996).

89. Norsk versjon av RAND 36-Item Short Form Health Survey - FHI. https://www.fhi.no/kk/brukererfaringer/sporreskjemabanken/norsk-versjon-av-rand-36-item-short-form-health-survey/.

90. Nguyen, M. Q., Dalen, I., Iversen, M. M., Harboe, K. & Paulsen, A. Ankle fractures: a systematic review of patient-reported outcome measures and their measurement properties. *Qual Life Res* (2022) doi:10.1007/S11136-022-03166-3.

91. Kitaoka, H. B. *et al.* Clinical Rating Systems for the Ankle-Hindfoot, Midfoot, Hallux, and Lesser Toes. *http://dx.doi.org/10.1177/107110079401500701* **15**, 349–353 (1994).

92. Veltman, E. S., Hofstad, C. J. & Witteveen, A. G. H. Are current foot- and ankle outcome measures appropriate for the evaluation of treatment for osteoarthritis of the ankle?: Evaluation of ceiling effects in foot- and ankle outcome measures. *Foot and Ankle Surgery* **23**, 168–172 (2017).

93. Pinsker, E. & Daniels, T. R. AOFAS Position Statement Regarding the Future of the AOFAS Clinical Rating Systems. *http://dx.doi.org/10.3113/FAI.2011.0841* **32**, 841–842 (2011).

94. Guyton, G. P. Theoretical limitations of the AOFAS scoring systems: an analysis using Monte Carlo modeling. *Foot Ankle Int* **22**, 779–787 (2001).

95. Olerud, C. & Molander, H. A scoring scale for symptom evaluation after ankle fracture. *Arch Orthop Trauma Surg* **103**, 190–194 (1984).

96. McKeown, R., Rabiu, A.-R., Ellard, D. R. & Kearney, R. S. Primary outcome measures used in interventional trials for ankle fractures: a systematic review. *BMC Musculoskelet Disord* **20**, 388 (2019).

97. Dawson, J. *et al.* Minimally important change was estimated for the Manchester-Oxford Foot Questionnaire after foot/ankle surgery. *J Clin Epidemiol* **67**, 697–705 (2014).

98. Hosman, A. H., Mason, R. B., Hobbs, T. & Rothwell, A. G. A New Zealand national joint registry review of 202 total ankle replacements

followed for up to 6 years. *New Pub: Medical Journals Sweden* **78**, 584–591 (2009).

99. Cöster, M., Karlsson, M. K., Nilsson, J.-Å. & Carlsson, Å. Validity, reliability, and responsiveness of a self-reported foot and ankle score (SEFAS). *Acta Orthop* **83**, 197–203 (2012).

100. Cöster, M. Frågeformulär bra utvärderings- metod vid fot- och fotledsbesvär. 9–11 (2015).

101. Cöster, M. C., Nilsdotter, A., Brudin, L. & Bremander, A. Minimally important change, measurement error, and responsiveness for the Self-Reported Foot and Ankle Score. *Acta Orthop* **88**, 300–304 (2017).

102. Cöster, M. C., Rosengren, B. E., Karlsson, M. K. & Carlsson, Å. Age- and Gender-Specific Normative Values for the Self-Reported Foot and Ankle Score (SEFAS). *Foot Ankle Int* **39**, 1328–1334 (2018).

103. Cöster, M. C., Rosengren, B. E., Bremander, A., Brudin, L. & Karlsson, M. K. Comparison of the Self-Reported Foot and Ankle Score (SEFAS) and the American Orthopedic Foot and Ankle Society Score (AOFAS). *Foot Ankle Int* **35**, 1031–1036 (2014).

104. Garratt, A. M., Naumann, M. G., Sigurdsen, U., Utvåg, S. E. & Stavem, K. Evaluation of three patient reported outcome measures following operative fixation of closed ankle fractures. *BMC Musculoskelet Disord* **19**, 134 (2018).

105. Williamson, A. & Hoggart, B. Pain: a review of three commonly used pain rating scales. *J Clin Nurs* **14**, 798–804 (2005).

106. McCormack, H. M., Horne, D. J. de L. & Sheather, S. Clinical applications of visual analogue scales: a critical review. *Psychol Med* **18**, 1007–1019 (1988).

107. Solheim, E., Hegna, J., Øyen, J. & Inderhaug, E. Arthroscopic Treatment of Lateral Epicondylitis: Tenotomy Versus Debridement. *Arthroscopy - Journal of Arthroscopic and Related Surgery* **32**, 578–585 (2016).

108. Saltzman, C. L. *et al.* Epidemiology of Ankle Arthritis: Report of a Consecutive Series of 639 Patients from a Tertiary Orthopaedic Center. *Iowa Orthop J* **25**, 44 (2005).

109. Zaghloul, A., Haddad, B., Barksfield, R. & Davis, B. Early complications of surgery in operative treatment of ankle fractures in those over 60: A review of 186 cases. *Injury* **45**, 780–783 (2014).

110. SooHoo, N. F. *et al.* Complication rates following open reduction and internal fixation of ankle fractures. *J Bone Joint Surg Am* **91**, 1042–1049 (2009).

111. Ebraheim, N. A., Mekhail, A. O. & Gargasz, S. S. Ankle Fractures Involving the Fibula Proximal to the Distal Tibiofibular Syndesmosis. *http://dx.doi.org/10.1177/107110079701800811* **18**, 513–521 (2016).

112. Sagi, H. C., Shah, A. R. & Sanders, R. W. The functional consequence of syndesmotic joint malreduction at a minimum 2-year follow-up. *J Orthop Trauma* **26**, 439–443 (2012).

113. Giannini, S. *et al.* Surgical treatment of post-traumatic malalignment of the ankle. *Injury* **41**, 1208–1211 (2010).

114. Brown, O. L., Dirschl, D. R. & Obremskey, W. T. Incidence of hardware-related pain and its effect on functional outcomes after open reduction and internal fixation of ankle fractures. *J Orthop Trauma* **15**, 271–274 (2001).

115. Redfern, D. J., Sauvé, P. S. & Sakellariou, A. Investigation of Incidence of Superficial Peroneal Nerve Injury Following Ankle Fracture. *http://dx.doi.org/10.1177/107110070302401006* **24**, 771–774 (2016).

116. Halm, J. A. & Schepers, T. Damage to the Superficial Peroneal Nerve in Operative Treatment of Fibula Fractures: Straight to the Bone? Case Report and Review of the Literature. *Journal of Foot and Ankle Surgery* **51**, 684–686 (2012).

117. Ray, R., Koohnejad, N., Clement, N. D. & Keenan, G. F. Ankle fractures with syndesmotic stabilisation are associated with a high rate of secondary osteoarthritis. *Foot and Ankle Surgery* **25**, 180–185 (2019).

118. Lübbeke, A. *et al.* Risk factors for post-traumatic osteoarthritis of the ankle: an eighteen year follow-up study. *Int Orthop* **36**, 1403 (2012).

119. Meng, J. *et al.* Deep surgical site infection after ankle fractures treated by open reduction and internal fixation in adults: A retrospective case-control study. *Int Wound J* **15**, 971–977 (2018).

120. Shao, J. *et al.* Incidence and risk factors for surgical site infection after open reduction and internal fixation of tibial plateau fracture: A systematic review and meta-analysis. *International Journal of Surgery* vol. 41 176–182 Preprint at https://doi.org/10.1016/j.ijsu.2017.03.085 (2017).

121. Ovaska, M. T., Mäkinen, T. J., Madanat, R., Kiljunen, V. & Lindahl, J. A comprehensive analysis of patients with malreduced ankle fractures undergoing re-operation. *Int Orthop* **38**, 83–88 (2014).

122. Belgaid, V. *et al.* Relationships of the superficial fibular nerve and sural nerve with respect to the lateral malleolus: implications for ankle surgeons. *Surg Radiol Anat* **44**, 609–615 (2022).

123. Relvas-Silva, M. *et al.* Anatomy of the superficial peroneal nerve: Can we predict nerve location and minimize iatrogenic lesion? *Morphologie* **105**, 204–209 (2021).

124. Solomon, L. B., Ferris, L., Tedman, R. & Henneberg, M. Surgical anatomy of the sural and superficial fibular nerves with an emphasis on the approach to the lateral malleolus. *J Anat* **199**, 717–723 (2001).

125. Mizia, E. *et al.* Risk of injury to the sural nerve during posterolateral approach to the distal tibia: An ultrasound simulation study. *Clin Anat* **31**, 870–877 (2018).

126. Ghani, Y., Najefi, A.-A., Aljabi, Y. & Vemulapalli, K. Anatomy of the Sural Nerve in the Posterolateral Approach to the Ankle: A Cadaveric Study. *The Journal of Foot and Ankle Surgery* (2022) doi:10.1053/j.jfas.2022.08.001.

127. Jowett, A. J. L., Sheikh, F. T., Carare, R. O. & Goodwin, M. I. Location of the sural nerve during posterolateral approach to the ankle. *Foot Ankle Int* **31**, 880–883 (2010).

128. Valderrabano, V., Horisberger, M., Russell, I., Dougall, H. & Hintermann, B. Etiology of Ankle Osteoarthritis. *Clin Orthop Relat Res* **467**, 1800 (2009).

129. Herrera-Pérez, M. *et al.* Ankle osteoarthritis: comprehensive review and treatment algorithm proposal. *EFORT Open Rev* **7**, 448–459 (2022).

130. Thomas, A. C., Hubbard-Turner, T., Wikstrom, E. A. & Palmieri-Smith, R. M. Epidemiology of Posttraumatic Osteoarthritis. *J Athl Train* **52**, 491 (2017).

131. Bäcker, H. C., Greisberg, J. K. & Vosseller, J. T. Fibular Plate Fixation and Correlated Short-term Complications. *Foot Ankle Spec* 193864001987353 (2019) doi:10.1177/1938640019873539.

132. Carragee, E. J., Csongradi, J. J. & Bleck, E. E. Early complications in the operative treatment of ankle fractures. Influence of delay before operation. *Journal of Bone and Joint Surgery - Series B* **73**, 79–82 (1991).

133. Naumann, M. G., Sigurdsen, U., Utvåg, S. E. & Stavem, K. Associations of timing of surgery with postoperative length of stay, complications, and functional outcomes 3–6 years after operative fixation of closed ankle fractures. *Injury* **48**, 1662–1669 (2017).

134. Zalavras, C. G., Christensen, T., Rigopoulos, N., Holtom, P. & Patzakis, M. J. Infection Following Operative Treatment of Ankle Fractures. *Clin Orthop Relat Res* **467**, 1715 (2009).

135. Court-Brown, C. M. *et al.* Open fractures in the elderly. The importance of skin ageing. *Injury* **46**, 189–194 (2015).

136. Sauvaget, C., Yamada, M., Fujiwara, S., Sasaki, H. & Mimori, Y. Dementia as a Predictor of Functional Disability: A Four-Year Follow-Up Study. *Gerontology* **48**, 226–233 (2002).

137. Sauvaget, C., Yamada, M., Fujiwara, S., Sasaki, H. & Mimori, Y. Dementia as a predictor of functional disability: a four-year follow-up study. *Gerontology* **48**, 226–233 (2002).

138. Murad, K. *et al.* Burden of Comorbidities and Functional and Cognitive Impairments in Elderly Patients at the Initial Diagnosis of Heart Failure and Their Impact on Total Mortality: The Cardiovascular Health Study. *JACC Heart Fail* **3**, 542–550 (2015).

139. McGuire, L. C., Ford, E. S. & Ajani, U. A. Cognitive functioning as a predictor of functional disability in later life. *American Journal of Geriatric Psychiatry* **14**, 36–42 (2006).

140. Cooke, M. E. *et al.* Open Ankle Fractures: What Predicts Infection? A Multicenter Study. *J Orthop Trauma* **36**, 43–48 (2022).

141. Gortler, H. *et al.* Diabetes and Healing Outcomes in Lower Extremity Fractures: A Systematic Review. *Injury* **49**, 177–183 (2018).

142. Sato, T. *et al.* Smoking and trimalleolar fractures are risk factors for infection after open reduction and internal fixation of closed ankle fractures: A multicenter retrospective study of 1,201 fractures. *Injury* **52**, 1959–1963 (2021).

143. Richardson, N. G. *et al.* Comparison study of patient demographics and risk factors for surgical site infections following open reduction and

internal fixation for lateral malleolar ankle fractures within the medicare population. *Foot Ankle Surg* **27**, 879–883 (2021).

144. Firnhaber, J. M. & Powell, C. S. Lower Extremity Peripheral Artery Disease: Diagnosis and Treatment. *Am Fam Physician* **99**, 362–369 (2019).

145. Sun, Y. *et al.* Incidence and risk factors for surgical site infection after open reduction and internal fixation of ankle fracture. *Medicine* **97**, e9901 (2018).

146. Schepers, T., De Vries, M. R., Van Lieshout, E. M. M. & Van Der Elst, M. The timing of ankle fracture surgery and the effect on infectious complications; A case series and systematic review of the literature. doi:10.1007/s00264-012-1753-9.

147. Depypere, M. *et al.* Pathogenesis and management of fracture-related infection. *Clinical Microbiology and Infection* **26**, 572–578 (2020).

148. Schepers, T., De Vries, M. R., Van Lieshout, E. M. M. & Van der Elst, M. The timing of ankle fracture surgery and the effect on infectious complications; A case series and systematic review of the literature. *Int Orthop* **37**, 489–494 (2013).

149. Sun, R. *et al.* Surgical site infection following open reduction and internal fixation of a closed ankle fractures: A retrospective multicenter cohort study. *Int J Surg* **48**, 86–91 (2017).

150. National Healthcare Safety Network, C. for D. C. and Prevention. Surgical site infection (SSI) event. http://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf.

151. Meng, J. *et al.* Deep surgical site infection after ankle fractures treated by open reduction and internal fixation in adults: A retrospective case-control study. *Int Wound J* **15**, 971–977 (2018).

152. Metsemakers, W. J. *et al.* Fracture-related infection: A consensus on definition from an international expert group. *Injury* **49**, 505–510 (2018).

153. Baertl, S. *et al.* Fracture-related infection. *Bone Joint Res* **10**, 351 (2021).

154. McNally, M., Dudareva, M., Govaert, G., Morgenstern, M. & Metsemakers, W. J. Definition and diagnosis of fracture-related infection. *EFORT Open Rev* **5**, 614 (2020).

155. Govaert, G. A. M. *et al.* Diagnosing Fracture-Related Infection: Current Concepts and Recommendations. *J Orthop Trauma* **34**, 8–17 (2020).

156. Onsea, J. *et al.* Validation of the diagnostic criteria of the consensus definition of fracture-related infection. *Injury* **0**, (2022).

157. Fitzpatrick, D. C., Otto, J. K., McKinley, T. O., Marsh, J. L. & Brown, T. D. Kinematic and contact stress analysis of posterior malleolus fractures of the ankle. *J Orthop Trauma* **18**, 271–278 (2004).

158. Vrahas, M., Fu, F. & Veenis, B. Intraarticular contact stresses with simulated ankle malunions. *J Orthop Trauma* **8**, 159–166 (1994).

159. Roberts, V., Mason, L. W., Harrison, E., Molloy, A. P. & Mangwani, J. Does functional outcome depend on the quality of the fracture fixation? Mid to long term outcomes of ankle fractures at two university teaching hospitals. *Foot Ankle Surg* **25**, 538–541 (2019).

160. Stufkens, S. A. S., Bekerom, M. P. J. Van Den, Kerkhoffs, G. M. M. J., Hintermann, B. & Dijk, C. N. Van. Long-term outcome after 1822 operatively treated ankle fractures : A systematic review of the literature. *Injury* **42**, 119–127 (2011).

161. Verhage, S. M., Schipper, I. B. & Hoogendoorn, J. M. Long-term functional and radiographic outcomes in 243 operated ankle fractures. *J Foot Ankle Res* (2015) doi:10.1186/s13047-015-0098-1.

162. Verhage, S. M., Hoogendoorn, J. M., Krijnen, P. & Schipper, I. B. When and how to operate the posterior malleolus fragment in trimalleolar fractures: a systematic literature review. *Arch Orthop Trauma Surg* **138**, 1213–1222 (2018).

163. Hoogendoorn, J. M. Posterior Malleolar Open Reduction and Internal Fixation Through a Posterolateral Approach for Trimalleolar Fractures. *JBJS Essent Surg Tech* **7**, e31 (2017).

164. Tornetta, P., Ricci, W., Nork, S., Collinge, C. & Steen, B. The posterolateral approach to the tibia for displaced posterior malleolar injuries. *J Orthop Trauma* **25**, (2011).

165. Verhage, S. M., Krijnen, P., Schipper, I. B. & Hoogendoorn, J. M. Persistent postoperative step-off of the posterior malleolus leads to higher incidence of post-traumatic osteoarthritis in trimalleolar fractures. *Arch Orthop Trauma Surg* **139**, 323–329 (2019).

166. McHale, S., Williams, M. & Ball, T. Retrospective cohort study of operatively treated ankle fractures involving the posterior malleolus. *Foot and Ankle Surgery* **26**, 138–145 (2020).

167. Verhage, S. M., Boot, F. & Schipper, I. B. Open reduction and internal fixation of posterior malleolar fractures using the posterolateral approach. 812–817 (2014) doi:10.1302/0301-620X.98B6.36497.

168. Odak, S., Ahluwalia, R., Unnikrishnan, P., Hennessy, M. & Platt, S. Management of Posterior Malleolar Fractures: A Systematic Review. *Journal of Foot and Ankle Surgery* **55**, 140–145 (2016).

169. Forberger, J. *et al.* Posterolateral approach to the displaced posterior malleolus: functional outcome and local morbidity. *Foot & ankle international / American Orthopaedic Foot and Ankle Society [and] Swiss Foot and Ankle Society* **30**, 309–314 (2009).

170. Bäcker, H. C., Greisberg, J. K. & Vosseller, J. T. Fibular Plate Fixation and Correlated Short-term Complications. *Foot Ankle Spec* **13**, 378–382 (2020).

171. Chou, L. B. & Lee, D. C. Current concept review: Perioperative soft tissue management for foot and ankle fractures. *Foot Ankle Int* **30**, 84–90 (2009).

172. Höiness, P., Engebretsen, L. & Strömsöe, K. The Influence of Perioperative Soft Tissue Complications on the Clinical Outcome in Surgically Treated Ankle Fractures. *Foot Ankle Int* **22**, 642–648 (2001).

173. Lloyd, J. M., Martin, R., Rajagopolan, S., Zieneh, N. & Hartley, R. An innovative and cost-effective way of managing ankle fractures prior to surgery, home therapy. *Ann R Coll Surg Engl* **92**, 615–618 (2010).

174. Manual of INTERNAL FIXATION: Techniques Recommended by the AO-ASIF Group - Martin Allgöwer, Maurice E. Müller, Robert

Schneider, Hans Willenegger - Google Bøker. https://books.google.no/books/about/Manual_of_INTERNAL_FIXATION.html?id=3J4iBgAAQBAJ&redir_esc=y.

175. Riedel, M. D. *et al.* Correlation of Soft Tissue Swelling and Timing to Surgery With Acute Wound Complications for Operatively Treated Ankle and Other Lower Extremity Fractures. *Foot Ankle Int* **40**, 526–536 (2019).

176. Wawrose, R. A. *et al.* Temporizing External Fixation vs Splinting Following Ankle Fracture Dislocation. *Foot Ankle Int* **41**, 177–182 (2020).

177. Saithna, A., Moody, W., Jenkinson, E., Almazedi, B. & Sargeant, I. The influence of timing of surgery on soft tissue complications in closed ankle fractures. *European Journal of Orthopaedic Surgery and Traumatology* **19**, 481–484 (2009).

178. Aigner, R., Salomia, C., Lechler, P., Pahl, R. & Frink, M. Relationship of Prolonged Operative Time and Comorbidities with Complications after Geriatric Ankle Fractures. *Foot Ankle Int* **38**, 41–48 (2017).

179. Oladeji, P. O., Broggi, M. S., Spencer, C., Hurt, J. & Hernandez-Irizarry, R. The impact of preoperative opioid use on complications, readmission, and cost following ankle fracture surgery. *Injury* **52**, 2469–2474 (2021).

180. Jones, K. B. *et al.* Ankle fractures in patients with diabetes mellitus. *https://doi.org/10.1302/0301-620X.87B4.15724* **87**, 489–495 (2005).

181. Bullen, C. Impact of tobacco smoking and smoking cessation on cardiovascular risk and disease. *http://dx.doi.org/10.1586/14779072.6.6.883* **6**, 883–895 (2014).

182. Bauersachs, R. *et al.* Burden of Coronary Artery Disease and Peripheral Artery Disease: A Literature Review. *Cardiovasc Ther* **2019**, (2019).

183. Heilbronner, S. & Foster, T. J. Staphylococcus lugdunensis: a Skin Commensal with Invasive Pathogenic Potential. *Clin Microbiol Rev* **34**, 1–18 (2020).

184. Seng, P. *et al.* Staphylococcus lugdunensis: a neglected pathogen of infections involving fracture-fixation devices. *Int Orthop* **41**, 1085–1091 (2017).

185. Definition of the Different Levels of Evidence (LoE). *http://dx.doi.org/10.1055/s-0035-1570346* **5**, 539–539 (2015).

186. Song, J. W. & Chung, K. C. Observational studies: Cohort and case-control studies. *Plast Reconstr Surg* **126**, 2234–2242 (2010).

187. Abdelgawad, A. A., Kadous, A. & Kanlic, E. Posterolateral Approach for Treatment of Posterior Malleolus Fracture of the Ankle. *Journal of Foot and Ankle Surgery* **50**, 607–611 (2011).

188. McHale, S., Williams, M. & Ball, T. Retrospective cohort study of operatively treated ankle fractures involving the posterior malleolus. *Foot and Ankle Surgery* **26**, 138–145 (2020).

189. Hellebrekers, P. *et al.* Getting it right first time: The importance of a structured tissue sampling protocol for diagnosing fracture-related infections. *Injury* **50**, 1649–1655 (2019).

190. In English: Centre on patient-reported outcomes data - Helse Bergen. https://helse-bergen.no/fag-og-forsking/forsking/fagsenter-for-

pasientrapporterte-data/in-english-centre-on-patient-reported-outcomes-data.

191. Wamper, K. E., Sierevelt, I. N., Poolman, R. W., Bhandari, M. & Haverkamp, D. The Harris hip score: Do ceiling effects limit its usefulness in orthopedics? *Acta Orthop* **81**, 703–707 (2010).

192. Cöster, M. C. *et al.* Validity, reliability, and responsiveness of the Self-reported Foot and Ankle Score (SEFAS) in forefoot, hindfoot, and ankle disorders. *Acta Orthop* **85**, 187 (2014).

193. Erichsen, J. L., Jensen, C., Larsen, M. S., Damborg, F. & Viberg, B. Danish translation and validation of the Self-reported foot and ankle score (SEFAS) in patients with ankle related fractures. *Foot Ankle Surg* **27**, 521–527 (2021).

194. Austevoll, I. M. *et al.* Follow-up score, change score or percentage change score for determining clinical important outcome following surgery? An observational study from the Norwegian registry for Spine surgery evaluating patient reported outcome measures in lumbar spinal stenosis and lumbar degenerative spondylolisthesis. *BMC Musculoskelet Disord* **20**, (2019).

195. Xu, H. *et al.* A retrospective study of posterior malleolus fractures. *Int Orthop* **36**, 1929–1936 (2012).

196. De Vries, J. S., Wijgman, A. J., Sierevelt, I. N. & Schaap, G. R. Long-term results of ankle fractures with a posterior malleolar fragment. *Journal of Foot and Ankle Surgery* **44**, 211–217 (2005).

197. Mertens, M., Wouters, J., Kloos, J., Nijs, S. & Hoekstra, H. Functional outcome and general health status after plate osteosynthesis of posterior

malleolus fractures - The quest for eligibility. *Injury* **51**, 1118–1124 (2020).

198. Høiness, P. & Strømsøe, K. The influence of the timing of surgery on soft tissue complications and hospital stay: A review of 84 closed ankle fractures. *Ann Chir Gynaecol* **89**, 6–9 (2000).

199. Crosby, R. D., Kolotkin, R. L. & Williams, G. R. Defining clinically meaningful change in health-related quality of life. *J Clin Epidemiol* **56**, 395–407 (2003).

200. Naumann, M. G., Sigurdsen, U., Utvåg, S. E. & Stavem, K. Functional outcomes following surgical-site infections after operative fixation of closed ankle fractures. *Foot Ankle Surg* **23**, 311–316 (2017).

201. Martin, C. W. *et al.* Surgical Site Complications in Open Pronation-Abduction Ankle Fracture-Dislocations With Medial Tension Failure Wounds. *J Orthop Trauma* **35**, E481–E485 (2021).

202. Shao, J. *et al.* Risk factors for surgical site infection following operative treatment of ankle fractures: A systematic review and meta-analysis. *International Journal of Surgery* vol. 56 124–132 Preprint at https://doi.org/10.1016/j.ijsu.2018.06.018 (2018).

203. Sultan, F. *et al.* Characteristics of intercalary fragment in posterior malleolus fractures. *Foot Ankle Surg* (2019) doi:10.1016/j.fas.2019.03.011.

204. Sun, C. *et al.* Posterior Locking Plate Fixation of Bartoníček Type IV Posterior Malleolar Fracture: A Focus on Die-Punch Fragment Size. *The Journal of Foot and Ankle Surgery* **61**, 109–116 (2022).

205. Blom, R. P. *et al.* Posterior malleolar fracture morphology determines outcome in rotational type ankle fractures. *Injury* **50**, 1392–1397 (2019).

206. Tosun, B., Selek, O., Gok, U. & Ceylan, H. Posterior Malleolus Fractures in Trimalleolar Ankle Fractures: Malleolus versus Transyndesmal Fixation. *Indian J Orthop* **52**, 309–314 (2018).

207. Baumbach, S. F. *et al.* Open reduction and internal fixation of the posterior malleolus fragment frequently restores syndesmotic stability. *Injury* **50**, 564–570 (2019).

208. Miller, M. A. *et al.* Stability of the Syndesmosis After Posterior Malleolar Fracture Fixation. *Foot Ankle Int* **39**, 99–104 (2018).

209. Buyukkuscu, M. O., Basilgan, S., Mollaomeroglu, A., Misir, A. & Basar, H. Splinting vs temporary external fixation in the initial treatment of ankle fracture-dislocations. *Foot Ankle Surg* **28**, 235–239 (2022).

210. Gerlach, R., Toepfer, A., Jacxsens, M., Zdravkovic, V. & Potocnik, P. Temporizing cast immobilization is a safe alternative to external fixation in ankle fracture-dislocation while posterior malleolar fragment size predicts loss of reduction: a case control study. *BMC Musculoskelet Disord* **23**, (2022).

211. Olson, J. J. *et al.* Judicious Use of Early Fixation of Closed, Complete Articular Pilon Fractures Is Not Associated With an Increased Risk of Deep Infection or Wound Complications. *J Orthop Trauma* **35**, 300–307 (2021).

212. Abarquero-Diezhandino, A. *et al.* Study of the relation between the posterior malleolus fracture and the development of osteoarthritis. *Revista espanola de cirugia ortopedica y traumatologia (English ed.)* **64**, 41–49 (2020).

213. Van Hooff, C. C. D., Verhage, S. M. & Hoogendoorn, J. M. Influence of fragment size and postoperative joint congruency on long-term outcome of posterior malleolar fractures. *Foot Ankle Int* **36**, 673–678 (2015).

214. Swierstra, B. A. & Enst, W. A. van. The prognosis of ankle fractures: a systematic review. *EFORT Open Rev* **7**, 692 (2022).

215. Xie, W. *et al.* Morphological analysis of posterior malleolar fractures with intra-articular impacted fragment in computed tomography scans. *Journal of Orthopaedics and Traumatology* **22**, 1–8 (2021).

216. Rbia, N. *et al.* High Prevalence of Chronic Pain With Neuropathic Characteristics After Open Reduction and Internal Fixation of Ankle Fractures. *Foot Ankle Int* **38**, 987–996 (2017).

217. McNally, M., Dudareva, M., Govaert, G., Morgenstern, M. & Metsemakers, W. J. Definition and diagnosis of fracture-related infection. *EFORT Open Rev* **5**, 614 (2020).

218. Sliepen, J. *et al.* What is the diagnostic value of the Centers for Disease Control and Prevention criteria for surgical site infection in fracture-related infection? *Injury* **52**, 2879–2885 (2021).

219. McNally, M. *et al.* What Factors Affect Outcome in the Treatment of Fracture-Related Infection? *Antibiotics* **11**, (2022).

220. Dudareva, M. *et al.* Providing an Evidence Base for Tissue Sampling and Culture Interpretation in Suspected Fracture-Related Infection. *J Bone Joint Surg Am* **103**, 977–983 (2021).

221. Greenwald, P. W. *et al.* Is single observer identification of wound infection a reliable endpoint? *Journal of Emergency Medicine* **23**, 333–335 (2002).

222. Audet, M. A., Benedick, A., Breslin, M. A., Schmidt, T. & Vallier, H. A. Determinants of functional outcome following ankle fracture. *OTA International* **4**, e139 (2021).

223. Szymski, D., Walter, N., Alt, V. & Rupp, M. Evaluation of Comorbidities as Risk Factors for Fracture-Related Infection and Periprosthetic Joint Infection in Germany. *J Clin Med* **11**, 5042 (2022).

224. Shivarathre, D. G., Chandran, P. & Platt, S. R. Operative fixation of unstable ankle fractures in patients aged over 80 years. *Foot Ankle Int* **32**, 599–602 (2011).

225. Schade, M. A. & Hollenbeak, C. S. Early Postoperative Infection Following Open Reduction Internal Fixation Repair of Closed Malleolar Fractures. *Foot Ankle Spec* **11**, 335–341 (2018).

226. Ovaska, M. T. *et al.* Risk factors for deep surgical site infection following operative treatment of ankle fractures. *J Bone Joint Surg Am* **95**, 348–353 (2013).

227. Jämsen, E., Nevalainen, P., Kalliovalkama, J. & Moilanen, T. Preoperative hyperglycemia predicts infected total knee replacement. *Eur J Intern Med* **21**, 196–201 (2010).

228. Korim, M. T., Payne, R. & Bhatia, M. A case-control study of surgical site infection following operative fixation of fractures of the ankle in a large U.K. trauma unit. *Bone Joint J* **96-B**, 636–640 (2014).

229. Olsen, L. L., Møller, A. M., Brorson, S., Hasselager, R. B. & Sort, R. The impact of lifestyle risk factors on the rate of infection after surgery for a fracture of the ankle. *Bone Joint J* **99-B**, 225–230 (2017).

230. Morris, P. B. *et al.* Cardiovascular Effects of Exposure to Cigarette Smoke and Electronic Cigarettes: Clinical Perspectives From the Prevention of Cardiovascular Disease Section Leadership Council and Early Career Councils of the American College of Cardiology. *J Am Coll Cardiol* **66**, 1378–1391 (2015).

231. Barrios, V. *et al.* Comprehensive management of risk factors in peripheral vascular disease. Expert consensus. *Rev Clin Esp* **222**, 82–90 (2022).

232. Ziegler, P., Bahrs, C., Konrads, C., Hemmann, P. & Ahrend, M.-D. Ankle fractures of the geriatric patient: a narrative review. *EFORT Open Rev* **8**, 1–10 (2023).

233. Willett, K. *et al.* Close Contact Casting vs Surgery for Initial Treatment of Unstable Ankle Fractures in Older Adults: A Randomized Clinical Trial. *JAMA* **316**, 1455–1463 (2016).

234. Gougoulias, N. & Sakellariou, A. When is a simple fracture of the lateral malleolus not so simple? *Bone and Joint Journal* **99B**, 851–855 (2017).

10 Appendices

SEFAS – Self Reported Foot and Ankle Score NORSK.

Pasient nr: ______

1. Hvordan vil du beskrive smerten som du vanligvis har fra den aktuelle foten/delen av foten?
    a. Ingen smerte
    b. Ganske ubetydelig
    c. Betydelig
    d. Moderat
    e. Sterk

2. Hvor langt kan du gå før det oppstår sterke smerter fra den aktuelle foten/delen av foten?
    a. Ingen smerte de første 30 min
    b. 16-30 min
    c. 5-10 min
    d. Jeg kan bare gå rundt huset eller tilsvarende strekning
    e. Jeg kan ikke gå i det hele tatt på grunn av sterke smerter

3. Har du kunnet gå på ujevnt underlag/terreng?
    a. Ja, med letthet
    b. Med ubetydelige vansker
    c. Med moderate vansker
    d. Med veldig stor vanskelighet
    e. Kan ikke gå på ulendt terreng i det hele tatt

4. Har du blitt nødt til å bruke innlegg i skoene, helforhøyelse eller spesiallagede sko?
    a. Aldri
    b. Bare av og til
    c. Ofte
    d. Største delen av tiden
    e. Alltid

5. Hvor mye har smerten fra den aktuelle foten hindret deg i ditt daglige husarbeid og hobbyer?
    a. Ikke i det hele tatt
    b. I liten grad
    c. I moderat grad
    d. I betydelig grad
    e. Hele tiden/hindrer meg fullstendig

6. Gjør smerten i den aktuelle foten at du halter?
    a. Aldri
    b. Noen ganger ila et par dager
    c. Av og til
    d. De fleste dager ila uka
    e. Hver dag

SEFAS – Self Reported Foot and Ankle Score NORSK.

Pasient nr: _____

7. Kan du gå i trapper?
    a. Ja, med letthet
    b. Med ubetydelige vansker
    c. Med moderate vansker
    d. Med veldig stor vanskelighet
    e. Kan ikke gå i trapp i det hele tatt

8. Har du vondt i den aktuelle foten om natten?
    a. Aldri
    b. Bare enkelte netter
    c. Av og til
    d. De fleste netter
    e. Hver natt

9. Hvor mye har smertene fra den aktuelle foten innvirket på dine vanlige fritidsaktiviteter?
    a. Ikke i det hele tatt
    b. I noen grad
    c. I moderat grad
    d. I høy grad
    e. Hindrer meg fullstendig

10. Er foten hoven?
    a. Ikke i det hele tatt
    b. Av og til/tilfeldig
    c. Ofte
    d. Største delen av tiden
    e. Alltid

11. Hvor mye smerter får du i den aktuelle foten når du reiser deg etter å ha sittet ved et bord og spist?
    a. Ikke smertefullt i det hele tatt
    b. Bare litt smertefullt
    c. Moderat smertefullt
    d. Veldig smertefullt
    e. Smertene har vært uutholdelige

12. Har du opplevd en plutselig knviskarp, huggende smerte eller krampe fra den aktuelle foten/delen av foten?
    a. Aldri
    b. Noen enkelte dager
    c. Av og til
    d. De fleste dager
    e. Hver dag

RAND-36 Din helse

Spørsmålene under handler om hvordan du oppfatter helsen din. Disse opplysningene vil hjelpe oss til å forstå hvordan du føler deg og hvor godt du er i stand til å utføre dine vanlige aktiviteter.

Hvert spørsmål skal besvares ved å sette et kryss (X) i den boksen som passer best for deg.

1. Stort sett, vil du si at helsen din er:

Utmerket	Veldig god	God	Nokså god	Dårlig
☐	☐	☐	☐	☐

2. <u>Sammenlignet med for ett år siden,</u> hvordan vil du si at helsen din stort sett er <u>nå</u>?

Mye bedre nå enn for ett år siden	Litt bedre nå enn for ett år siden	Omtrent som for ett år siden	Litt dårligere nå enn for ett år siden	Mye dårligere nå enn for ett år siden
☐	☐	☐	☐	☐

3. De neste spørsmålene handler om aktiviteter som du kanskje utfører i løpet av en vanlig dag. <u>Er helsen din slik at den begrenser deg</u> i utførelsen av disse aktivitetene <u>nå</u>? Hvis ja, hvor mye? [Kryss (X) en boks på hver linje.]

		Ja, begrenser meg mye	Ja, begrenser meg litt	Nei, begrenser meg ikke i det hele tatt
a	**Anstrengende aktiviteter** som å løpe, løfte tunge gjenstander, delta i anstrengende idrett	☐	☐	☐
b	**Moderate aktiviteter** som å flytte et bord, støvsuge, gå en spasertur eller drive med hagearbeid	☐	☐	☐
c	Løfte eller bære poser med dagligvarer	☐	☐	☐
d	Gå opp trappen **flere** etasjer	☐	☐	☐
e	Gå opp trappen **én** etasje	☐	☐	☐
f	Bøye deg eller gå ned på kne	☐	☐	☐
g	Gå **mer enn to kilometer**	☐	☐	☐
h	Gå **flere hundre meter**	☐	☐	☐
i	Gå **hundre meter**	☐	☐	☐
j	Dusje eller kle på deg	☐	☐	☐

4. I løpet av de siste fire ukene, har du hatt noen av de følgende problemene i arbeidet ditt eller i andre daglige aktiviteter på grunn av din fysiske helse?

		Ja	Nei
a	Kuttet ned på **hvor mye tid** du brukte på arbeid eller andre aktiviteter	☐	☐
b	**Fått gjort mindre** enn du ønsket	☐	☐
c	Vært begrenset i type **arbeidsoppgaver** eller andre aktiviteter	☐	☐
d	Hatt **problemer** med å utføre arbeidet eller andre aktiviteter (for eksempel at det krevde en ekstra innsats av deg)	☐	☐

5. I løpet av de siste fire ukene, har du hatt noen av de følgende problemene i arbeidet ditt eller i andre daglige aktiviteter på grunn av følelsesmessige problemer (som å føle seg engstelig eller deprimert)?

		Ja	Nei
a	Kuttet ned på **hvor mye tid** du brukte på arbeid eller andre aktiviteter	☐	☐
b	**Fått gjort mindre** enn du ønsket	☐	☐
c	Utført arbeid eller andre aktiviteter **mindre grundig** enn vanlig	☐	☐

6. I løpet av de siste fire ukene, i hvilken grad har den fysiske helsen din eller følelsesmessige problemer påvirket dine vanlige sosiale aktiviteter med familie, venner, naboer eller andre grupper mennesker?

Ikke i det hele tatt	Litt	Moderat	Ganske mye	Ekstremt mye
☐	☐	☐	☐	☐

7. Hvor mye kroppslige smerter har du hatt i løpet av de siste fire ukene?

Ingen	Veldig svake	Svake	Moderate	Sterke	Veldig sterke
☐	☐	☐	☐	☐	☐

8. I løpet av <u>de siste fire ukene</u>, hvor mye har <u>smerter</u> påvirket det vanlige arbeidet ditt (gjelder både arbeid utenfor hjemmet og husarbeid)?

Ikke i det hele tatt	Litt	Moderat	Ganske mye	Ekstremt mye
☐	☐	☐	☐	☐

9. De neste spørsmålene handler om hvordan du føler deg og hvordan du har hatt det <u>i løpet av de siste fire ukene.</u> For hvert spørsmål, ber vi deg velge det svaret som best beskriver hvordan du har følt deg.

Hvor ofte i løpet av de <u>siste fire ukene</u>:

		Hele tiden	Mesteparten av tiden	En god del av tiden	Noe av tiden	Litt av tiden	Aldri
a	Har du følt deg full av liv?	☐	☐	☐	☐	☐	☐
b	Har du vært veldig nervøs?	☐	☐	☐	☐	☐	☐
c	Har du følt deg så langt nede at ingenting kunne gjøre deg glad?	☐	☐	☐	☐	☐	☐
d	Har du følt deg rolig og avslappet?	☐	☐	☐	☐	☐	☐
e	Har du hatt mye overskudd?	☐	☐	☐	☐	☐	☐
f	Har du følt deg nedfor og deprimert?	☐	☐	☐	☐	☐	☐
g	Har du følt deg utslitt	☐	☐	☐	☐	☐	☐
h	Har du følt deg glad?	☐	☐	☐	☐	☐	☐
i	Har du følt deg sliten?	☐	☐	☐	☐	☐	☐

10. I løpet av <u>de siste fire ukene</u>, hvor mye av tiden har den <u>fysiske helsen din eller følelsesmessige problemer</u> påvirket dine sosiale aktiviteter (som å besøke venner, slektninger osv.)?

Hele tiden	Mesteparten av tiden	En del av tiden	Litt av tiden	Aldri
☐	☐	☐	☐	☐

11. Hvor RIKTIG eller GAL er hver av de følgende påstandene for deg?

		Helt riktig	Stort sett riktig	Vet ikke	Stort sett galt	Helt galt
a	Det virker som om jeg blir syk litt lettere enn andre	☐	☐	☐	☐	☐
b	Jeg er like frisk som de fleste jeg kjenner	☐	☐	☐	☐	☐
c	Jeg regner med at helsen min blir dårligere	☐	☐	☐	☐	☐
d	Helsen min er utmerket	☐	☐	☐	☐	☐

Smerte
På en skala fra 0 til 10 hvordan vil du gradere opplevd smerte i den opererte ankelen din, som en gjennomsnittsscore for de siste to ukene?

O er ingen smerte og 10 er uutholdelig/verst tenkelige smerte.

0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

Tilfredshet
På en skala fra 0-10 fornøyd er du med resultatet etter operasjonen av ankelen din?

O er veldig lite fornøyd og 10 er veldig fornøyd.

0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

Forespørsel om deltakelse i kvalitetsprosjekt – Studie om ankelbrudd

Bakgrunn og hensikt
Dette er et spørsmål til deg om å delta i et kvalitetssikringsprosjekt ved Haukeland Universitetssykehus. Årlig er det ca 7500 personer som får ankelbrudd. 7% av disse har brudd tre steder i ankelen, på fagspråket kalles disse "trimalleolære" brudd.

Du blir nå kontaktet fordi du har blitt operert for en slik skade med brudd tre steder i ankelen. Vi ønsker å gjøre en studie og kvalitetssjekk med et utvalg av pasientene som har blitt operert for denne typen skade ved vår avdeling. Det er frivillig å delta.

Hva innebærer prosjektet?
Vi ønsker å samle inn informasjon om hvordan du har det etter operasjonen. Dersom du samtykker vil vi undersøke røntgen- og CT-bilder samt lese i de aktuelle journalnotatene for å finne informasjon rundt skaden din. Vi ønsker også å samle inn opplysninger fra deg om smerter og funksjonsnivå etter operasjonen på egne skjema (vedlagt). De innsamlede opplysningene vil bli brukt til å kartlegge hvordan det går med dem vi har operert med samme metode, både som gruppe og som individ. Informasjonen vil gi oss tilbakemelding på hvordan operasjonsmetoden virker inn på deg som pasient. Funnene vil bli publisert i en artikkel i et ortopedisk tidsskrift.

Mulige fordeler og ulemper
Du blir med dette innkalt til poliklinisk time med undersøkelse hos fysioterapeut samt at det blir tatt røntgenbilder av den opererte ankelen, se vedlagte innkallingsbrev til disse timene. Alt dette vil være gratis for deg som pasient. Dersom du velger å delta må du sette av tid til å svare på spørreskjemaene og ta dem til oss når du kommer til poliklinisk undersøkelse. Informasjonen du gir oss kan hjelpe oss til å forbedre oss.

Om du vil bytte dag eller ikke ønsker å komme kan du ringe telefonnummeret på innkallingsbrevet og flytte eller avbestille timen.

Hva skjer med informasjonen om deg?
Informasjonen vi registrerer om deg vil bare bli brukt som beskrevet i hensikten med studien. Alle opplysningene vil bli behandlet uten navn, fødselsnummer eller andre direkte identifiserbare personopplysninger. En kode knytter deg til dine opplysninger og prøver gjennom en navneliste.

Bare autorisert personell tilknyttet prosjektet har tilgang til opplysningene dine.
Det vil ikke være mulig å identifisere deg i resultatene av studien når disse publiseres.

Rett til innsyn og sletting av opplysninger om deg
Dersom du deltar i prosjektet, har du rett til å få innsyn i hvilke opplysninger som er registrert om deg. Du har også rett til å få korrigert eventuelle i feil i opplysningene vi har registrert. Du kan trekke deg fra prosjektet når som helst uten å oppgi noen

begrunnelse for dette. Dersom du trekker deg kan du kreve å få slettet innsamlede opplysninger, med mindre disse allerede er anonymisert.

Vi ønsker gjerne å ha deg med i studien og ber derfor om at du signerer på dette arket og tar det med til poliklinikktimen hos vår fysioterapeut . Å delta i studien vil ikke påføre deg noen flere kostnader eller medføre nytt oppmøte eller ekstra reising.

Spørsmål kan rettes til prosjektleder, Kristian Pilskog. Tlf: 55970567/55975000.

Jeg, ……………………………………………………., født ……………… , ønsker å bli med i studien og aksepterer med dette at informasjon tilknyttet meg og min skade blir brukt i studien.

Signatur, sted og dato:

Pasientnummer: …………. (fylles ut på poliklinikken av fysioterapeut/lege)

Article

Foot & Ankle International®
2021, Vol. 42(4) 389–399

DOI: 10.1177/1071100720969431
journals.sagepub.com/home/fai

Traditional Approach vs Posterior Approach for Ankle Fractures Involving the Posterior Malleolus

Kristian Pilskog, MD[1], Teresa Brnic Gote, MSc[2], Heid Elin Johannessen Odland, MD[1], Knut Andreas Fjeldsgaard, MD[1], Håvard Dale, PhD, MD[1], Eivind Inderhaug, PhD, MD[1], and Jonas Meling Fevang, PhD, MD[1]

Abstract

Background: In the past, posterior malleolus fragments (PMFs) commonly have been indirectly reduced and fixed when fragments involve 25% or more of the tibial articular surface, while smaller fragments were left unfixed. The posterior approach has become increasingly popular and allows fixation of even smaller fragments. This study compares clinical outcome for the 2 treatment strategies.
Methods: Patients with ankle fractures involving a PMF treated from 2014 to 2016 were eligible for inclusion. Patients were allocated to group A (treated with a posterior approach) or group B (treated with the traditional approach) according to the treatment given. A one-to-one matching of patients from each group based on the size of the PMF was performed. Patient charts were reviewed, and outcome evaluation was performed clinically, radiographically, and by patient-reported outcome measures (PROMs; Self-Reported Foot and Ankle Score, RAND-36, visual analog scale [VAS] of pain, and VAS of satisfaction). Forty-three patients from each group were matched. Median follow-up was 26 (interquartile range [IQR], 19-35) months postoperatively.
Results: The median PMF size was 17% (IQR, 12-24) in both groups, and they reported similar results in terms of PROMs. Fixation of the PMF was performed in 42 of 43 (98%) patients in group A and 7 of 43 (16%) patients in group B ($P < .001$). The former group more frequently got temporary external fixation (56% vs 12%, $P < .01$) and less frequently had syndesmotic fixation (14% vs 49%, $P < .01$), and they had less mechanical irritation and hardware removal but more noninfectious skin problems (28% vs 5%, $P < .01$). Median time from injury to definitive surgery (8 vs 0 days, $P < .001$) and median length of stay (12 vs 3 days, $P < .001$) were longer in group A.
Conclusion: Comparison of treatment strategies for ankle fractures involving the posterior malleolus showed similar results between patients treated with a traditional approach and a posterior approach.
Level of Evidence: Level III, retrospective comparative study.

Keywords: ankle fracture, posterior malleolus, posterolateral, fixation, PROM, SEFAS, operative, outcome

Ankle fractures constitute 9% of all fractures and have an incidence of approximately 107 to 187 per 100 000 persons per year.[9,22] A posterior malleolar fragment (PMF) is present in up to 46% of Weber B and Weber C fractures.[2] Traditionally, the recommended cutoff for fixation of the PMF has been fragment size over 25% of the distal tibial articular surface.[31,37] Biomechanical studies have displayed that the posterior 25% of the articular surface is not involved in weightbearing during dorsi- and plantarflexion of the ankle.[40]

Poor clinical outcomes for trimalleolar fractures have been reported in several studies.[41,46,54] For this reason, the indication and choice of intervention for these fractures

[1]Orthopedic Department, Haukeland University Hospital, Bergen, Norway
[2]Department of Physiotherapy, Haukeland University Hospital, Bergen, Norway

Corresponding Author:
Kristian Pilskog, MD, Orthopedic Department, Haukeland University Hospital, Postbox 1400, 5021, Bergen, Norway.
Email: kpilskog@gmail.com

have been the object of increased interest in recent years. The PMF has traditionally been treated with closed, indirect, reduction, and, if needed, anteroposterior screw fixation.[52] Despite lack of solid evidence, there has been a trend toward use of a posterior approach allowing open reduction and internal fixation (ORIF).[13,20,29] It is advocated that this approach allows more anatomical reduction of the PMF and fixation of fragments smaller than 25%.[48] In addition, fixation of the distal fibular fracture through the same incision gives good soft tissue coverage by the peroneal muscles.[51] The posterior inferior tibiofibular ligament (PITFL) attaches to the posterior malleolus, and fixation of the PMF may therefore also reduce the need for syndesmotic screws.[14,18,21,34,49] Several studies have demonstrated good clinical outcome and few complications using this posterior approach.[12,51]

Our clinic changed in 2015 toward more use of a posterior approach, aiming to improve clinical outcomes and patient satisfaction. Few studies have reported on the comparative outcomes after use of the traditional approach and the posterior approach for PMF fixation. The purpose of this study was therefore to compare the short-term patient-reported outcome measures (PROMs) and rate of complications in patients with ankle fractures including a PMF that were treated surgically with or without a posterior approach.

Methods

All patients treated for ankle fractures with a low-energy mechanism of injury involving a PMF at a level 1 trauma hospital in Bergen, Norway, were eligible for inclusion in the study. A selective search through the operation planning system, Orbit version 5.11.2, was conducted based on Nordic Medico-Statistical Committee (NOMESCO) Classification of Surgical Procedures (NCSP) codes for bi- and trimalleolar fractures from January 2014 through December 2016. Radiographs from the time of injury were thereafter examined, so that only patients with an ankle fracture that involved the posterior malleolus were included. Included patients were invited to a follow-up evaluation involving questionnaires, clinical examination, and radiographs.

Exclusion criteria were deceased patients, follow-up at other hospital or in another country, high-energy mechanism, open fractures, former injury of the ipsilateral lower extremity causing current symptoms, and noncompliant patients. Patients with dementia and severe drug or alcohol abuse were considered noncompliant.

Patients were placed in groups according to the treatment approach given: group A (patients operated upon with a posterior approach) or group B (patients who received the traditional approach). To reduce bias in terms of differences in PMF size while analyzing outcomes across group A and group B, a one-to-one matching according to the size of the posterior malleolus fragment was performed. A size difference of maximum ±2% was allowed for within each matched pair.

Postoperative radiographs were assessed for intra-articular step-off after surgery. Patient selection and inclusion and exclusion criteria are illustrated in Figure 1.

In total, 130 patients were evaluated at a median 25 (interquartile range [IQR], 19-35 months) months after surgery. Median age was 57 (IQR, 41-67) years, 94 patients were female and 36 were male patients, and 79 fractures were classified as Weber B and 51 as Weber C. Median PMF size was 17% (IQR, 10%-26%). Median time from injury to operation was 5 (IQR, 0-9) days, median length of stay was 7 (IQR, 3-13) days, and median duration of surgery was 91 (IQR, 71-122) minutes.

Surgical Technique

Fracture fixation was performed after standard principles of the Arbeitsgemeinschaft für Osteosynthesefragen (AO). In group A, patients were operated upon in a prone position. A posterolateral and, if needed, posteromedial direct approach was used. Ankle joint debridement was performed before the PMF was anatomically reduced. Fixation was achieved with 3.5-mm screws with or without a one-third tubular plate. The fibular fracture was reduced and fixed through the posterolateral incision while any medial malleolus fracture was addressed via a separate direct medial approach. Fibular plates were applied posteriorly on the fibula. The posterior approach was used when the PMF was planned to be fixed.

Patients in group B were treated in a supine position. The lateral and, if present, the medial malleolus fracture were treated first, through a direct lateral and direct medial approach. If the size of the PMF was considered 25% or more of the distal tibial articular surface on the lateral radiograph, the posterior malleolus fragment was thereafter fixed with anteroposterior, partially threaded, 3.5-mm cancellous screws. All posterior fragments had attempted indirect reduction by ligamentotaxis regardless of whether they were fixed or not.

In both groups, plating of the fibula fracture was performed with standard one-third tubular plates, standard plates, or anatomical locking compression plates (LCPs) depending on fracture type, bone quality, and comminution of the fracture.

In both groups, the ankle syndesmosis was tested for stability after fixation of the fractures with the Cotton test or external rotation at the surgeon's discretion.[50] If instability was seen, syndesmosis fixation was done with 1 quadricortical screw, 2 tricortical 3.5-mm screws, or a suture button.

Mobilization with partial weightbearing supported by crutches was allowed for the first 6 weeks. In cases of syndesmosis fixation, patients were allowed foot touch weightbearing for the first 6 weeks and thereafter partial weightbearing the next 6 weeks. Full weightbearing was

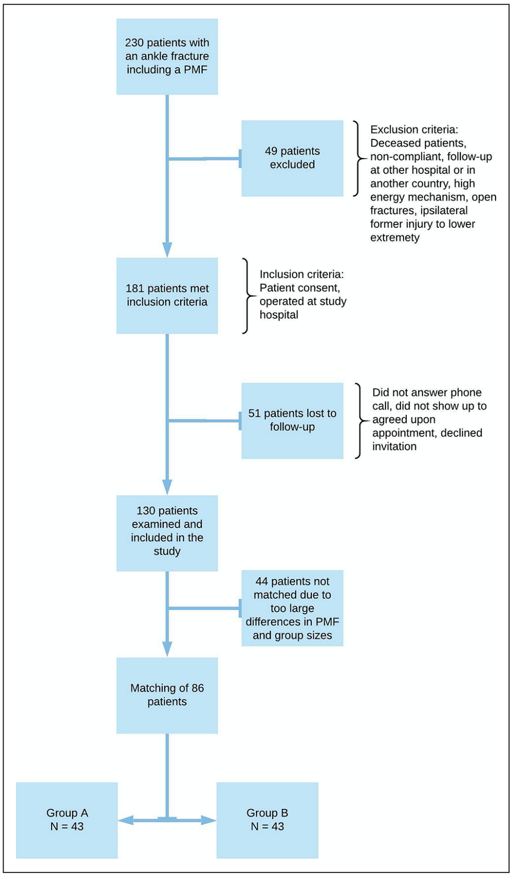


Figure 1. Search results, exclusion criteria, and inclusion criteria. In total, 130 patients met for a follow-up visit. To compare patients who received the traditional treatment (group B, n = 76 patients) to those operated through a posterior approach (group A, n = 54 patients), we matched patients one by one from each group according to the size of the posterior malleolus fragment. This rendered 86 patients, 43 in each group, for analysis. Due to too large discrepancies in the size of the posterior malleolus fragments (PMFs), 11 patients from group A and 33 patients from group B could not be matched.

allowed from 12 weeks in the latter cases. At our department, syndesmotic screws were routinely removed at 12 weeks with a planned operation at the outpatient clinic.

Outcome Assessment

The primary outcome was Self-Reported Foot and Ankle Score (SEFAS).[5-8,15] SEFAS was translated to Norwegian, and the translation was approved by the Center on Patient-Reported Outcome Data in Helse Bergen before use in patient evaluation. Median normative values of SEFAS are 48 for men and 47 for women, and the minimal important clinical difference has been reported to be a change of 5 points.[6,8] As a generic quality-of-life assessment tool, we used the RAND-36,[17] recently translated and validated into Norwegian by the Norwegian Institute of Public Health.[38]

Patients also completed a visual analog scale (VAS) of pain and VAS of satisfaction (0 meaning no pain/very unsatisfied and 10 meaning worst possible pain/very satisfied) to grade their level of pain and their level of satisfaction with surgery. VAS is a quick and easy way of assessing function that has commonly been used to evaluate outcomes after orthopedic surgery.[45]

PROMs in the matched patients were compared. Subanalyses were performed on patients with fragments smaller than 25%, comparing those who had the PMF fixed in group A to the patients in group B who did not have the PMF fixed. Also, the results of matched patients with the PMF fixed were compared.

Clinical examination included range of motion (ROM) in passive dorsi- and active plantarflexion and heel raise distance for both the operated and the uninjured ankle. Any differences between the sides were noted. Positive numbers denote larger movement of the uninjured ankle and negative numbers larger movement of the injured ankle. Dorsiflexion was performed with the foot being measured on top of a 2-step stool. The patient leaned forward as far as possible before the heel left the surface. The angle between the stool's top surface and the anatomical axis of the fibula was measured with a goniometer. Plantarflexion was measured with the patient sitting on an examination bench with straight knees and actively plantarflexing the foot. The angle between neutral position and the axis of the fifth metatarsal was measured with a goniometer. Heel raise test was performed with the patients standing on a stool with one foot at the time. They would then perform a 1-leg heel raise. The distance between neutral and maximum height after heel raise was measured in centimeters.

Patient charts were reviewed for demographic data and information on fracture characteristics, time from injury to definitive operation, duration of operation, and length of stay. Complications were registered as surgical site infections, noninfectious skin problems, nerve injury, reoperations, mechanical irritation from the implant, and implant removal. Reoperation was defined as any new surgery due to malreduction of the fracture(s) or fixation of the syndesmosis after the primary operation.

The Weber classification and the Lauge Hansen classification were used to describe the fracture.[26] The size of the PMF was measured as percentage of joint involvement of the anteroposterior length of the distal tibial articular surface on lateral radiographs of the ankle (Figure 2).[1] Radiographs acquired at follow-up were examined by 2 of the authors, both experienced ankle surgeons. Grading of

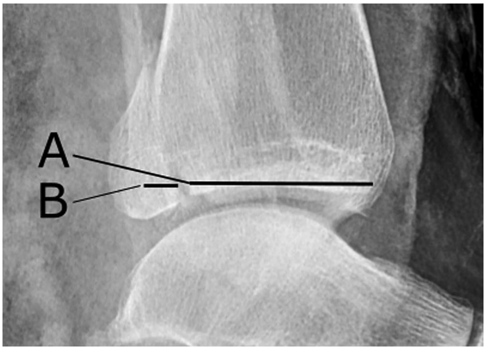


Figure 2. The size of the posterior malleolus fracture was measured as percentage joint involvement (B) of the anteroposterior length of the distal tibial articular surface (A + B) on lateral radiographs of the ankles ((B/(A + B)) *100 = % size of the distal tibial articulate surface).

Grade	Radiologic findings
0	No radiologic findings of osteoarthritis
1	Doubtful narrowing of joint space and possible osteophytic lipping
2	Definite osteophytes and possible narrowing of joint space
3	Moderate multiple osteophytes, definite narrowing of joint space, small pseudocystic areas with sclerotic walls and possible deformity of bone contour
4	Large osteophytes, marked narrowing of joint space, severe sclerosis and definite deformity of bone contour.

Figure 3. The Kellgren-Lawrence classification of grading of osteoarthritis.

osteoarthritis (OA) was performed using the Kellgren and Lawrence classification (Figure 3).[24]

Statistical Methods

Categorical variables were analyzed with Pearson χ^2 test and nonparametric continuous variables were analyzed by Mann-Whitney *U* test. An a priori *P* value of <.05 was set to denote statistically significance. IBM SPSS version 24 (SPSS, Inc) was used for data management and analyses.

Ethics

The Helse Bergen Data Protection Officer and Regional Committee for Medical and Health Research Ethics (REK) approved the project, REC ref.nr: 2016/1720. Informed consent was obtained from all patients before inclusion in the study.

Results

At the follow-up evaluation, median SEFAS was 39 (IQR, 31-44) points, median RAND-36 was 78 (IQR, 59-88) points, median VAS of pain was 1 (IQR, 0-3), and median reported VAS of satisfaction was 8.5 (IQR, 7-10).

The matching procedure rendered 86 patients, 43 in each group, for analysis. Matching was not possible in 11 patients from group A and 33 from group B. When comparing patients included in the matching (n = 86) and those not included (n = 44), similar results were found between those groups in age, sex distribution, American Society of Anesthesiology class, severity of fracture, time from injury to operation, length of stay, use of temporary external fixator, infections, or other complications (all $P > .1$) Furthermore, there were no differences between groups in SEFAS ($P = .53$), RAND-36 ($P = .39$), VAS of pain ($P = .23$), or VAS of satisfaction ($P = .91$) at the follow-up evaluation. Also, similar results were found between patients in group A (n = 11) and group B (n = 33) within the unmatched patients.

Comparison of Results in the Matched Patient Groups

No differences in patient demographics or fracture characteristics were found between matched patients across the groups (*ns*), but median time to follow-up was shorter ($P < .01$) in group A than in group B: 19 (range, 12-43) months vs 34 (range, 15-46) months (Table 1).

Definitive surgery was performed within the first 24 hours of the injury in 30 (70%) patients in group B compared to 3 patients (7%) in group A ($P < .001$). At surgery, syndesmotic fixation was performed in 7 patients with Weber B and 20 patients with Weber C fractures, as well as in 5 of 8 patients with anteroposterior screw fixation of the PMF. In most patients, the quality of reduction of the PMF could not be assessed as the implants concealed the potential postoperative intra-articular step-off in the distal tibia on plain radiographs.

Outcomes at Follow-up Evaluation. No differences were found between groups A and B in SEFAS, RAND-36, VAS of pain, and VAS of satisfaction (all $P > .05$) at the follow-up evaluation (Figure 4 and Table 2).

The median difference in dorsiflexion, plantarflexion, and heel raise between the injured and noninjured ankle for group A was 10 (range, –1 to 27) degrees, 6.5 (range, –9 to 35) degrees, and 1.5 (range, –2 to 8) cm, respectively. Median differences in group B were 9 (range, –8 to 27) degrees, 5 (range, –50 to 35) degrees, and 1 (range, –6 to 8) cm, respectively. There were no statistically significant differences between the groups (all $P > .05$) (Table 3).

Subanalyses of patients with PMFs smaller than 25% comparing those who had fixation of the fragment in group

Table 1. Patient and Fracture Characteristics, Treatment Factors, and Complications.[a]

Characteristic	Group A (n = 43)	Group B (n = 43)	*P* value[b]
Demographics			
Female	28 (65)	35 (81)	.1
Male	15 (35)	8 (19)	
Age, median (IQR), y	53 (35-67)	60 (41-69)	.2
ASA ≥3	3 (7)	2 (5)	.6
Diabetes	2 (5)	1 (2)	.6
Smoking	4 (9)	5 (12)	.7
Fracture characteristics			
Weber class B/C	27 (63)/16 (37)	28 (67)/14 (33)[c]	.7
Lauge Hansen SER/PER	27 (63)/16 (37)	28 (65)/15 (35)	.09
Ankle fracture-dislocation	21 (49)	19 (44)	.7
PMF size,[d] median (IQR), %	17 (12-24)	17 (12-24)	.99
Treatment summary			
Time from injury to definitive operation, median (IQR), d	8 (6-11)	0 (0-2)	<.001
Length of stay, median (IQR), d	12 (9-16)	3 (2-4)	<.001
Duration of operation, median (IQR), min	109 (89-147)	80 (60-103)	<.001
Fixation of PMF	42 (98)[e]	7 (16)	<.01
External fixator prior to operation	24 (56)	5 (12)	<.01
Syndesmotic fixation	6 (14)	21 (49)	<.01
Complications			
Infection	6 (14)	5 (12)	.8
Skin problems	12 (28)	2 (5)	<.01
Nerve injury	9 (21)	7 (16)	.6
Reoperations	3 (7)	3 (7)	1
Mechanical irritation	9 (21)	21 (49)	.01
Implant removal	3 (7)	27 (63)	<.01
Osteoarthritis grades 2-4	9 (21)	3 (7)	.06

Abbreviations: ASA, American Society of Anesthesiology; IQR, interquartile range; PER, pronation, external rotation; PMF, posterior malleolus fragment; SER, supination, external rotation.
[a]Values are presented as number (%) unless otherwise indicated. Group A: Patients operated upon in a prone position with a posterior approach to the ankle. Group B: Patients operated upon in a supine position with fixation of the PMF if the fragment was considered larger than 25% of the tibial articular surface, while smaller fragments were left unfixed.
[b]*P* values derived from Mann-Whitney *U* test for nonparametric continuous variables and Pearson's χ^2 test for categorical values.
[c]One patient in the traditional group did not have a fibular fracture; percentages calculated out of 42 patients.
[d]Measured as the percentage of the size of the PMF articular surface to the articular size of the distal tibia on a lateral radiograph.
[e]One patient got the posterolateral approach, but the PMF was not fixated as the surgeon considered the fragment to be well reduced.

A to the patients in group B who did not have fixation of the PMF revealed similar results between the groups (Table 4). Similar PROM results were also found among patients who got the PMF fixed (Table 5). The median PMF size among patients who had the PMF fixed was 34% (IQR, 26%-39%) in group A and 35% (IQR, 26%-39%) in group B (*P* = .6). The median time to follow-up was 31 (IQR, 19-41) months in group A and 35 (IQR, 34-40) months in group B (*P* = .6)

Complications. Overall, 7% (6 of 86) patients were treated for a deep infection in the operated ankle—2 of 43 (5%) in group A and 4 of 43 (9%) in group B (*ns*). Mechanical irritation was reported by 17 patients in group B and 6 patients in group A located at 1 or both of the lateral and medial malleoli (*ns*). In group B, 15 patients had planned, routine implant removal. Ten patients removed implants due to mechanical irritation, and 2 further patients removed implants due to an infection. In group A, mechanical irritation led to implant removal in 3 cases (Table 1).

Radiographs taken at follow-up revealed more patients with higher grade of osteoarthritis in group A (*P* = .06) (Table 1).

Discussion

Patient-reported outcomes were similar in patients who had their ankle fracture, involving a posterior malleolus fragment, treated compared to those who did not. Patients in the latter group more frequently received temporary external fixation prior to definitive surgery, waited longer for

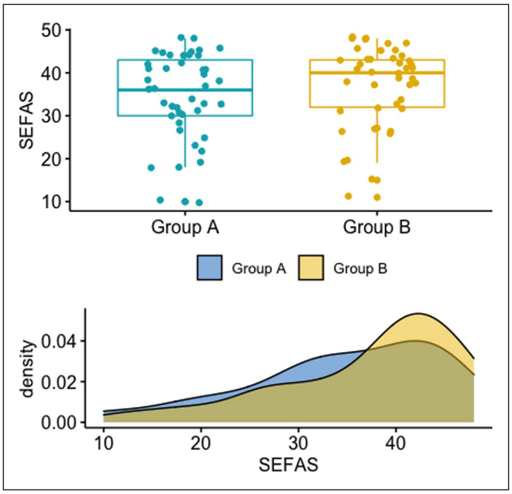


Figure 4. Boxplot (upper half) and density plot (lower half) showing the distribution of the Self-Reported Foot and Ankle Score (SEFAS, score from 0-48) in the 2 groups. n = 43 patients in each group. Each point in the boxplot graph represents a patient. The points are scattered for better visualization of the variation among the patients.

definitive surgery, had longer length of stay, had more postoperative noninfectious skin problems, and displayed more cases of severe posttraumatic osteoarthritis. Those treated in group A, however, experienced less mechanical irritation, less frequently had implant removal, and less frequently required additional syndesmotic stabilization. Only 7 of the 43 patients in group B had fixation of the PMF. Rate of infection, nerve injury, and reoperation were similar between the groups.

The difference between the 2 groups in length of stay and time from injury to surgery could be explained by the practice at our department in the study period. From the autumn of 2015, an increasing number of patients were treated using a posterior approach, but only a few surgeons were familiar with this method. Consequently, some patients were primarily treated with an external fixator in the absence of the appropriate surgeon. The aim of delaying surgery was to achieve better postoperative results, and the patients were kept in-house until definitive surgery, which was further postponed by waiting for the soft tissue swelling to resolve. External fixation was chosen for better control of the ankle fracture and to facilitate better inspection of the skin and soft tissue swelling. We also wanted to avoid potential dislocation of the ankle every time the plaster cast would be opened for inspection of the swelling. However, the results of this study show no improvement of this treatment strategy. As the fracture characteristics display, there were no differences in mechanism of injury or fracture classification. We would therefore argue that the increased time from injury to surgery, longer length of stay, and more frequent soft tissue challenges in group A reflect this practice rather than more severe injuries in this group of patients. Despite the differences in time to surgery and noninfectious skin problems in our study, no difference in clinical and patient-reported outcome was found between the groups.

Compared to the normative values of SEFAS,[8] our results of median 36 for group A and 40 for group B reflect the serious impact on function and quality of life of an ankle fracture involving the posterior malleolus. Mason et al[29] also reported low PROM scores in patients with posterior malleolus fractures, with a mean Olerud-Molander Ankle Score of 74.1. Xu et al[56] found an average American Orthopaedic Foot & Ankle Society (AOFAS) score of 95.9 in a similar population. Xu et al[56] could not find any difference in treatment effect between fixation and nonfixation of the PMF. Both groups in the current study reported similar RAND-36, VAS of satisfaction, and VAS of pain like De Vries et al[10] and Langenhuijsen.[25] Loss of dorsiflexion is known as a predictor of outcome after ankle fractures[16]; we did not find any differences in range of motion between the 2 groups in the current study.

The size of the PMF and the need for fixation is a matter of ongoing debate. Some authors report no difference in outcome in patients with fixation and without fixation of smaller fragments, and they more conventionally recommend fixation if the PMF involves 25% or more of the articular surface.[9,10,33,35,44,55] Other authors recommend ORIF of all PMFs regardless of their size as this this was found to reduce the need for syndesmotic fixation and improve outcomes in their study.[3,23,29,30] The subanalyses of patients with PMF smaller than 25% in the current study displayed similar SEFAS scores between treatment groups, although fragments were fixed in group A and no fixation was performed in group B. There was a trend of better results in group B. Also, PROM results were similar when comparing patients who had their PMF fixed across treatment groups. These patients also had similar time to follow-up. However, comparison was difficult due to the small number of patients. Both subanalyses suggest that the treatment in group B gave equally good results as the posterior approach, used in group A. Some authors suggest that clinical outcome is related to fracture displacement, articular surface congruency, and residual tibiotalar subluxation, rather than PMF size.[39,45,48] Several studies,[11,53,56] including a review from 2018 by Verhage et al,[52] argue that postoperative step-off is the most important factor predicting posttraumatic osteoarthritis. The current study showed a surprising trend toward more osteoarthritis in group A (P = .06). The result is surprising as we expected less osteoarthritis and pain in this group of patients due to shorter time to follow-up and proposed better fracture reduction. One could speculate

Table 2. Patient-Reported Outcome Measures at Follow-up of Matched Patients.[a]

Characteristic	Group A (n = 43), median (IQR)	Group B (n = 43), median (IQR)	*P* value[b]
PROM			
SEFAS	36 (30-44)	40 (32-43)	.2
RAND-36[c]	73 (54-88)	81 (55-89)	.6
VAS of pain[d]	2 (1-4)	1 (0-3)	.2
VAS of satisfaction[e]	9 (7-10)	8 (7-10)	.9

Abbreviations: IQR, interquartile range; PROM, patient-reported outcome measure; SEFAS, Self-Reported Foot and Ankle Score; VAS, visual analog scale.
[a]Group A: Patients operated upon in a prone position with a posterior approach to the ankle. Group B: Patients operated upon in a supine position with fixation of the posterior malleolus fragment if the fragment was considered larger than 25% of the tibial articular surface, while smaller fragments were left unfixed.
[b]*P* values derived from nonparametric continuous variables analyzed by Mann-Whitney *U* test.
[c]RAND-36: generic PROM for quality of life.
[d]0 = no pain and 10 = worst possible pain. Pain score experienced the past 2 weeks prior to the clinical examination.
[e]0 = very disappointed and 10 = very satisfied with the result.

Table 3. Range of Motion.[a]

Characteristic	Group A (n = 43), median (IQR)	Group B (n = 43), median (IQR)	*P* value[b]
Difference in dorsiflexion	10 (5-19)	9 (4-15)	.3
Difference in plantarflexion	6.5 (2-12)	5 (0-10)	.2
Difference in heel raise (cm)	1.5 (0-3)	1 (0-3)	.2

Abbreviation: IQR, interquartile range.
[a]The difference in dorsiflexion and plantarflexion is measured in degrees on a goniometer. Positive numbers denote larger movement of the uninjured ankle and negative numbers larger movement of the injured ankle. Group A: Patients operated upon in a prone position with a posterior approach to the ankle. Group B: Patients operated upon in a supine position with fixation of the posterior malleolus fragment if the fragment was considered larger than 25% of the tibial articular surface, while smaller fragments were left unfixed.
[b]*P* values derived from Mann-Whitney *U* test for nonparametric continuous variables.

Table 4. Subanalyses of Patients With Posterior Malleolus Fragment Size Smaller Than 25%.[a]

Characteristic	Group A: PMF fixed (n = 31), median (IQR)	Group B: PMF not fixed (n = 34), median (IQR)	*P* value[b]
PROM			
SEFAS	36 (27-42)	40 (27-43)	.2
RAND-36[c]	68 (57-88)	76 (46-88)	.8
VAS of pain[d]	2 (1-5)	1.5 (0-4)	.2
VAS of satisfaction[e]	8 (6-10)	8 (7-10)	.9

Abbreviations: IQR, interquartile range; PMF, posterior malleolus fragment; PROM, patient-reported outcome measure; SEFAS, Self-Reported Foot and Ankle Score; VAS, visual analog scale.
[a]Patient-reported outcome measures at follow-up by surgical approach in patients with fragments smaller than 25%, comparing those who had the PMF fixed in the posterior approach group to the patients in the traditional approach group who did not have the PMF fixed. Group A: Patients operated upon in a prone position with a posterior approach to the ankle. Group B: Patients operated upon in a supine position with fixation of the posterior malleolus fragment if the fragment was considered larger than 25% of the tibial articular surface, while smaller fragments were left unfixed.
[b]*P* values derived from Mann-Whitney *U* test for nonparametric continuous variables.
[c]RAND-36: generic PROM for quality of life.
[d]0 = no pain and 10 = worst possible pain. Pain score experienced the past 2 weeks prior to the clinical examination.
[e]0 = very disappointed and 10 = very satisfied with the result.

whether fractures in group A were more comminuted than seen on lateral radiographs and that the degree of soft tissue injuries was worse than those in group B. Additional computed tomography (CT) scans would have given more detailed information on preoperative severity of the fracture—and postoperative reduction—but were not available for this patient cohort. In most patients, the quality of reduction of the PMF could not be assessed as the implants concealed the potential postoperative intra-articular step-off in the distal tibia on plain radiographs.

Table 5. Subanalyses of Matched Patients With Fixed Posterior Malleolus Fragment (PMF).[a]

Characteristic	Group A (n = 7), median (IQR)	Group B (n = 7), median (IQR)	*P* value[b]
PROM			
SEFAS	41 (30-44)	43 (38-45)	.3
RAND-36[c]	87 (73-88)	90 (85-92)	.3
VAS of pain[d]	1 (1-3)	1 (0-2)	1
VAS of satisfaction[e]	10 (9-10)	10 (9.5-10)	.6

Abbreviations: IQR, interquartile range; PROM, patient-reported outcome measure; SEFAS, Self-Reported Foot and Ankle Score; VAS, visual analog scale.
[a]Patient-reported outcome measures at follow-up, with comparison of matched patients from groups A and B with the PMF fixed. Group A: Patients operated upon in a prone position with a posterior approach to the ankle. Group B: Patients operated upon in a supine position with fixation of the PMF if the fragment was considered larger than 25% of the tibial articular surface, while smaller fragments were left unfixed.
[b]*P* values derived from Mann-Whitney *U* test for nonparametric continuous variables.
[c]RAND-36: generic PROM for quality of life.
[d]0 = no pain and 10 = worst possible pain. Pain score experienced the past 2 weeks prior to the clinical examination.
[e]0 = very disappointed and 10 = very satisfied with the result.

The current finding of a lower rate of syndesmotic stabilization in group A, in whom a posterior approach was used, is also in accordance with other studies.[14,27,34,49] However, the use of the posterior approach could serve as bias toward not fixating the syndesmosis even if it was slightly unstable. One could speculate whether this could explain the present increased rate of high-grade osteoarthritis in the group of patients treated with this approach. These patients had less mechanical irritation and less frequently required implant removal. These findings are consistent with other reports and illustrates that the posterior approach gave better soft tissue coverage than when the direct lateral approach was applied for fixation of the fibular fracture.[28,42] The postoperative protocols could also serve as bias. Nearly half of the patients in group B had syndesmotic fixation and were not allowed to bear full weight until after 3 months. The difference in follow-up time could also serve as a bias for the reported PROM and clinical outcomes. Patients from group B had a longer median follow-up time and could therefore have a higher degree of adaptation to the state of their previously injured ankle. Patients from group A, with the more recent injury fresh in mind, might have a lesser degree of adaptation and therefore report worse function than if follow-up time was equal between groups.

Furthermore, there was an evident difference in time from injury to definitive surgery, where most of the patients in group B were operated on within the first day of admission. The literature in general recommends definitive surgery as early as possible.[4,19,36,43,47] Therefore, if use of the posterior approach leads to a delay in surgery, this adds to the discussion on the benefit of changing approaches.

The SEFAS questionnaire was chosen as the primary outcome as it is validated for patients with ankle fractures—and normative values from the general population have been established.[8] Across several PROMs, SEFAS is considered to have the best measurement properties for the current population.[15] Further strengths include use of a multitude of outcome measures, radiographs, and complication rates. This gives a more complete picture of the effectiveness of the different approaches for treating ankle fractures. The current study is a transparent evaluation of clinical practice and change in operative treatment at a level 1 trauma hospital. The use of one-to-one matching allowed for comparison of outcomes in similar fractures treated with 2 different approaches. The evident similarities in fracture characteristics and soft tissue injuries support this as a basis for comparison across a traditional and a more novel surgical approach.

The retrospective study design has several well-known limitations. In the current study, only 130 (72%) of the 181 eligible patients were available for the follow-up evaluation. The reasons for nonparticipation varied, but we cannot rule out a selection bias. The current exclusion criteria were chosen as high-energy injuries and open fractures have a different soft tissue prognosis than fractures with lower energy. Furthermore, although a matching algorithm was applied, to adjust for potential differences that could bias the outcome, patients likely hold a certain degree of heterogeneity. As this report is on the first patients operated upon with a new technique, the results might also reflect a certain learning curve. The results with the posterior approach could therefore improve with time—displaying the need for an ongoing evaluation of results after surgery. The more frequent use of temporary stabilization prior to definitive surgery in group A could have led to a prolonged length of stay and more noninfectious skin complications. If all patients had undergone definitive surgery within 24 hours, this potential effect on outcomes would have been eliminated. Finally, several studies have shown that pre- and postoperative CT scans are preferred over radiographs to accurately assess the anatomy of the PMF and the quality of fracture reduction.[32-34] Unfortunately, only radiographs were available in the current patient series.

Conclusion

In the current study, clinical outcomes of patients treated for ankle fractures involving PMFs were not improved by reduction and fixation, through a posterior approach, compared to a traditional indirect reposition and anteroposterior fixation. Most of the patients in the traditional group did not have fixation of the PMF. Among patients with a PMF smaller than 25%, patients in the group without fixation reported similar results to those who got fixation in the posterior approach group. Also, matched patients with the PMF fixed from each group reported similar results. Although the need for syndesmotic fixation was reduced with the change to a posterior approach, patients waited longer until definitive surgery, had longer length of stay, more frequently developed severe posttraumatic osteoarthritis, and more frequently reported noninfectious skin problems. Although limitations apply, these results challenge the view that all posterior malleolus fractures need fixation.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. ICMJE forms for all authors are available online.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Kristian Pilskog, MD, https://orcid.org/0000-0002-8866-9045
Teresa Brnic Gote, MSc, https://orcid.org/0000-0002-3902-1218
Håvard Dale, PhD, MD, https://orcid.org/0000-0002-2962-2706
Eivind Inderhaug, PhD, MD, https://orcid.org/0000-0001-7959-163X

References

1. Altun G, Reis HÇ, Bayram B, Saka G. Comparison of two plain radiographic and 3D-based measurement methods for posterior malleolar fragment size in trimalleol ankle fractures. *Arch Clin Exp Med*. 2020;5(1):11-15.
2. Bartoníček J, Rammelt S, Tuček M, Naňka O. Posterior malleolar fractures of the ankle. *Eur J Trauma Emerg Surg*. 2015;41(6):587-600.
3. Baumbach SF, Herterich V, Damblemont A, Hieber F, Böcker W, Polzer H. Open reduction and internal fixation of the posterior malleolus fragment frequently restores syndesmotic stability. *Injury*. 2019;50(2):564-570.
4. Burchard R, Hamidy K, Pahlkötter A, et al. Influence of time to surgery in ankle fractures on the rate of complications and length of stay—a multivariate analysis. *Z Orthop Unfall*. 2019;157(2):183-187.
5. Cöster M, Karlsson MK, Nilsson J-Å, Carlsson Å. Validity, reliability, and responsiveness of a Self-Reported Foot and Ankle Score (SEFAS). *Acta Orthop*. 2012;83(2):197-203.
6. Cöster MC, Nilsdotter A, Brudin L, Bremander A. Minimally important change, measurement error, and responsiveness for the Self-Reported Foot and Ankle Score. *Acta Orthop*. 2017;88(3):300-304.
7. Cöster MC, Rosengren BE, Bremander A, Brudin L, Karlsson MK. Comparison of the Self-Reported Foot and Ankle Score (SEFAS) and the American Orthopaedic Foot & Ankle Society Score (AOFAS). *Foot Ankle Int*. 2014;35(10):1031-1036.
8. Cöster MC, Rosengren BE, Karlsson MK, Carlsson Å. Age- and gender-specific normative values for the Self-Reported Foot and Ankle Score (SEFAS). *Foot Ankle Int*. 2018;39(11):1328-1334.
9. Daly PJ, Fitzgerald RH, Melton LJ, Llstrup DM. Epidemiology of ankle fractures in Rochester, Minnesota. *Acta Orthop Scand*. 1987;58(5):539-544.
10. De Vries JS, Wijgman AJ, Sierevelt IN, Schaap GR. Long-term results of ankle fractures with a posterior malleolar fragment. *J Foot Ankle Surg*. 2005;44(3):211-217.
11. Drijfhout van Hooff CC, Verhage SM, Hoogendoorn JM. Influence of fragment size and postoperative joint congruency on long-term outcome of posterior malleolar fractures. *Foot Ankle Int*. 2015;36(6):673-678.
12. Forberger J, Sabandal P V, Dietrich M, Gralla J, Lattmann T, Platz A. Posterolateral approach to the displaced posterior malleolus: functional outcome and local morbidity. *Foot Ankle Int*. 2009;30(4):309-314.
13. Gandham S, Millward G, Molloy AP, Mason LW. Posterior malleolar fractures: a CT guided incision analysis. *Foot*. 2020;43:101662.
14. Gardner MJ, Brodsky A, Briggs SM, Nielson JH, Lorich DG. Fixation of posterior malleolar fractures provides greater syndesmotic stability. *Clin Orthop Relat Res*. 2006;447:165-171.
15. Garratt AM, Naumann MG, Sigurdsen U, Utvåg SE, Stavem K. Evaluation of three patient reported outcome measures following operative fixation of closed ankle fractures. *BMC Musculoskelet Disord*. 2018;19(1):134.
16. Hancock MJ, Herbert RD, Stewart M. Prediction of outcome after ankle fracture. *J Orthop Sports Phys Ther*. 2005;35(12):786-792.
17. Hays RD, Morales LS. The RAND-36 measure of health-related quality of life. *Ann Med*. 2001;33(5):350-357.
18. Hermans JJ, Beumer A, De Jong TAW, Kleinrensink GJ. Anatomy of the distal tibiofibular syndesmosis in adults: a pictorial essay with a multimodality approach. *J Anat*. 2010;217(6):633-645.
19. Höiness P, Engebretsen L, Strömsöe K. The influence of perioperative soft tissue complications on the clinical outcome in surgically treated ankle fractures. *Foot Ankle Int*. 2001;22(8):642-648.
20. Hoogendoorn JM. Posterior malleolar open reduction and internal fixation through a posterolateral approach for trimalleolar fractures. *JBJS Essent Surg Tech*. 2017;7(4):e31.

21. Jayatilaka MLT, Philpott MDG, Fisher A, Fisher L, Molloy A, Mason L. Anatomy of the insertion of the posterior inferior tibiofibular ligament and the posterior malleolar fracture. *Foot Ankle Int*. 2019;40(11):1319-1324.
22. Jensen SL, Andresen BK, Mencke S, Nielsen PT. Epidemiology of ankle fractures: a prospective population-based study of 212 cases in Aalborg, Denmark. *Acta Orthop Scand*. 1998;69(1):48-50.
23. Kang C, Hwang D-S, Lee J-K, Won Y, Song J-H, Lee G-S. Screw fixation of the posterior malleolus fragment in ankle fracture. *Foot Ankle Int*. 2019;40(11):1288-1294.
24. Kohn MD, Sassoon AA, Fernando ND. Classifications in brief: Kellgren-Lawrence classification of osteoarthritis. *Clin Orthop Relat Res*. 2016;474(8):1886-1893.
25. Langenhuijsen JF, Heetveld MJ, Ultee JM, Steller EP, Butzelaar RMJM. Results of ankle fractures with involvement of the posterior tibial margin. *J Trauma*. 2002;53(1):55-60.
26. Lauge-Hansen N. Fractures of the ankle. IV. Clinical use of genetic roentgen diagnosis and genetic reduction. *AMA Arch Surg*. 1952 Apr;64(4):488-500.
27. Li M, Collier RC, Hill BW, Slinkard N, Ly TV. Comparing different surgical techniques for addressing the posterior malleolus in supination external rotation ankle fractures and the need for syndesmotic screw fixation. *J Foot Ankle Surg*. 2017;56(4):730-734.
28. Little MTM, Berkes MB, Lazaro LE, Sculco PK, Helfet DL, Lorich DG. Complications following treatment of supination external rotation ankle fractures through the posterolateral approach. *Foot Ankle Int*. 2013;34(4):523-529.
29. Mason LW, Kaye A, Widnall J, Redfern J, Molloy A. Posterior malleolar ankle fractures: an effort at improving outcomes. *JB JS Open Access*. 2019;4(2):e0058.
30. McHale S, Williams M, Ball T. Retrospective cohort study of operatively treated ankle fractures involving the posterior malleolus. *Foot Ankle Surg*. 2020;26(2):138-145.
31. McLaughlin, HL. Injuries of the ankle. In: H.L. McLaughlin, ed. *Trauma*. W. B. Saunders; Philadelphia, 1959:357-60.
32. Meijer DT, de Muinck Keizer R-JO, Doornberg JN, et al. Diagnostic accuracy of 2-dimensional computed tomography for articular involvement and fracture pattern of posterior malleolar fractures. *Foot Ankle Int*. 2016;37(1):75-82.
33. Meijer DT, Doornberg JN, Sierevelt IN, et al. Guesstimation of posterior malleolar fractures on lateral plain radiographs. *Injury*. 2015;46(10):2024-2029.
34. Miller AN, Carroll EA, Parker RJ, Helfet DL, Lorich DG. Posterior malleolar stabilization of syndesmotic injuries is equivalent to screw fixation. *Clin Orthop Relat Res*. 2010;468(4):1129-1135.
35. Mingo-Robinet J, López-Durán L, Galeote JE, Martinez-Cervell C. Ankle fractures with posterior malleolar fragment: management and results. *J Foot Ankle Surg*. 2011;50(2):141-145.
36. Naumann MG, Sigurdsen U, Utvåg SE, Stavem K. Associations of timing of surgery with postoperative length of stay, complications, and functional outcomes 3-6 years after operative fixation of closed ankle fractures. *Injury*. 2017;48(7):1662-1669.
37. Nelson M, Jensen N. The treatment of trimalleolar fractures of the ankle. *Surg Gynecol Obs*. 1940;71:509-514.
38. Norsk versjon av RAND 36-Item Short Form Health Survey [Norwegian version of the RAND 36-Item Short Form Health Survey]. https://www.fhi.no/kk/brukererfaringer/sporreskjemabanken/norsk-versjon-av-rand-36-item-short-form-health-survey/. Accessed April 26, 2020.
39. Odak S, Ahluwalia R, Unnikrishnan P, Hennessy M, Platt S. Management of posterior malleolar fractures: a systematic review. *J Foot Ankle Surg*. 2016;55(1):140-145.
40. Papachristou G, Efstathopoulos N, Levidiotis C, Chronopoulos E. Early weight bearing after posterior malleolar fractures: an experimental and prospective clinical study. *J Foot Ankle Surg*. 2003;42(2):99-104.
41. Roberts V, Mason LW, Harrison E, Molloy AP, Mangwani J. Does functional outcome depend on the quality of the fracture fixation? Mid to long term outcomes of ankle fractures at two university teaching hospitals. *Foot Ankle Surg*. 2019;25(4):538-541.
42. Ruokun H, Ming X, Zhihong X, et al. Postoperative radiographic and clinical assessment of the treatment of posterior tibial plafond fractures using a posterior lateral incisional approach. *J Foot Ankle Surg*. 2014;53(6):678-682.
43. Schepers T, De Vries MR, Van Lieshout EMM, Van der Elst M. The timing of ankle fracture surgery and the effect on infectious complications: a case series and systematic review of the literature. *Int Orthop*. 2013;37(3):489-494.
44. Shi H, Xiong J, Chen Y, et al. Comparison of the direct and indirect reduction techniques during the surgical management of posterior malleolar fractures. *BMC Musculoskelet Disord*. 2017;18(1):109.
45. Solheim E, Hegna J, Øyen J, Inderhaug E. Arthroscopic treatment of lateral epicondylitis: tenotomy versus debridement. *Arthrosc J Arthrosc Relat Surg*. 2016;32(4):578-585.
46. Stufkens SAS, Bekerom MPJ Van Den, Kerkhoffs GMMJ, Hintermann B, Dijk CN Van. Long-term outcome after 1822 operatively treated ankle fractures: a systematic review of the literature. *Injury*. 2011;42(2):119-127.
47. Tantigate D, Ho G, Kirschenbaum J, et al. Timing of open reduction and internal fixation of ankle fractures. *Foot Ankle Spec*. 2019;12(5):401-408.
48. Tornetta P, Ricci W, Nork S, Collinge C, Steen B. The posterolateral approach to the tibia for displaced posterior malleolar injuries. *J Orthop Trauma*. 2011;25(2):123-126.
49. Tosun B, Selek O, Gok U, Ceylan H. Posterior malleolus fractures in trimalleolar ankle fractures: malleolus versus transyndesmal fixation. *Indian J Orthop*. 2018;52(3):309-314.
50. Van den Bekerom MPJ. Diagnosing syndesmotic instability in ankle fractures. *World J Orthop*. 2011;2(7):51-56.
51. Verhage SM, Boot F, Schipper IB. Open reduction and internal fixation of posterior malleolar fractures using the posterolateral approach. *Bone Joint J*. 2016;98B:812-817.
52. Verhage SM, Hoogendoorn JM, Krijnen P, Schipper IB. When and how to operate the posterior malleolus fragment in trimalleolar fractures: a systematic literature review. *Arch Orthop Trauma Surg*. 2018;138(9):1213-1222.
53. Verhage SM, Krijnen P, Schipper IB, Hoogendoorn JM. Persistent postoperative step-off of the posterior malleolus

leads to higher incidence of post-traumatic osteoarthritis in trimalleolar fractures. *Arch Orthop Trauma Surg*. 2019;139(3):323-329.
54. Verhage SM, Schipper IB, Hoogendoorn JM. Long-term functional and radiographic outcomes in 243 operated ankle fractures. *J Foot Ankle Res*. 2015;8:45.
55. Vosoughi AR, Jayatilaka MLT, Fischer B, Molloy AP, Mason LW. CT analysis of the posteromedial fragment of the posterior malleolar fracture. *Foot Ankle Int*. 2019;40(6):648-655.
56. Xu H, Li X, Zhang D, et al. A retrospective study of posterior malleolus fractures. *Int Orthop*. 2012;36(9):1929-1936.

Article

AMERICAN ORTHOPAEDIC FOOT & ANKLE SOCIETY

Foot & Ankle International®
2022, Vol. 43(6) 762–771

DOI: 10.1177/10711007211070540
journals.sagepub.com/home/fai

Association of Delayed Surgery for Ankle Fractures and Patient-Reported Outcomes

Kristian Pilskog, MD[1,2], Teresa Brnic Gote, MSc[3], Heid Elin Johannessen Odland, MD[1], Knut Andreas Fjeldsgaard, MD[1], Håvard Dale, MD, PhD[1,2], Eivind Inderhaug, MD, PhD[1,2], and Jonas Meling Fevang, MD, PhD[1,2]

Abstract

Background: Several studies probe the association between prolonged time to surgery and postoperative complications in ankle fractures, but little is known about how a longer wait time affects clinical outcomes. The present study aims to assess the association between time from injury to surgery and patient-reported outcomes after operative treatment of severe ankle fractures.

Method: Patients treated operatively for low-energy ankle fractures that also involve the posterior malleolus from 2014 to 2016 were included. Patient charts were reviewed for patient demographics, type of trauma, fracture characteristics, treatment given, and complications. Ankle function was evaluated on a follow-up visit by clinical examination, radiographs, and patient-reported outcome measures (Self-Reported Foot and Ankle Score [SEFAS], RAND-36, visual analog scale [VAS] of Pain, VAS of Satisfaction). We compared patients treated within 1 week to those treated later than a week from injury for analyses.

Results: Follow-up visits of 130 patients were performed at mean 26 (SD 9) months after surgery. Patient demographics and fracture characteristics were similar between groups. Mean SEFAS was 34 (SD 10) in patients treated later than a week from injury vs 38 (SD 9) in those treated earlier ($P = .012$). Patients operated on later than 7 days from injury reported more pain ($P = .008$) and lower satisfaction than those treated earlier ($P = .016$).

Conclusion: In this retrospective patient series of low-energy ankle fractures with posterior malleolar fragments, we found that waiting >7 days for definitive surgery was associated with poorer clinical outcomes and more pain compared with those who had surgery earlier.

Level of Evidence: Level III, retrospective comparative study.

Keywords: fracture, ankle, posterior malleolus, complications, PROM, outcome, SEFAS, operation, delay

Introduction

Operative treatment of ankle fractures comes with the risk of various short- and long-term complications, such as soft tissue problems and fracture-related infections (FRIs), malreduction, hardware-related symptoms, pain, and reduced range of motion.[4,5,15,21,23,31] Timing of surgery and its impact on such complications is an ongoing debate. Schepers et al[26] found a complication rate of 12.9% in delayed (>6 days from day of injury) ankle fracture surgery. A delay of surgery might be due to delayed admission to hospital, need for additional computed tomography (CT) scans, or more commonly, preoperative soft tissue challenges or scheduled treatment at a later point in time.[2,19,24] In case of soft tissue challenges, a delay is considered beneficial for the patients as reduced soft tissue swelling might lower the risk of complications.[2] A temporary external fixator may be applied prior to definitive surgery as immediate care of the injured

[1]Orthopedic department, Haukeland University Hospital, Norway
[2]Clinical Institute 1, The University of Bergen
[3]Department of Physiotherapy, Haukeland University Hospital, Norway

Corresponding Author:
Kristian Pilskog, MD, Orthopedic Department, Haukeland University Hospital, Pb. 1400, Bergen, 5021, Norway.
Email: kpilskog@gmail.com

ankle.[29] On the other hand, an early and immediate operation might prevent the aforementioned complications and allow early-onset rehabilitation.[25] Although the association between time from injury to surgery and postoperative complications is well documented, there is a paucity in the literature on any effect from a delay in surgery on postoperative clinical outcomes.[1,25] The current study therefore aimed to investigate whether a delay from time of injury to definitive operation has an impact on patient-reported outcome after operative treatment of severe ankle fractures compared with earlier surgery.

Patients and Methods

Patients with ankle fractures involving the posterior malleolus treated at Haukeland University hospital in Bergen, Norway, from January 2014 through December 2016 were eligible for the study. Ankle fractures with a posterior malleolus fragment (PMF) are known to have a poor outcome and are therefore defined as "severe ankle fractures" in the current paper.[10,23] Inclusion and exclusion criteria are presented in Figure 1. Patients were identified by a selective search in the operation planning system (Orbit version 5.11.2, Evry Healthcare Systems AB) on Nordic Medico-Statistical Committee Classification of Surgical Procedures codes for bi- and trimalleolar fractures. Preoperative radiographs were examined, and only patients with ankle fractures that also involved the posterior malleolus were included.[20] All injuries were low-energy mechanism fractures. Patient charts were reviewed for information concerning patient demographics, type of trauma, fracture characteristics, treatment given, and complications. Eligible patients were invited to a follow-up visit that included clinical examination, radiographs, and patient-reported outcome measures (PROMs)—and the ankle-specific questionnaires thereunder.

The Helse Bergen data protection officer and regional committee for medical and health research ethics (REC) approved the project (REC ID 2016/1720). Informed, signed consent was obtained from all patients prior to inclusion.

The current study assessed if there was a difference in patient-reported outcome between patients treated with definitive surgery within a week from injury (0-7 days) compared with those treated later than a week from injury. To further examine the impact of time for injury to definitive surgery, the patients were stratified based on time from injury to definitive surgery: group 1, within the same day; group 2, within 1-7 days; and group 3, later than 7 days after injury.

Outcome Assessment

Primary outcome was the Self-Reported Foot and Ankle Score (SEFAS).[6–9,11,12] SEFAS was translated into Norwegian,

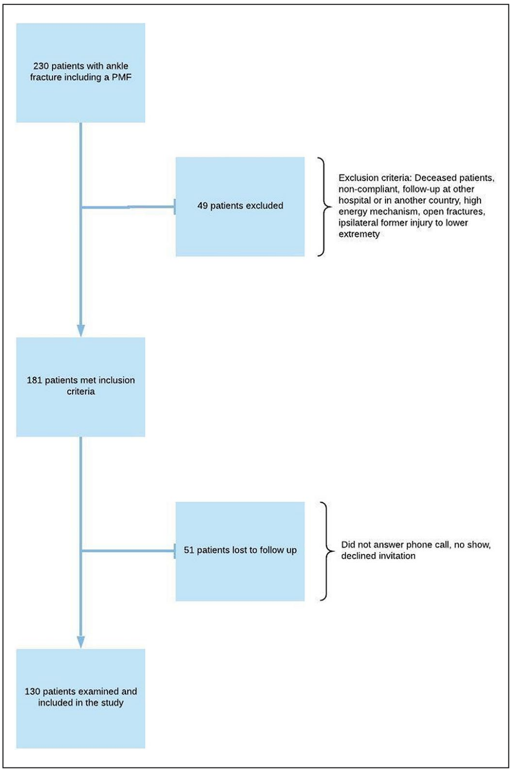


Figure 1. Patient selection, exclusion, and inclusion criteria. PMF, posterior malleolus fracture.

and the translation was approved by the Center on Patient Reported Data.[16] The worst possible score was 0, and the best possible score 48.

Quality of life was assessed using the RAND-36, translated into Norwegian by the Norwegian Institute of Public Health.[14]

Patients scored a visual analog scale (VAS) of Pain from 0 (no pain) to 10 (worst imaginable pain) describing an average of the pain experienced the last 2 weeks before the follow-up appointment. VAS of Satisfaction was rated from 0 (very unsatisfied) to 10 (very satisfied) based on how satisfied the patients were with the result after the injury and the following surgical treatment.

Clinical examination included range of motion (ROM) in passive dorsiflexion and active plantarflexion and heel raise distance for both the operated and the uninjured ankle. Any differences between sides were noted. Positive numbers denote larger movement of the uninjured ankle and negative numbers larger movement of the injured ankle.

Based on chart reviews, complications such as reoperations and revisions, nerve injuries, FRIs,[21] mechanical irritation from implants, and implant removal were registered. Reoperation was defined as any new surgery associated to the primary open reduction and internal fixation (ORIF), due to malreduction or failed syndesmotic fixation after primary surgery. Revision was defined as surgery performed owing to FRI.

Preoperative radiographs were used to grade fractures according to the Weber classification.[30] Grade of osteoarthritis (OA) was assessed according to the Kellgren and Lawrence classification from radiographs acquired at follow-up.[18] Radiographic examination was performed by 2 of the authors, both experienced ankle fracture surgeons (HEJO and KP).

Surgical Technique

Fractures were treated after standard AO principles. Depending on the size of the PMF, patients were either treated with a traditional approach or a posterior approach. With the traditional approach, the fractures of the lateral and/or medial malleoli were openly reduced and fixed via a direct lateral and medial skin incision. If the size of the PMF was considered to involve 25% or more of the distal tibial articulate surface on lateral radiographs, they were fixed with closed reduction and an anteroposterior screw. Smaller fragments were left unfixed. Patients treated with a posterior approach had the PMF fixed after open reduction with a posterolateral and/or medial approach to the fragment. Fibular fractures were fixed through the same posterolateral incision.

Statistics. IBM SPSS version 24 (IBM Corp) and R (CRAN) was used for analyses. SEFAS was assessed both between the group of patients treated within a week vs those treated after a week from injury, and between the 3 stratification groups (definitive surgery at <1 day, 1-7 days, and >7 days from injury). The significance threshold for SEFAS was set at .05. The association of time from injury to definitive surgery on SEFAS was assessed using a linear model while adjusting for age, gender (female), and American Association of Anesthesiologists (ASA) classification. Secondary patient-reported outcomes were tested with a Bonferroni correction at $0.05/3 = 0.017$. Continuous variables for the 3 stratification groups were analyzed with the analysis of variance with 2 degrees of freedom and with post hoc Bonferroni and Tukey honestly significant difference tests. One patient did not report their RAND-36 score and another did not report the VAS of Satisfaction score. Categorical variables were analyzed with Pearson chi-squared test, and between-group differences were controlled for with the Bonferroni method for adjusting P values while comparing column proportions. Dichotomous variables were analyzed with the Student t test for independent variables. The analyses of the reasons for use of external fixation and complications are exploratory and secondary analyses with a threshold of $P = .05$.

Results

The search rendered 181 patients eligible for inclusion. Of these, a total of 130 patients (72%) were available and met to a follow-up consultation at mean 26 (SD 9) months after surgery. Definitive surgery within a week from injury was performed on 86 patients (66%), and 44 patients (34%) were treated >7 days from injury. Distribution of gender, American Society of Anesthesiologists classification, current smoking status, diabetes mellitus, type of fracture (Weber B or C), rate of dislocation fractures, and use of syndesmotic fixation did not differ between these 2 groups of patients (all with P value $> .07$). However, patients who had definitive surgery after a week from injury more frequently got a temporary external fixator prior to definitive surgery (7/86 patients [8%] vs 34/44 [77%], P value $<.001$).

After stratification into 3 groups, there were 44 patients in group 1 (definitive surgery within the same day as the injury), 42 patients in group 2 (definitive surgery within 1-7 days from injury), and 44 patients in group 3 (definitive surgery later than 7 days from injury). Patient demographics and fracture characteristics did not differ between the 3 groups (Table 1).

The mean duration of operation was longer in group 3 compared with the 2 other groups. Patients who were treated with temporary external fixator prior to definitive surgery were only found in group 2 (7 of 42 patients, 17%) and group 3 (34 of 44 patients, 77%) (Table 1). The treatment summary in Table 1 shows that mean time from injury to operation and mean length of stay was longer for these patients. The mean time from injury to application of external fixator was 1 day (SD 1) in group 2 and 2 days (SD 2) in group 3 ($P = .33$). The reasons for applying temporal external fixation were similar across groups (Table 2). The exceptions were a higher frequency of unreducible (by cast application) fractures and that the surgeon on call considered it better for the patient to temporarily have the ankle reduced in an external fixator in group 3. Severe soft tissue swelling (33/41 patients) and skin necrosis or blisters in need of healing (8/41 patients) were the main reasons for a delay from application of external fixation until definitive surgery. Among the 59 patients with a dislocation fracture of the ankle, 31 (53%) patients did not get an external fixator, whereas 28 (47%) patients did. Patient and fracture characteristics of patients who did and did not get an external fixator and patients with and without a dislocation fracture are presented in Table 3.

A posterior approach for surgery was used in 54 (42%) patients whereas the traditional approach was used in 76

Table 1. Patient Demographics, Fracture Characteristics, Treatment Summary, and Complications Based on Time (Days) From Injury to Definitive Surgery.

	<1 d (n = 44)	1-7 d (n = 42)	>7 d (n = 44)	*P* Value
Patient factors				
Female, n (%)	34 (77)	30 (71)	30 (68)	.6
Age, y, mean (SD)	53 (16)	54 (18)	55 (16)	.9
ASA ≥ 3, n (%)	0 (0)	2 (5)	4 (9)	.1
Diabetes, n (%)	1 (2)	1 (2)	4 (9)	.2
Smoking, n (%)	8 (18)	6 (14)	10 (23)	.6
Fracture characteristics, n (%)				
Weber class B/C	29 (66)/15 (34)	25 (60)/17 (40)	25 (57)/19 (43)	.7
Ankle fracture dislocation	17 (39)	18 (43)	24 (55)	.3
Treatment summary[a]				
Time from injury to operation, d, mean (SD)	0 (0)[b]	4 (2)[c]	12 (3)[d]	<.001
Length of stay, d, mean (SD)	3 (2)[b]	8 (4)[c]	16 (5)[d]	<.001
Postoperative length of stay, d, mean (SD)	3 (2)	3 (3)	4 (4)	.2
Duration of operation, min, mean (SD)	86 (37)	89 (36)	124 (51)[d]	<.001
External fixator, temporary, n (%)	0 (0)[b]	7 (17)[c]	34 (77)[d]	<.001
Syndesmotic fixation, n (%)	31 (71)	21 (50)	20 (46)	.04[e]

Abbreviation: ASA, American Society of Anesthesiologists classification.
[a]Post hoc analyses for differences between groups were performed with both Tukey honestly significant difference and Bonferroni.
[b]Statistically significant difference at an alpha level of 0.017 between group 1 and both groups 2 and 3.
[c]Group 2 differs from groups 1 and 3.
[d]Group 3 (≥7 days) differs from both groups 1 and 2.
[e]Post hoc analysis of between-group differences of categorical variables were performed with Bonferroni method for adjusting *P* values while comparing column proportions. Significant difference was found in the use of syndesmotic fixation between group 1 and 3 ($P = .018$), but not between group 1 and 2 or group 2 and 3.

Table 2. Reasons for Applying External Fixator.[a]

	<1 d, n (%) (n = 44)	1-7 d, n (%) (n = 42)	>7 d, n (%) (n = 44)	*P* Value[b]
Difficult fracture reduction in the ED	0	4 (10)	14 (32)[c]	.01
Soft tissue swelling and blisters	0	1 (2)	4 (9)	.2
Dislocation of fracture while in cast	0	2 (5)	8 (18)	.04
Considered initially better for soft tissue	0	0	7 (16%)[c]	.01
Skin excoriation at time of injury	0	0	1 (2)	.3

Abbreviation: ED, emergency department.
[a]A total of 41 patients had an external fixator applied prior to definitive surgery.
[b]*P* values in the table are calculated with chi-square analyses from a cross-table with 1 degree of freedom comparing group 2 (1-7 days) and group 3 (>7 days).
[c]Using Bonferroni post hoc analyses, group 3 (>7 days) significantly differs from group 1 and 2. Post hoc analysis does not reveal any significant difference between group 1 and group 2.

(58%) patients. In patients treated later than 7 days from injury, 33 of 44 were treated with a posterior approach ($P < .001$).

Outcome Evaluation at Follow-up

When applying a dichotomous analysis strategy, patients treated later than a week from injury had a lower mean SEFAS, higher VAS of Pain, and lower VAS of Satisfaction than patients treated within a week from injury (Table 4). The distribution of SEFAS in these patient groups are presented in Figure 2.

After stratifying the patients into 3 groups, the patients in group 3 (>7 days) had a lower mean SEFAS than patients in groups 1 and 2 (Table 5). Linear modeling of SEFAS by time from injury to definitive operation adjusted for age, gender (female), and American Society of Anesthesiologists classification showed that time to operation ($P = .002$) and

Table 3. Patient Demographics, Fracture Characteristics, and Treatment Summary for Patients Treated With or Without a Temporary External Fixator, and Patients With and Without a Dislocation Fracture.

				Patients With Dislocation Fracture (n = 59)		
	No Ex-Fix (n = 89)	Ex-Fix (n = 41)	*P* Value	<7 d (n = 35)	>7 d (n = 24)	*P* Value
Patient factors						
Female, n (%)	66 (74%)	28 (68%)	.5	25 (71%)	18 (75%)	.8
Age, y, mean (SD)	53 (17)	57 (16)	.2	55 (17)	56 (13)	.7
ASA ≥ 3, n (%)	2 (2%)	4 (10%)	.06	2 (6%)	2 (8%)	.7
Diabetes, n (%)	4 (5%)	2 (5%)	.9	2 (6%)	3 (13%)	.4
Smoking, n (%)	16 (18%)	8 (20%)	.4	4 (11%)	6 (25%)	.2
Fracture characteristics, n (%)						
Weber class B/C	54 (61%)/ 35 (49%)	25 (61%)/ 16 (39%)	>.99	22 (63%)/ 13 (37%)	14 (58%)/ 10 (42%)	.7
Dislocation fracture	31 (35%)	28 (68%)	<.001			
External fixator				6 (17%)	22 (92%)	<.001
Treatment summary, mean (SD)						
Time from injury to operation, d	3 (4)	11 (4)	<.001	2 (3)	11 (3)	<.001
Length of stay, d	6 (4)	16 (6)	<.001	6 (4)	16 (5)	<.001
Duration of operation, min	91 (41)	119 (48)	.01	94 (39)	126 (49)	.009

Abbreviations: ASA, American Society of Anesthesiologists classification; Ex-Fix, external fixator.

Table 4. PROMs at Follow-up Stratified by Treatment Within or More Than 1 Week From Injury.

	≤ 7 d, Mean (SD) (n = 86)	>7 d, Mean (SD) (n = 44)	*P* Value[a]
SEFAS	38 (9)	34 (10)	.01
RAND-36[b]	74 (20)	71 (18)	.4
VAS of Pain[c]	2 (2)	3 (2)	<.01
VAS of Satisfaction[d]	8 (2)	7 (3)	.02

Abbreviations: PROMs, patient-reported outcome measures; SEFAS, Self-Reported Foot and Ankle Score; VAS, visual analog scale.
[a]Post hoc analysis for between-group differences were performed with the Tukey honestly significant difference and Bonferroni tests.
[b]RAND-36 is a generic PROM for quality of life.
[c]VAS of Pain: 0 = no pain and 10 = worst possible pain. Pain score is an average value of pain experienced the last 2 weeks before the clinical examination.
[d]VAS of Satisfaction: 0 = very disappointed and 10 = very satisfied with the result.

gender (female) (P = .001) were associated with poorer SEFAS (Table 6). Group 3 had a significantly lower SEFAS compared with both group 1 (P = .015) and group 2 (P = .021) when analyzed in a general linear model with time from injury to operation stratified to the 3 groups as an ordinal variable (Table 6). Quality of life (RAND-36) and satisfaction (VAS) was similar between the 3 stratification groups (Table 5). VAS of pain (P = .03) was not significant at $\alpha = 0.017$ (Table 5).

Mean SEFAS at follow-up for patients who were treated with a temporary external fixation prior to definitive surgery was 33 (SD 10) compared to 38 (SD 8) for patients that did not get an external fixator, P = .005 (Table 7). The 5 patients treated with temporal external fixator due to severe soft tissue swelling and blisters had the lowest reported mean SEFAS of 27 (SD 9).

Fracture type (Weber B and C) and patients with and without a dislocation fracture reported similar score on subanalyses of SEFAS (P = .6 and P = .4, respectively). Mean SEFAS among patients who had a dislocation fracture of the ankle and who were treated within a week from injury was 38 (SD 10) points and 32 (SD 12) points for those treated after a week from injury, P = .05 (Table 7).

The mean difference in dorsal flexion at follow-up between the injured and noninjured ankle was similar between patients treated within a week (9 degrees [SD 9]) and patients treated later than a week from injury (11 degrees [SD 8]), P = .16. It was also similar across the

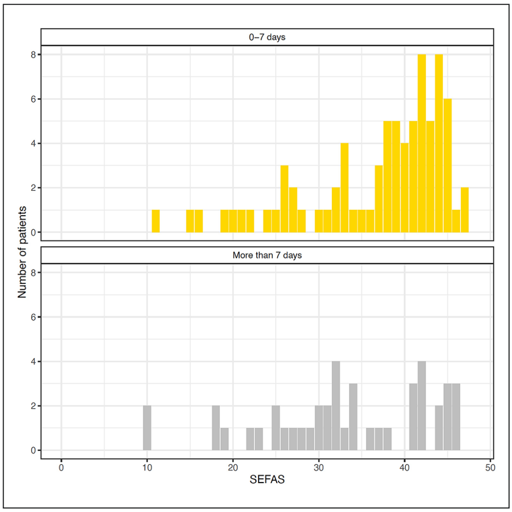


Figure 2. Histograms of the distribution of Self-Reported Foot and Ankle Score (SEFAS) in patients treated within (upper panel) and after (lower panel) a week from injury.

3 stratification groups: 9 degrees (SD 10) in group 1, 9 degrees (SD 7) in group 2, and 11 degrees (SD 8) in group 3, P = .37.

Complications

Applying a dichotomous analysis of complications comparing patients treated within a week from injury to patients treated after a week from injury revealed similar frequencies of FRI (P = .83), postoperative soft tissue problems (P = .34), nerve injury (P = .12), and reoperations (P = .45). However, patients treated later than a week from injury had more frequent preoperative soft tissue problems (<.001) and high-grade osteoarthritis (.02). Implant removal was more frequent among patients treated within a week from injury (P = .002).

A total of 9 patients (7%) needed revision surgery; there was no difference in reoperation between the 3 stratification groups (Table 8).

Clinical signs of FRI were found in 25 (19%) of the 130 patients, with no difference between the groups (Table 8). Comparing patients with FRI to those without FRI within group 3, a tendency toward lower mean SEFAS at follow-up was seen in patients with FRI (27 [SD 12] vs 35 [SD 9]; P = .07).

Nerve injuries were present—either as a reduced skin sensation or paresthesia on the dorsolateral side of the foot—in 23 of 130 (18%) patients. The incidence was similar across the 3 groups.

Planned removal of syndesmotic screws was the main reason for a high frequency of implant removal in group 1 (11 of the 23 patients).

Discussion

A major finding in this study was that patients with severe ankle fractures waiting >7 days until definitive surgery reported lower patient-reported outcome, a lower VAS of Satisfaction, and a higher VAS of Pain than to those who had definitive surgery within a week from injury. Those who waited more than a week had more frequently received temporary external fixation prior to definitive surgery and had a longer duration of surgery. Gender (female) was also an independent risk factor for worse patient-reported outcome, similarly to Storesund et al,[28] who found women to report a higher postoperative VAS of Pain than men.

Lower patient-reported outcome and more pain in patients who had definitive surgery after a week from injury is also reported by others.[22,26] Normative mean values for SEFAS are 46 (SD 5) for men and 42 (SD 6) for women, and the minimal clinically important difference has formerly been described to be 5 points.[7,9] At a mean 26 months, patients in all 3 stratification groups in the current study reported an SEFAS that was more than 5 points lower than that found in the general population among men and 4 points lower than among women, reflecting the severity of their injury. However, the use of minimal clinically important difference or minimal clinically important change (MCIC) is intended for interpretation of the treatment effect within individual patients. To apply these cutoffs as a yardstick on a group level is warned against and even termed misleading.[3,17] Further research is needed to aid the interpretation of ankle-specific PROMs, including further estimates of minimal important differences between treatment groups. Based on limited available evidence, we believe that there is an important difference between the 2 groups (treatment within or after a week from injury). The histogram of SEFAS among patients treated after 1 week from injury shows that the majority of these patients report below 35 points while patients treated within 1 week from injury are clustered above 35 points. Fractures that are difficult to reduce might suggest more extensive and complex fractures, but the patient and fracture characteristics and injury mechanisms were similar, regardless of time between injury and definitive surgery. The tendency of more frequent high-grade osteoarthritis in patients who waited more than a week until definitive surgery may explain the inferior ankle function found among these patients (P = .05). Also, neither the presence of a dislocation fracture or the fracture type had an association to lower PROM score. However, patients with a dislocation fracture who were treated within a week from injury reported better PROM than those treated after a week from injury. Loss of dorsiflexion has formerly

Table 5. PROMs at Follow-up Stratified by Time From Injury to Definitive Surgery.

	<1 d, Mean (SD) (n = 44)	1-7 d, Mean (SD) (n = 42)	>7 d, Mean (SD) (n = 44)	*P* Value[a]
SEFAS	38 (9)	38 (9)	34 (10)	0.04
RAND-36[b]	77 (19)	71 (20)	71 (18)	0.3
VAS of Pain[c]	2 (2)	2 (2)	3 (2)	0.03
VAS of Satisfaction[d]	8 (2)	8 (2)	7 (3)	0.06

Abbreviations: PROMs, patient-reported outcome measures; SEFAS, Self-Reported Foot and Ankle Score; VAS, visual analog scale.
[a]Post hoc analysis for between-group differences were performed with the Tukey honestly significant difference and Bonferroni tests. Group 3 (<7 days) had a mean 1.1 points (95% CI, –2.6, 2.2) higher VAS of Pain than group 1 (<1 day), with a *P* value = .03. However, the result was not significant at an alpha level of .017.
[b]RAND-36 is a generic PROM for quality of life.
[c]VAS of Pain: 0 = no pain and 10 = worst possible pain. Pain score is an average value of pain experienced the last 2 weeks before the clinical examination.
[d]VAS of Satisfaction: 0 = very disappointed and 10 = very satisfied with the result. Siginificance level for SEFAS is .05 and .05/3 = .017 for RAND-36, VAS of Pain, and VAS of Satisfaction.

Table 6. General Linear Model With Univariate Analysis of Variance of SEFAS With Time From Injury to Operation, Adjusted for Age, Gender (Female), and ASA Classification.[a]

Parameter	Beta	SE	*t*	Significance Level	95% CI Lower Bound	95% CI Upper Bound
Time from injury to operation (days) as a continuous variable (*R*-squared = 0.153)						
Intercept	42.43	3.25	13.05	<.001	35.99	48.86
Time from injury to operation (days)[b]	–0.45	0.15	–3.09	.002	–0.73	–0.16
Gender (female)	–5.79	1.73	–3.35	.001	–9.22	–2.37
Age, y	0.08	0.05	1.56	.12	–0.02	0.17
ASA classification	–2.13	1.43	–1.49	.14	–4.96	0.69
Time from injury to operation (days) as a categorical, ordinal variable (3 groups) (*R*-squared = 0.142)						
Intercept	37.72	3.48	10.85	<.001	30.84	44.60
Time from injury to operation						
Group 1 (<1 d)	4.63	1.88	2.46	.015	0.90	8.35
Group 2 (1-7 d)	4.41	1.89	2.34	.02	0.67	8.15
Groups 3 (>7 d)	0[c]					
Gender (female)	–5.48	1.74	–3.15	.002	–8.92	–2.03
ASA classification	–2.55	1.44	–1.78	.08	–5.39	0.29
Age, y	0.07	0.05	1.47	.15	–0.03	0.17

Abbreviations: ASA, American Society of Anesthesiologists classification; SEFAS, Self-Reported Foot and Ankle Score.
[a]Results of analyses with time to operation as both a continuous variable and a categorical, ordinal, variable.
[b]The continuous variable of time from injury to operation was used in this analysis.
[c]Reference group.

been reported to predict a poor clinical outcome,[13] but no such association was found in the present study.

Patients who were treated with a temporal external fixator reported poorer clinical outcome. The use of temporal external fixator was an important contributor to the prolonged length of stay. For some of the patients the external fixator was applied several days after admission and thus further prolonging the time to definitive operation. After application of the external fixator, there could be some complacency—the ankle would be considered safe and not in need of urgent surgery, further postponing definitive surgery. Further, as a consequence of the use of temporary external fixation, the patients were exposed to surgery twice—with the risks of complications that might follow. It has been suggested that the temporal external fixator could be placed in the emergency department in local anesthetics

Table 7. SEFAS for Patients Treated With or Without a Temporary External Fixator, and Patients With and Without a Dislocation Fracture.

	No Ex-Fix, Mean (SD) (n = 89)	Ex-Fix, Mean (SD) (n = 41)	*P* Value	Patients With Dislocation Fracture (n = 59) <7 d, Mean (SD) (n = 35)	>7 d, Mean (SD) (n = 24)	*P* Value
SEFAS	38 (8)	33 (10)	.005	38 (10)	32 (12)	.05
VAS of Pain[a]	2 (2)	3 (2)	.001	2 (2)	3 (2)	.008
VAS of Satisfaction[b]	8 (2)	7 (3)	.04	9 (2)	7 (2)	.001

Abbreviations: Ex-Fix, external fixator; SEFAS, Self-Reported Foot and Ankle Score; VAS, visual analog scale.
[a]VAS of Pain: 0 = no pain and 10 = worst possible pain. Pain score is an average value of pain experienced in the last 2 weeks before the clinical examination.
[b]VAS of Satisfaction: 0 = very disappointed and 10 = very satisfied with the result.

Table 8. Distribution of Complications Based on Time From Injury to Operation.[a]

	<1 d, n (%) (n = 44)	1-7 d, n (%) (n = 42)	>7 d, n (%) (n = 44)	*P* Value
Complications				
Fracture-related infection	9 (20)	8 (19)	8 (18)	>.99
Soft tissue problems preoperatively	0	2 (5)	10 (23)[b]	.001
Soft tissue problems postoperatively	3 (7)	9 (21)	9 (20)	.10
Nerve injury	7 (16)	5 (12)	11 (25)	.30
Reoperations	5 (11)	2 (5)	2 (4)	.40
Implant removal	23 (52)[c]	14 (33)	7 (16)	.02
Osteoarthritis grade 2-4	3 (7)	5 (12)	11 (25)	.05

[a]Removal of syndesmotic screws were part of the treatment protocol and is the cause of removal for 11 of 23 patients in group 1 (<1 day). Preoperative soft tissue problems were severe swelling and bullae development. Postoperative problems were prolonged wound healing, skin necrosis, and wound secretion. Patients included in fracture-related infections had either prolonged wound healing, wound discharge/secretion, or wound dehiscence, and does not include skin necrosis that were not surgically treated. Post hoc analysis of between-group differences of categorical variables were performed with Bonferroni method for adjusting *P* values while comparing column proportions.
[b]Statistically significant difference at an alpha level of 0.05 between group 3 and both group 1 and 2, but not between groups 1 and 2.
[c]Statistically significant difference at an alpha level of 0.05 between group 1 and both group 2 and 3, but not between groups 2 and 3.

and sedation to reduce delay till definitive surgery.[27] This is, however, not common practice at our clinic. The application of a temporal external fixator to reduce soft tissue complications and improve outcome did not seem to benefit the patients in the present study. Almost 80% of patients who had definitive surgery more than 1 week from the time of injury got a temporary external fixation. Due to sparse data for the patients who had external fixation and definitive surgery within 1 week from injury, and those without external fixation with definitive surgery after 1 week from injury, subanalyses of SEFAS on these groups would have limited value. With the current data, it is not possible to distinguish between the impact of external fixation and time from injury to operation on SEFAS. Patient characteristics and fracture type (Weber B/C) did not differ between those who did not and those who did get an external fixator. In addition, the majority of patients with a dislocation fracture did not get a temporary external fixator. Even among patients with a dislocation fracture, those treated within a week from injury had the highest mean SEFAS. All in all, acute, definitive surgery would reduce both the use of external fixation and time until definitive surgery.

The longer duration of surgery among patients who waited more than a week till ORIF might reflect a more complex injury or operation. The fact that three-quarters of these patients were treated with a posterior approach also supports such a notion. Mean time to definitive operation was 12 days among patients who waited more than a week. Such a delay could make the soft tissue and fractures more challenging to handle intraoperatively compared to at an immediate operation—leading to a more meticulous surgical procedure. Poorer outcome in this group, compared to those with a shorter wait, is similar to the findings of other studies.[22,25]

Similar rates of FRIs were found between the 3 groups of the current study with an overall rate of 19%.[21] All groups had a higher complication rate than the 12.9% that Schepers et al found in patients operated later than 6 days from injury and 3.4% in patients treated within 6 days from injury.[26] The same authors also reported inferior clinical outcomes in patients with infectious wound complications, similar to the current study. Saithna et al also report higher incidence of infection in patients treated after 6 days from injury (3.6% vs 20.7%, $P = .010$).[25] The high rate of postoperative infection in the present study was a worrying finding that requires further investigation.

SEFAS was chosen as the primary outcome, as it is validated for ankle fractures. This strengthens the reliability of the current results. Among several questionnaires, SEFAS has been considered to have the best measurement properties for patients treated for ankle fractures.[12] The current cohort was also evaluated with a multitude of outcome measures, including radiographs. Further, a focus on a thorough reporting of complication rates has allowed for subanalyses across the stratified groups of the study. In summary, this gives a more complete picture of outcomes and functional performance after severe ankle fractures. The current study presents a transparent evaluation of clinical practice at a Level 1 trauma hospital.

The retrospective study design limits the generalizability of the current results. Seventy-two percent (130/180) of the eligible patients were examined. A level of nonresponder bias may therefore be present. Similarly, although fracture characteristics are similar between the groups, a selection of more severe injuries to group 3 cannot be ruled out. This may confound our findings to some extent. In addition, there may have been an interaction between the use of temporary external fixation and time to surgery, as discussed above. The majority of patients who waited more than 7 days until definitive surgery had their ankle fracture treated via a posterior approach.

Conclusion

In our study, we found that patients with low-energy ankle fractures with a posterior malleolar fragment who waited more than a week for definitive surgery had a higher rate of preoperative soft tissue problems and reported poorer clinical outcome and more pain. The patients with delayed treatment were more often treated with a temporary external fixation before definitive surgery. In our series, use of temporary external fixation to resolve soft tissue problems preoperatively did not prevent poorer ankle function 2 years after surgery. A delay from injury until definitive surgery of more than 7 days was not found beneficial for the patients included in this study. Our findings further suggest that patients with dislocation fractures had better outcomes when definitively treated within 7 days.

Acknowledgments

We would like to thank professor and statistician Stein Atle Lie for advice on the statistical analyses.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. ICMJE forms for all authors are available online.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Kristian Pilskog, MD, https://orcid.org/0000-0002-8866-9045
Teresa Brnic Gote, MSc, https://orcid.org/0000-0002-3902-1218
Håvard Dale, MD, PhD, https://orcid.org/0000-0002-2962-2706
Eivind Inderhaug, MD, PhD, https://orcid.org/0000-0001-7959-163X

References

1. Aigner R, Salomia C, Lechler P, Pahl R, Frink M. Relationship of prolonged operative time and comorbidities with complications after geriatric ankle fractures. *Foot Ankle Int*. 2017;38(1):41-48. doi:10.1177/1071100716667315
2. Allgöwer M, Müller ME, Schneider R, Willenegger H. *Manual of Internal Fixation: Techniques Recommended by the AO-ASIF Group*. Springer Science and Business Media; 2013. Accessed September 7, 2020. https://books.google.no/books/about/Manual_of_INTERNAL_FIXATION.html?id=3J4iBgAAQBAJ&redir_esc=y
3. Austevoll IM, Gjestad R, Grotle M, et al. Follow-up score, change score or percentage change score for determining clinical important outcome following surgery? An observational study from the Norwegian Registry for Spine Surgery evaluating patient reported outcome measures in lumbar spinal stenosis and lumbar degenerative spondylolisthesis. *BMC Musculoskelet Disord*. 2019;20(1):31. doi:10.1186/S12891-018-2386-Y
4. Bäcker HC, Greisberg JK, Vosseller JT. Fibular plate fixation and correlated short-term complications. *Foot Ankle Spec*. 2020;13(5):378-382. doi:10.1177/1938640019873539
5. Chou LB, Lee DC. Current concept review: Perioperative soft tissue management for foot and ankle fractures. *Foot Ankle Int*. 2009;30(1):84-90. doi:10.3113/FAI.2009.0084
6. Cöster M, Karlsson MK, Nilsson JÅ, Carlsson Å. Validity, reliability, and responsiveness of a self-reported foot and ankle score (SEFAS). *Acta Orthop*. 2012;83(2):197-203. doi:10.3109/17453674.2012.657579
7. Cöster MC, Nilsdotter A, Brudin L, Bremander A. Minimally important change, measurement error, and responsiveness for the Self-Reported Foot and Ankle Score. *Acta Orthop*. 2017;88(3):300-304. doi:10.1080/17453674.2017.1293445

8. Cöster MC, Rosengren BE, Bremander A, Brudin L, Karlsson MK. Comparison of the Self-Reported Foot and Ankle Score (SEFAS) and the American Orthopedic Foot and Ankle Society Score (AOFAS). *Foot Ankle Int*. 2014;35(10): 1031-1036. doi:10.1177/1071100714543647.
9. Cöster MC, Rosengren BE, Karlsson MK, Carlsson Å. Age- and gender-specific normative values for the Self-Reported Foot and Ankle Score (SEFAS). *Foot Ankle Int*. 2018;39(11): 1328-1334. doi:10.1177/1071100718788499.
10. Drijfhout van Hooff CC, Verhage SM, Hoogendoorn JM. Influence of fragment size and postoperative joint congruency on long-term outcome of posterior malleolar fractures. *Foot Ankle Int*. 2015;36(6):673-678. doi:10.1177/1071100715570895.
11. Erichsen JL, Jensen C, Larsen MS, Damborg F, Viberg B. Danish translation and validation of the Self-Reported Foot and Ankle Score (SEFAS) in patients with ankle related fractures. *Foot Ankle Surg*. 2021;27(5):521-527. doi:10.1016/J.FAS.2020.06.014.
12. Garratt AM, Naumann MG, Sigurdsen U, Utvåg SE, Stavem K. Evaluation of three patient reported outcome measures following operative fixation of closed ankle fractures. *BMC Musculoskelet Disord*. 2018;19(1):134. doi:10.1186/s12891-018-2051-5.
13. Hancock MJ, Herbert RD, Stewart M. Prediction of outcome after ankle fracture. *J Orthop Sports Phys Ther*. 2005;35(12):786-792. doi:10.2519/jospt.2005.35.12.786
14. Hays RD, Morales LS. The RAND-36 measure of health-related quality of life. *Ann Med*. 2001;33(5):350-357.
15. Höiness P, Engebretsen L, Strömsöe K. The influence of perioperative soft tissue complications on the clinical outcome in surgically treated ankle fractures. *Foot Ankle Int*. 2001;22(8):642-648. doi:10.1177/107110070102200805
16. In English: Centre on patient-reported outcomes data - Helse Bergen. Accessed February 27, 2021. https://helse-bergen.no/fag-og-forsking/forsking/fagsenter-for-pasientrapportert-data/in-english-centre-on-patient-reported-outcomes-data
17. Katz NP, Paillard FC, Ekman E. Determining the clinical importance of treatment benefits for interventions for painful orthopedic conditions. *J Orthop Surg Res*. 2015;10(1). doi:10.1186/S13018-014-0144-X
18. Kohn MD, Sassoon AA, Fernando ND. Classifications in brief: Kellgren-Lawrence classification of osteoarthritis. *Clin Orthop Relat Res*. 2016;474(8):1886-1893. doi:10.1007/s11999-016-4732-4
19. Lloyd JM, Martin R, Rajagopolan S, Zieneh N, Hartley R. An innovative and cost-effective way of managing ankle fractures prior to surgery, home therapy. *Ann R Coll Surg Engl*. 2010;92(7):615-618. doi:10.1308/003588410X12699663904358
20. Mason LW, Marlow WJ, Widnall J, Molloy AP. Pathoanatomy and associated injuries of posterior malleolus fracture of the ankle. *Foot Ankle Int*. 2017;38(11):1229-1235. doi:10.1177/1071100717719533
21. Metsemakers WJ, Morgenstern M, McNally MA, et al. Fracture-related infection: A consensus on definition from an international expert group. *Injury*. 2018;49(3):505-510. doi:10.1016/j.injury.2017.08.040
22. Naumann MG, Sigurdsen U, Utvåg SE, Stavem K. Associations of timing of surgery with postoperative length of stay, complications, and functional outcomes 3–6 years after operative fixation of closed ankle fractures. *Injury*. 2017;48(7): 1662-1669. doi:10.1016/j.injury.2017.03.039
23. Pilskog K, Gote TB, Odland HEJ, et al. Traditional approach vs posterior approach for ankle fractures involving the posterior malleolus. *Foot Ankle Int*. 2021;42(4):389-399. doi:10.1177/1071100720969431
24. Riedel MD, Parker A, Zheng M, et al. Correlation of soft tissue swelling and timing to surgery with acute wound complications for operatively treated ankle and other lower extremity fractures. *Foot Ankle Int*. 2019;40(5):526-536. doi:10.1177/1071100718820352
25. Saithna A, Moody W, Jenkinson E, Almazedi B, Sargeant I. The influence of timing of surgery on soft tissue complications in closed ankle fractures. *Eur J Orthop Surg Traumatol*. 2009;19(7):481-484. doi:10.1007/s00590-009-0455-5
26. Schepers T, De Vries MR, Van Lieshout EMM, Van der Elst M. The timing of ankle fracture surgery and the effect on infectious complications; A case series and systematic review of the literature. *Int Orthop*. 2013;37(3):489-494. doi:10.1007/s00264-012-1753-9
27. Shah KN, Johnson JP, O'Donnell SW, Gil JA, Born CT, Hayda RA. External fixation in the emergency department for pilon and unstable ankle fractures. *J Am Acad Orthop Surg*. 2019;27(12):e577-e584. doi:10.5435/JAAOS-D-18-00080
28. Storesund A, Krukhaug Y, Olsen MV, Rygh LJ, Nilsen RM, Norekvål TM. Females report higher postoperative pain scores than males after ankle surgery. *Scand J Pain*. 2016;12:85-93. doi:10.1016/j.sjpain.2016.05.001
29. Wawrose RA, Grossman LS, Tagliaferro M, Siska PA, Moloney GB, Tarkin IS. Temporizing external fixation vs splinting following ankle fracture dislocation. *Foot Ankle Int*. 2020;41(2):177-182. doi:10.1177/1071100719879431
30. Weber BG. Classification of ankle fractures. In: *Die Verletzungen des oberen Sprung-gelenkes*. 2nd ed. Verlag Hans Huber; 1972.
31. Zaghloul A, Haddad B, Barksfield R, Davis B. Early complications of surgery in operative treatment of ankle fractures in those over 60: a review of 186 cases. *Injury*. 2014;45(4): 780-783. doi:10.1016/j.injury.2013.11.008

Injury 54 (2023) 841–847

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Fracture-related infection: Prevalence and application of the new consensus definition in a cohort of 1004 surgically treated ankle fractures

Kristian Pilskog[a,b,*], Pål Høvding[a], Eivind Inderhaug[a,b], Jonas Meling Fevang[a,b], Håvard Dale[a,b]

[a] Orthopedic Department, Haukeland University Hospital, Pb 1700, Bergen 5021, Norway
[b] Department of Clinical Medicine (K1), University of Bergen, Pb 7804, Bergen 5020, Norway

ARTICLE INFO

Article history:
Accepted 30 December 2022

Keywords:
Fracture-related infection
FRI
Ankle
Fracture
Definition
Infection
Surgical site infection
Operative treatment
Orthopedic
Postoperative infection

ABSTRACT

Background: Surgical treatment of ankle fractures comes with a substantial risk of complications, including infection. An unambiguously definition of fracture-related infections (FRI) has been missing. Recently, FRI has been defined by a consensus group with a diagnostic algorithm containing suggestive and confirmatory criteria. The aim of the current study was to report the prevalence of FRI in patients operated for ankle fractures and to assess the applicability of the diagnostic algorithm from the consensus group.

Patients and methods: Records of all patients with surgically treated ankle fractures from 2015 to 2019 were retrospectively reviewed for signs of postoperative infections. Patients with suspected infection were stratified according to *confirmatory* or *suggestive criteria* of FRI. Rate of FRI among patients with *confirmatory* and *suggestive criteria* were calculated.

Results: Suspected infection was found in 104 (10%) out of 1004 patients. Among those patients, *confirmatory criteria* were met in 76/104 (73%) patients and *suggestive criteria* were met in 28/104 (27%) at first evaluation. Patients with clinical confirmatory criteria ($N = 76$) were diagnosed with FRI. Patients with suggestive criteria were further examined with either bacterial sampling at the outpatient clinic, revision surgery including bacterial sampling, or a wait-and-see approach. Eleven (39%) of the 28 patients had positive cultures and were therefore diagnosed as having FRI at second evaluation. In total 87 (9%) patients were diagnosed with FRI according to the consensus definition. Only 73 (70%) of the 104 patients with suspected FRI had adequate bacterial sampling.

Conclusion: The prevalence of FRI, applying the FRI-consensus criteria, for patients with surgically treated ankle fractures was 9%. Twenty-two percent of patients who met the *confirmatory criteria* had negative bacterial cultures. The current study shows that we did not have a systematic approach to patients with suspected FRI as recommended by the consensus group. A systematic approach to adequate bacterial sampling when FRI is suspected is paramount. The consensus definition of FRI and its diagnostic algorithm facilitates such an approach.

Level of evidence: Level III – retrospective cohort study

Introduction

Ankle fractures constitute 9% of all fractures and have an incidence of 107–187 per 100,000 persons per year [1,2]. Operative treatment comes with a substantial risk of complications, including wound healing problems and postoperative infection. After ankle fracture surgery the incidence of infection and wound dehiscence reportedly varies from 2.6% to 17.6% [3–5]. Until recently, except the more general Center for Disease Control and Prevention (CDC) definition of postoperative surgical site infection (SSI), the lack of a standardized definition of infection after fracture surgery has precluded comparisons across studies [6–8].

A consensus group of orthopedic surgeons, radiologists, microbiologists, pharmacists, and infection disease specialists proposed a new definition denoted *fracture-related infection* (FRI) in 2017 [9]. The definition was updated in 2020 [10]. This consensus distin-

* Corresponding author at: Orthopedic Department, Haukeland University Hospital, Pb 1700, Bergen 5021, Norway.
E-mail address: kpilskog@gmail.com (K. Pilskog).

https://doi.org/10.1016/j.injury.2022.12.030

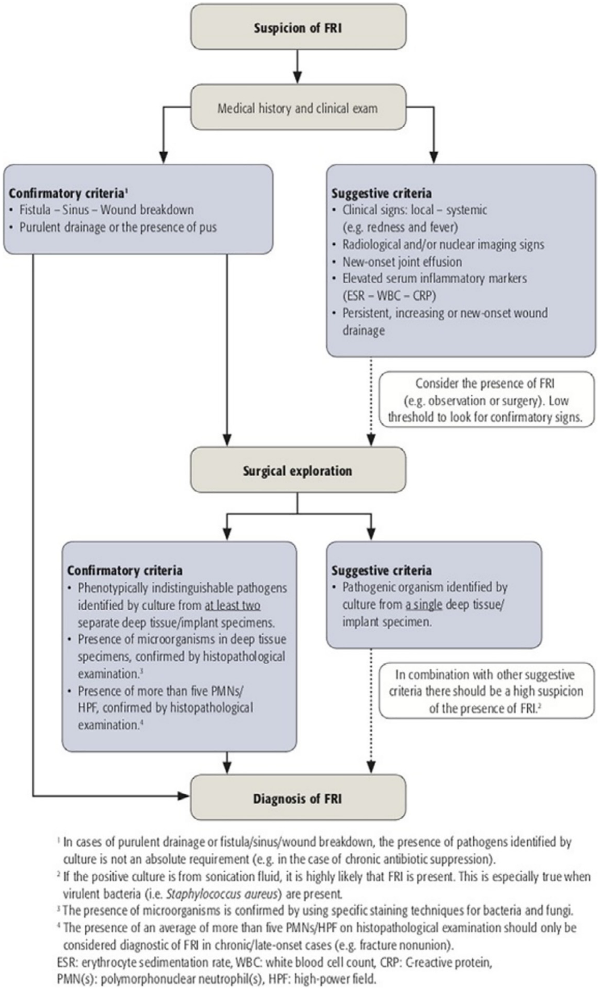


Fig. 1. Definition and flow-chart for diagnosis of Fracture-related infection. Figure from "Diagnosing Fracture-related Infection: Current Consepts and Recommendations", Govaert GAM, Kuehl R, Atkins BL, Trampuz A, Morgenstern M, Obremskey WT, Verhofstad MHJ, McNally MA, Metsemakers WJ; Fracture-Related Infection (FRI) Consensus Group. J Orthop Trauma. 2020 Jan;34(1):8–17.
The figure is adapted from: Fracture-related infection: A consensus on definition from an international expert group. Metsemakers WJ, Morgenstern M, McNally MA, Moriarty TF, McFadyen I, Scarborough M, Athanasou NA, Ochsner PE, Kuehl R, Raschke M, Borens O, Xie Z, Velkes S, Hungerer S, Kates SL, Zalavras C, Giannoudis PV, Richards RG, Verhofstad MHJ. Injury. 2018 Mar;49(3):505–510.

guishes between *confirmatory* and *suggestive* criteria of FRI (Fig. 1). *Confirmatory criteria* are the presence of fistulas, sinus formation, or wound breakdown with communication to bone or implant. Presence of purulent drainage or pus also confirms an infection. These clinical signs are considered pathognomonic of FRI [11]. Further *confirmatory criteria* include phenotypically indistinguishable pathogens identified by culture from at least two separate deep tissue/implant specimens - and the presence of microorganisms in deep tissue specimens, confirmed by histopathological examination. In the updated definition from 2020 the presence of ≥5 polymorphonuclear neutrophils per high-power-field (PMN/HPF) was also included as a confirmatory sign for late-onset cases [10].

Suggestive criteria include clinical signs of infection (redness, swelling, warmth, pain, and fever), radiological signs, new-onset joint effusion, elevated serum inflammatory markers (white blood cell count (WBC), C-reactive protein (CRP), erythrocyte sedimentation rate (ESR)), and persistent, increasing or new-onset wound drainage. The *suggestive criteria* require a surgical exploration for the confirmation of FRI. A positive culture from a single deep tissue/implant specimen is also considered a suggestive criterion which, in combination with other *suggestive criteria*, should give a high suspicion of FRI [9]. Positive findings on nuclear imaging such as 3-phase bone scan, fluorodeoxyglucose positron emission tomography (FDG-PET), and white blood cell (WBC) scintigraphy were included as suggestive criteria in 2020 [10].

Currently there are only a few studies reporting the rate of postoperative infection after ankle fracture surgery, applying the FRI definition [9,10,12].

The aim of the current study was to report the prevalence of FRI in patients operated for ankle fractures and to assess the applicability of the diagnostic algorithm from the consensus group at a level 1 trauma hospital in Bergen, Norway.

Patients and methods

Patient records of all patients with ankle fractures operated at Haukeland University Hospital in the period January 2015 through December 2019 were retrospectively assessed for indications of postoperative infection. Patients < 18 years of age at the time of primary surgery, those with bilateral injuries, and patients with follow-up at other hospitals were excluded.

Patients were identified by a selective search through the operation planning system, Orbit version 5.11.2 (Tieto Evry, Kristianstad, Sweden), based on Nordic Medico-Statistical Committee (NOMESCO) Classification of Surgical Procedures (NCSP) codes for uni-, bi- and trimalleolar fractures and infection complication diagnoses. Records were examined for information concerning clinical, radiological, biochemical, and microbiological signs of postoperative infection and wound problems, as well as for classification of fractures. Sectra software version 22.1 (Sectra AB, Linköping, Sweden) was used for radiograph examination.

Information indicating wound problems such as prolonged healing or dehiscence as well as clinical signs of infection, drainage or puss resulted in suspicion of infection. These patients were stratified to either have *confirmatory criteria* or *suggestive criteria* of FRI. Following the diagnostic algorithm published by FRI consensus group patients were considered to have FRI when meeting either of the *confirmatory criteria* (Fig. 1) [9,10]. Culture status (negative/positive) was evaluated thereafter. Patients meeting the *suggestive criteria* were classified as having an FRI if they had one positive culture with virulent pathogens (*Staphylococcus aureus (S. aureus), Staphylococcus lugdunensis (S. lugdunensis), Streptococci species, or gram-negative species*), or phenotypically equal bacterial cultures in two or more bacterial samples. Although it is a coagulase negative staphylococcus, *S. lugdunensis*, was included as a virulent bacterium due to similarities to *S. aureus* in causing infection [13,14]. Those who had *suggestive criteria*, but negative cultures, were classified as not having an FRI. Also, patients without bacterial sampling, not having received any antibiotic treatment and who did not develop any *confirmatory criteria* of FRI, were defined as not having had FRI. Patients with *suggestive clinical signs* of FRI treated without revision surgery were considered to have a good treatment outcome if the infection or soft tissue problems resolved and they were infection free 12 months after the initial treatment.

Revision surgery of patients with suspected FRI was performed by the surgeon on call. Both swab and tissue sampling were performed. We accepted two or more samples as adequate in the current study. A single swab sample in the outpatient clinic or the operating room was considered inadequate.

Depending on the samples taken, the Department of microbiology at the study hospital use different agars for cultivation. Direct PCR is performed in cases with high suspicion of infection but negative cultures. Standard incubation time for swabs is two days. In suspected FRI, the incubation time was five days early in the study period but later extended to 10 days for peroperatively taken bacterial samples, to identify slow growing bacteria with affinity for implants.

Results

Patient journal examination was concluded by 1st of July 2022 giving a mean follow-up period of 59 (Standard deviation (SD) 17) months. The search rendered 1064 operations for ankle fractures in 1057 patients. Patients with bilateral injuries (seven patients) and patients with follow-up elsewhere (46 patients) were excluded from the study. A total of 1004 patients (60% women, 40% men) were eligible for inclusion in the study (Fig. 2). The patients' mean age at time of primary fracture surgery was 52 (SD = 18) years and the mean body mass index (BMI) was 27.5 (SD = 4.8). Eight-hundred and ninety-one (89%) patients were American Society of Anesthesiologist (ASA) class 1 or 2, 109 (11%) were ASA 3 and four (0.4%) patients were ASA class 4.

Table 1
Fracture characteristics for the 104 patients with suspected fracture-related infection (FRI).

		n (%)
AO classification	44A3.3	1 (1)
	44B1	17 (16)
	44B2	7 (7)
	44B3	43 (41)
	44C1	12 (12)
	44C2	18 (17)
	44C3	6 (6)
Dislocation fracture		32 (31)
Open fracture		4 (4)
Multitrauma		1 (1)
High energy trauma		7 (7)

Fracture characteristics for the 104 patients with suspected Fracture-related infection (FRI). Number of patients (n) with percentages in parenthesis.

FRI was suspected in 104 (10%) of the 1004 patients. Among the suspected FRIs, *confirmatory criteria* were met in 76/104 (73%) and *suggestive criteria* in 28/104 (27%) of cases at first evaluation. AO 44B was the most common fracture type (67 (64%) of 104 patients, Table 1) among patients with suspected FRI.

Prevalence of fracture-related infection

Eighty-seven of 1004 (9%) patients were finally diagnosed with FRI after second evaluation (Fig. 2). One of the patients with FRI underwent below the knee amputation for infection control.

Confirmatory criteria

Fistula, sinus tract or wound breakdown were the most common *confirmatory criteria* (Table 2). Seventy-one (93%) of 76 patients with *confirmatory criteria* developed the clinical signs of FRI after the primary fracture surgery, while in 5 (7%) patients the wound problems occurred after a reoperation.

All 76 patients who met the *confirmatory criteria* had bacterial samples taken (Table 3), but only in 64 (84%) patients the samples were adequately taken. Fifty of the 64 patients had bacterial sampling without prior antibiotic treatment. Among them, 36 (72%) patients had two or more positive cultures, 2 had one positive culture, 1 had one positive culture with a non-virulent pathogen, and 11 patients (22%) had negative cultures.

Revision surgery due to suspected FRI was performed in 67 (88%) of 76 patients who met the *confirmatory criteria*. Seventy (92%) of the 76 patients received treatment for FRI. Six patients did not receive any further antimicrobial treatment after evaluation of bacterial cultures and did not develop further signs of FRI.

Suggestive criteria

Twenty-eight patients presented with clinical *suggestive criteria*. All wound problems suspicious of FRI for these patients occurred after the primary fracture surgery. Wound drainage was the most common clinical sign of infection among patients with *suggestive criteria* (Table 2). Radiographic signs suggesting infection

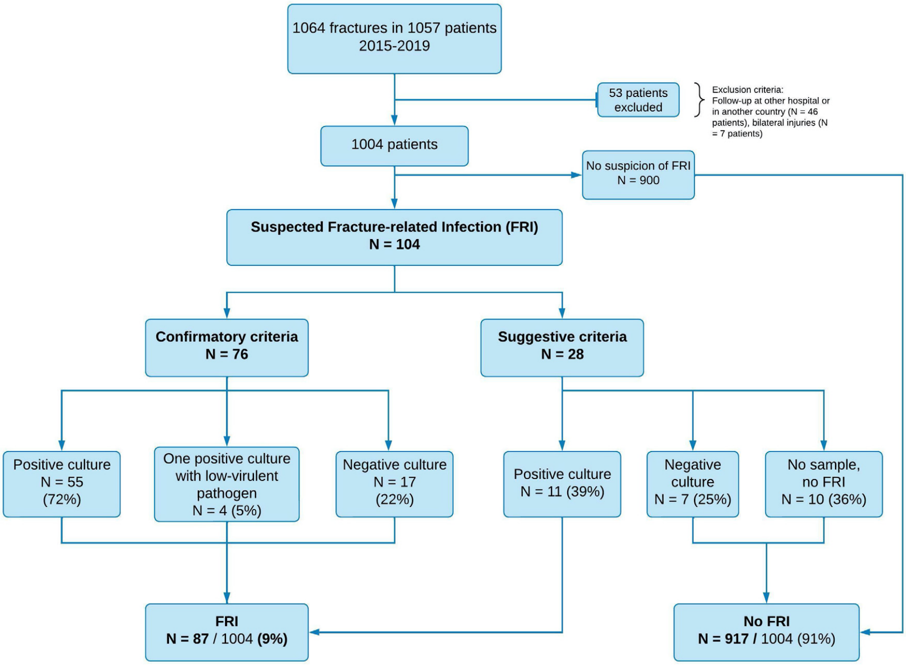


Fig. 2. Patient inclusion flow-chart. N – Number of patients. FRI – Fracture-related Infection.

Table 2
Distribution of confirmatory and suggestive criteria among the 104 patients with suspected Fracture-related Infection.

		n (%)
Patients with confirmatory criteria, clinical signs, n = 76[*]		
Fistula, sinus, wound breakdown		55 (72)
Purulent drainage, pus		21 (28)
Clinical signs of infection[**]		46 (61)
Patients with suggestive criteria, n = 28[*]		
Local clinical signs		7 (25)
Systemic clinical signs (fever)		n.a.
Other clinical signs	New-onset joint effusion	n.a.
	Wound drainage	27 (96)
Histopathology		0
Radiografic signs		1 (4)
Serum inflammatory markers[#]	Erythrocyte Sedimation Rate (ESR)	2 (7)
	Leukocyte particle count (LPC)	0
	Neurophile count	0
	C-reactive protein (CRP)	4 (14)

Distribution of confirmatory (clinical) and suggestive criteria among the 104 patients suspected of FRI. N.a. = not applicable.
[*] A patient may have more than one confirmatory or suggestive criteria.
[**] Clinical signs of infection: redness, warmth, swelling and pain.
[#] For the serum inflammatory markers the number of patients with abnormal values are presented with percetages in parenthesis. Normal values: ESR <=20, LPC <=11 × 10^9, Neutrophile count 1–8.5 × 10^9, CRP <5.

was found in only one patient, but FRI was not confirmed in this patient. The 28 patients were further examined with either bacterial sampling at the outpatient clinic, revision surgery including bacterial sampling, or a wait-and-see approach. Eighteen (64%) of 28 patients had bacterial samples taken but only in 9 patients an adequate sample method was used (Table 3). Eleven (39%) of 28 patients had positive cultures. Bacterial sampling was not performed in 10 (36%) of 28 patients who met the *suggestive criteria*. These 10 patients had close, subsequent follow-up by an orthopedic surgeon until the wound problem and suspicion of infection was resolved.

Revision surgery was performed in 10 (36%) of 28 patients with suggestive criteria. Even though only 11 of 28 patients were diagnosed with FRI, 16 patients with *suggestive criteria* were treated for a suspected infection including 11 with positive cultures, 4 patients with negative cultures, and one patient in which bacterial sampling

Table 3
Bacterial sampling and culture results.

		Confirmatory criteria of FRI ($n = 76$)	Suggestive criteria of FRI ($n = 28$)
		n (%)	n (%)
Patients with bacterial sampling	Yes	76 (100)	18 (64)
	No	0	10 (36)
Quantity of bacterial samples	Swab only	10 (13)	9 (32)
	One sample	2 (3)	0
	2 or more samples	64 (84)	9 (32)
Antibiotics prior to sampling	Yes	19 (25)	0
	No	57 (75)	28 (100)
Bacterial findings	No bacterial culture	0	10 (36)
	Negative culture	17 (22)	7 (25)
	1 culture low-virulent	4 (5)	0
	1 culture virulent	7 (9)	5 (18)
	2 or more positive cultures	48 (63)	6 (21)

Bacterial sampling and culture results. Number of patients (n) with percentages in parenthesis.

was not performed. All 28 patients who met the *suggestive criteria* were infection free one year after treatment of the wound problems and FRI.

The number of samples taken per patient are presented in Table 3.

No histopathology was performed.

Discussion

In this study, FRI was suspected in 104 out of 1004 patients with surgically treated ankle fractures and a FRI, as defined by the consensus group, was subsequently confirmed in 87 of 1004 (9%) patients.

Fracture-related infection

While the prevalence of FRI in the current study was 9%, the prevalence of infection after ankle fracture surgery varies in the literature, from 2.6% to 8.4% depending on the definition of infection in the given study and the duration of follow-up [3,8,15]. The criteria from CDC for defining SSI is commonly used [8,16]. Sun et al. and Sato et al. found an SSI-rate of 3.7% and 5.7%, respectively, both lower than the current study [8,17]. However, the follow-up period in these studies was only 12-weeks as opposed to nearly 5 years in our study, allowing us to identify late infections in addition to the early ones. The use of FRI has been shown to capture more patients with postoperative infection than using the SSI definition [18]. Cooke et al. reported a 15% FRI-rate in patients with open ankle fractures [12]. To our knowledge the current study is one of the first to report the prevalence of FRI applying the diagnostic criteria and algorithm suggested by the FRI consensus group in patients operated for ankle fractures [9,10,12,19].

Confirmatory criteria

Seventy-three percent of the patients with suspected infection in the current cohort met the *confirmatory criteria* of FRI, compared to 97.5% in the study by Onsea et al. which however comprised other injuries in addition to ankle fractures, possibly explaining the different findings between the studies [11].

Three percent of patients with *confirmatory criteria* of FRI in the current study had only one positive culture after adequate bacterial sampling. Still, Onsea highlights that a single positive culture with a virulent pathogen should raise a high suspicion of infection and reported a low sensitivity but a specificity of 100% for a single positive culture.

All patients who met the *confirmatory criteria* in the current study had clinical *confirmatory signs* of FRI. However, 22% were culture negative, suggesting culture negative infections or no infection at all. In the study by Onsea 8.5% of patients with FRI were culture negative.

Bacterial samples were collected in a total of 96 patients having *confirmatory* or *suggestive criteria*. Negative bacterial culture results were found in 29 (31%) of these 96 patients. Culture negative infections may be assumed, particularly in patients with *confirmatory criteria*. Due to the potential dire consequences of an FRI, patients with clinical findings of *confirmatory criteria* should be treated with revision surgery. Swift surgery facilitates adequate bacterial sampling and restores the soft tissue envelope around implants and fracture.

Suggestive criteria

Few patients in the current study were reported to have local signs of inflammation (local redness, swelling or warmth. As pain is not registered in a satisfactory manner in the patient's records, data regarding pain were not included in our study. However, pain has been shown to have a weak association with FRI as it might be due to several causes [11]. Fever was also not systematically reported in the current study, but Onsea found a specificity of 98.7% and argues that if FRI is suspected, and the patient presents with fever, the diagnosis must be strongly considered [11].

Radiographic signs of infection appear late, and their value remain unclear. Contra-intuitively Onsea et al. found a higher rate of radiographic suggestive signs among patients without FRI [11]. Comparatively, only one patient in our study had radiographic findings suggesting infection. This patient, however, did not have a confirmation of the FRI diagnosis. X-ray findings of FRI, such as osteolysis, may appear several weeks after infection onset at which time the FRI in most cases will already have been diagnosed and treated.

Few patients who met the *suggestive criteria* and were confirmed to have an FRI in the current study, had blood samples taken as part of the diagnostics. This suggests the need for improved routines for diagnosing FRI at the study hospital. However, given the low levels of WBC, CRP, and ESR among the patients with clinical *suggestive criteria* in the current study, these tests seemed to add little value in the search of the FRI diagnosis in ankle fractures. Wound drainage, however, was reported in all patients diagnosed with FRI in the current study. This result contrasts those of Onsea et al. where only a few patients had wound drainage [11].

Increased leucocyte (WBC) level or prolonged or recurrent wound drainage in combination with local clinical signs of inflammation is reported to have a high sensitivity for FRI [11].

The majority of the study period was prior to the publication of the FRI definition (2018) and the tissue sampling was consequently not undertaken according to the requirements described by Hellebrekers et al. [20]. Later, the practice has changed to comply with sampling routines similar to periprosthetic joint infections (PJI) with a minimum of five samples taken with separate, non-contaminated, instruments.

A swab was used for bacterial sampling in half of the patients who met the *suggestive criteria* of FRI and who had bacterial samples taken. Inadequate sampling is challenging when a culture returns negative or positive with a low-virulent pathogen. One may wonder if the result is due to contamination or an infection. In such cases further assessment through revision surgery and adequate bacterial sampling is needed. Finding a single positive culture with a virulent pathogen has a sensitivity of 100% for the diagnosis of FRI and PJI [11,21]. Therefore, adequate, and meticulous tissue sampling and wound assessment must be performed. Patients presenting *suggestive criteria* should be thoroughly investigated and followed.

All bacterial samples taken in patients with *suggestive criteria* were collected without prior antibiotic treatment. Orthopedic trauma is treated at public hospitals in Norway and the access as well as distance to secondary health care is generally easy. This allows a wait-and-see approach until results of bacterial cultures are available, and even a 14-day cessation of antibiotics prior to bacterial sampling, which is likely to reduce the number of false negative bacterial samples. In this period of expectancy, the wound problem may be closely observed by an orthopedic surgeon at the outpatient clinic at subsequent visits. In case of changes- or additional clinical signs of FRI, the patient may be admitted for further assessment, revision surgery and bacterial sampling. This is in line with the diagnostic algorithm of FRI by the consensus group [9,10].

Strengths

This study is a transparent report of FRI from a level 1 trauma hospital, with a high number of ankle fractures and consecutive complications. We had access to comprehensive data on patient demographics, fracture characteristics, type of surgery, samples, treatment, and clinical course. In this unselected cohort, the prevalence of FRI after ankle fracture surgery was calculated [11] and we believe the external validity is good. Another strength is the chronology for patient inclusion and application of the FRI algorithm [9]. Onsea et al. used intention-to-treat as recommended by a multidisciplinary team to select patients to a FRI group and a control group. The current study stratified patients to the *confirmatory* or *suggestive criteria* groups according to clinical signs presented either at the outpatient clinic or postoperatively while admitted, before culture results. Consequently, this study presents a recognizable setting for orthopedic surgeons including the clinical pathway for their patients and the applicability of the FRI algorithm as a diagnostic tool.

Limitations

The retrospective study design has inherent limitations. The FRI criteria were not in use when the patients were treated and for this reason data from the patient's records in some cases were imprecise or inadequate. None of the patients with suggestive criteria but a quarter of the patients with *confirmatory criteria* had antibiotic treatment prior to revision surgery and bacterial sampling, similar to the report by Onsea et al. [11]. Such use of antibiotics may result in false negative bacterial cultures. The bacterial sampling method applied in this study, with at least two bacterial samples taken, is not in line with current recommendations, but was deemed adequate due to the practice during that time period. This sampling protocol is a limitation, but we believe it to be recognizable in other clinical settings. However, from 2018, after establishing an orthopedic infection ward with dedicated surgeons, the sampling routines have been changed in concordance with PJI and FRI recommendations. A culturing protocol including five or more separate deep tissue samples, each collected with individual sterile instruments, is now standard of care [10,22]. In retrospect, routines for infection diagnostics and sampling were unsatisfactory and not in accordance with the FRI algorithm. A more systematic and standardized sampling might have influenced the results regarding prevalence of FRI. A swab from the skin or wound secretion is considered an inadequate sampling method [20,23]. Adequate bacterial sampling was performed in a minority of patients with suggestive criteria, and in some cases no bacterial sampling were collected at all. More patients with clinical suggestive signs may have been classified as FRI with improved bacterial sampling [10,11]. Another challenge in retrospective classification of infections is the differentiation between the clinical confirmatory criteria “wound breakdown” and the clinical suggestive criteria “increasing or new onset wound drainage”. A misclassification in some of these cases may therefore not be ruled out.

Conclusion

The prevalence of FRI, applying the FRI-consensus criteria, for patients with surgically treated ankle fractures was 9%. Twenty-two percent of patients who met the confirmatory criteria had negative bacterial cultures. The current study shows that we did not have a systematic approach to patients with suspected FRI as recommended by the consensus group. A systematic approach to adequate bacterial sampling when FRI is suspected is paramount. The consensus definition of FRI and its diagnostic algorithm facilitates such an approach.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Jensen SL, Andresen BK, Mencke S, Nielsen PT. Epidemiology of ankle fractures. A prospective population-based study of 212 cases in Aalborg, Denmark. Acta Orthop Scand 1998;69:48–50. doi:10.3109/17453679809002356.
[2] Daly PJ, Fitzgerald RH, Melton LJ, Llstrup DM. Epidemiology of ankle fractures in Rochester, Minnesota. Acta Orthop Scand 1987;58:539–44. doi:10.3109/17453678709146395.
[3] Naumann MG, Sigurdsen U, Utvåg SE, Stavem K. Associations of timing of surgery with postoperative length of stay, complications, and functional outcomes 3–6 years after operative fixation of closed ankle fractures. Injury 2017;48:1662–9. doi:10.1016/j.injury.2017.03.039.
[4] Høiness P, Strømsøe K. The influence of the timing of surgery on soft tissue complications and hospital stay: a review of 84 closed ankle fractures. Ann Chir Gynaecol 2000;89:6–9.
[5] Naumann MG, Sigurdsen U, Utvåg SE, Stavem K. Functional outcomes following surgical-site infections after operative fixation of closed ankle fractures. Foot Ankle Surg 2017;23:311–16. doi:10.1016/J.FAS.2016.10.002.
[6] National Healthcare Safety Network C for DC and Prevention. Surgical site infection (SSI) event n.d. http://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf (accessed January 25, 2017).
[7] Meng J, Sun T, Zhang F, Qin S, Li Y, Zhao H. Deep surgical site infection after ankle fractures treated by open reduction and internal fixation in adults: a retrospective case-control study. Int Wound J 2018;15:971–7. doi:10.1111/iwj.12957.
[8] Sun R, Li M, Wang X, Li X, Wu L, Chen Z, et al. Surgical site infection following open reduction and internal fixation of a closed ankle fractures: a retrospective multicenter cohort study. Int J Surg 2017;48:86–91. doi:10.1016/J.IJSU.2017.10.002.

[9] Metsemakers WJ, Morgenstern M, McNally MA, Moriarty TF, McFadyen I, Scarborough M, et al. Fracture-related infection: a consensus on definition from an international expert group. Injury 2018;49:505–10. doi:10.1016/j.injury.2017.08.040.
[10] Govaert GAM, Kuehl R, Atkins BL, Trampuz A, Morgenstern M, Obremskey WT, et al. Diagnosing fracture-related infection: current concepts and recommendations. J Orthop Trauma 2020;34:8–17. doi:10.1097/BOT.0000000000001614.
[11] Onsea J, van Lieshout EMM, Zalavras C, Sliepen J, Depypere M, Noppe N, et al. Validation of the diagnostic criteria of the consensus definition of fracture-related infection. Injury 2022;0. doi:10.1016/J.INJURY.2022.03.024.
[12] Cooke ME, Tornetta P, Firoozabadi R, Vallier H, Weinberg DS, Alton TB, et al. Open ankle fractures: what predicts infection? A multicenter study. J Orthop Trauma 2022;36:43–8. doi:10.1097/BOT.0000000000002293.
[13] Heilbronner S, Foster TJ. Staphylococcus lugdunensis: a skin commensal with invasive pathogenic potential. Clin Microbiol Rev 2020;34:1–18. doi:10.1128/CMR.00205-20.
[14] Seng P, Traore M, Lavigne JP, Maulin L, Lagier JC, Thiery JF, et al. Staphylococcus lugdunensis: a neglected pathogen of infections involving fracture-fixation devices. Int Orthop 2017;41:1085–91. doi:10.1007/S00264-017-3476-4.
[15] Aigner R, Salomia C, Lechler P, Pahl R, Frink M. Relationship of prolonged operative time and comorbidities with complications after geriatric ankle fractures. Foot Ankle Int 2017;38:41–8. doi:10.1177/1071100716667315.
[16] Schepers T, de Vries MR, van Lieshout EMM, van der Elst M. The timing of ankle fracture surgery and the effect on infectious complications; A case series and systematic review of the literature. Int Orthop 2013;37:489–94. doi:10.1007/s00264-012-1753-9.
[17] Sato T, Takegami Y, Sugino T, Bando K, Fujita T, Imagama S. Smoking and trimalleolar fractures are risk factors for infection after open reduction and internal fixation of closed ankle fractures: a multicenter retrospective study of 1,201 fractures. Injury 2021;52:1959–63. doi:10.1016/j.injury.2021.04.017.
[18] Sliepen J, Onsea J, Zalavras CG, Depypere M, Govaert GAM, Morgenstern M, et al. What is the diagnostic value of the Centers for Disease Control and Prevention criteria for surgical site infection in fracture-related infection? Injury 2021;52:2879–85. doi:10.1016/J.INJURY.2021.08.009.
[19] Pilskog K., Gote T.B., Odland H.E.J., Fjeldsgaard K.A., Dale H., Inderhaug E., et al. Association of delayed surgery for ankle fractures and patient-reported outcomes: 2022:107110072110705. 10.1177/10711007211070540.
[20] Hellebrekers P, Rentenaar RJ, McNally MA, Hietbrink F, Houwert RM, Leenen LPH, et al. Getting it right first time: the importance of a structured tissue sampling protocol for diagnosing fracture-related infections. Injury 2019;50:1649–55. doi:10.1016/J.INJURY.2019.05.014.
[21] McNally M, Sousa R, Wouthuyzen-Bakker M, Chen AF, Soriano A, Vogely HC, et al. The EBJIS definition of periprosthetic joint infection. Bone Joint J 2021;103-B:18–25. doi:10.1302/0301-620X.103B1.BJJ-2020-1381.R1.
[22] Dudareva M, Barrett LK, Morgenstern M, Atkins BL, Brent AJ, McNally MA. Providing an evidence base for tissue sampling and culture interpretation in suspected fracture-related infection. J Bone Joint Surg Am 2021;103:977–83. doi:10.2106/JBJS.20.00409.
[23] Walsh AS, Sinclair V, Watmough P, Henderson AA. Ankle fractures: getting it right first time. Foot 2018;34:48–52. doi:10.1016/j.foot.2017.11.013.

Risk Factors for Fracture-related Infection After Ankle Fracture Surgery

Grafisk design: Kommunikasjonsavdelingen, UiB / Trykk: Skipnes Kommunikasjon AS

uib.no

9788230854907 (print)
9788230855140 (PDF)