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Epidemiology and Outcomes of Ankle Fractures

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Declaration

This thesis has been composed by me, Kate Ella Bugler, and is my own work. The small proportion of the work with contributions from others has been clearly indicated in the relevant sections and in the acknowledgements section. The work has not been submitted for any other degree or professional qualification. The two included publications are my own work with the contributions of others clearly indicated in the acknowledgements section.

Kate Bugler

December 2019.

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Abbreviations

AAOS	American Academy of Orthopedic Surgeons
AFO	Ankle Foot Orthosis
AIS	Abbreviated Injury Scale
BMI	Body Mass Index
CI	Confidence Interval
COPD	Chronic Obstructive Pulmonary Disease
DVT	Deep Vein Thrombosis
ED	Emergency Department
EQ5D	EuroQol Five Dimension Scale
GSR	Gravity Stress Radiograph
ISS	Injury Severity Score
LMWH	Low Molecular Weight Heparin
MCS	Medial Clear Space
MOXFQ	Manchester Oxford Score
OMS	Olerud and Molander Score
ORIF	Open Reduction Internal Fixation

PACS	Patient Archiving and Communication System
PAB	Pronation Abduction
PC	Pearson Correlation
PE	Pulmonary Embolism
PER	Pronation External Rotation
PROMs	Patient Reported Outcome Measures
RCT	Randomised Controlled Trial
RIE	Royal Infirmary Edinburgh
RTA	Road Traffic Accident
SAD	Supination Adduction
SCS	Superior Clear Space
SD	Standard Deviation
SER	Supination External Rotation
SF-12	Short Form 12
SIMD	Scottish Index of Multiple Deprivation
UCLA	University of California, Los Angeles
VTE	Venous Thromboembolic Event

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Abstract

Ankle fractures are common injuries which can have major effects on the lives of patients. Recent detailed investigation into the epidemiology of ankle fractures is lacking, particularly work on the effect of social deprivation and open injuries. Assessment of outcomes is key to selecting the optimal treatment for individual patients. Outcomes of the investigations used in assessing ankle fractures, and their surgical management, post injury rehabilitation and post injury thromboprophylaxis require further investigation.

A database was collated prospectively of 1,262 consecutive ankle fractures presenting to the RIE over a 21-month period from 8/9/10 to 29/6/12. Data were collected on several variables including age, gender, mechanism of injury, fracture classification, past medical history, drug history, body mass index (BMI), measures of social deprivation and date of injury. Some studies used additional datasets including a database of open fractures and a retrospectively collated cohort of patients managed with the use of the fibular nail.

Investigation into the epidemiology of ankle fractures found the majority were low energy injuries (65.2% due to a fall from a standing height) with a mean age of 48.5 years. There was a significantly higher incidence in women than in men ($p<0.001$) and the women sustaining ankle fractures were significantly older than the men ($p=0.007$). Social deprivation was shown to be related to ankle fractures with a significantly higher incidence in patients in the most deprived quintile of society ($p<0.001$).

The subgroup of open ankle fractures were also predominantly low energy injuries with 48.9% due to a fall from a standing height. The mean age was higher than that of ankle fractures as a whole at 55 years. The modal Gustillo Anderson type was IIIa with 82% of injuries being isolated with a median ISS of 13.

Investigation into the outcomes of gravity stress radiographs found a high rate of false positives with the risk of over-treatment of patients with stable ankle fractures if gravity stress radiographs were used for surgical decision making. A total of 79% of patients with stable ankle fractures had gravity stress radiographs with an MCS of greater than 4 mm.

The fibular nail was found to be a good treatment method for unstable ankle fracture management with good clinical and radiographic outcomes. A retrospective review of 105 patients, 79% with comorbidities, treated with the fibular nail found good outcomes particularly once the technique for fixation to the bone had been refined.

Weight bearing after ankle fractures was found to be safe in the majority of patients, whether treated operatively or non-operatively. Of 847 patients with ankle fractures 99.7% had good radiographic and clinical outcomes following a protocol of early weight-bearing post injury.

Investigation into current venous thromboembolic prophylaxis protocols found low rates of VTEs when patients did not routinely receive chemoprophylaxis after discharge from hospital. The incidence of VTEs among non-operatively managed ankle fractures within 30 and 90 days was 0.12% and 0.35% respectively.

Operatively treated fractures were at greater risk, at 0.48% within 30 days and 0.72% at 90 days.

In conclusion, ankle fractures remain common injuries affecting large numbers of patients. Gravity stress radiographs have not been shown to be a useful tool in assessing their stability whilst fibular nailing, early weight bearing and current VTE prophylaxis all have been found to have good outcomes for patients.

Lay summary

Fractures of the ankle are common injuries. Understanding who gets these injuries and how they are sustained is currently incomplete, particularly in ankle fractures where there is also a break to the skin around the fracture. Treating ankle fractures involves many decisions including whether a patient would be best treated with an operation, if so what operation, whether they should be allowed to walk on their ankle fracture and how to prevent blood clots. This thesis has investigated these issues.

1,262 patients with ankle fractures were included in a database. The majority of studies were undertaken using patients from this database. Some studies required other data including a database of open fractures and a group of patients whose ankle fractures had been treated with a novel device called a fibular nail.

Investigation into who gets ankle fractures found that more women than men currently fracture their ankle. Most people break their ankle when they fall from a standing height and those in the most deprived areas in society are more likely to break their ankle than those in the least deprived. Open ankle fractures also usually happen when someone falls from standing but mostly in older people than closed ankle fractures.

The use of special x-rays to decide whether to treat an ankle fracture with an operation or not found that this x-ray technique risks over-treating patients with surgery. A novel method of fixing ankle fractures was found to have good outcomes as was allowing patients with ankle fractures to put their weight through the broken

ankle as soon as possible. Finally, the risk of developing a blood clot following an ankle fracture was found to be higher than the background risk but much lower than the risk after a hip or knee replacement.

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Introduction

1.1 Ankle fractures

Fractures to the distal tibia or fibula involving the medial, lateral or posterior malleoli are referred to as ankle fractures¹. Ankle fractures are common injuries affecting patients of all ages². Indeed ankle fractures are amongst the most common fractures sustained, second only to proximal femoral fractures in the lower limb, making up 9% of all fractures in adults³ with an incidence of 137/100,000/year².

Early epidemiological studies between 1953 and 1957⁴ found ankle fractures to be second only to finger phalangeal fractures in incidence. Further investigation of fracture epidemiology in 2000 found ankle fractures to be the fifth most common fractures sustained after distal radius, metacarpal, proximal femoral and finger phalangeal fractures³. In children ankle fractures have been reported to be the eighth most common fracture sustained in a cohort of 1,403 fractures in children under the age of 16 with 22% of these fractures requiring surgical intervention⁵.

The mean age of patients sustaining ankle fractures is 45 years² with ankle fractures having a bimodal distribution, affecting younger men and older women. They are predominantly low energy injuries with the majority occurring due to a fall from a standing height⁶. This has led to interest regarding the osteoporotic nature of these fractures. A number of studies^{7,8} have found normal bone density in patients with ankle fractures but it has been suggested that this may mask local changes in the bony architecture. Stein et al⁷ reported altered microarchitecture of the trabecular

bone in the distal tibia with reduced bone stiffness when comparing patients with ankle fractures to controls.

It has been suggested that the incidence of ankle fractures is increasing, with Kannus previously reporting a 319% increase in ankle fracture incidence in the elderly in Finland between 1970 and 2000⁹. However, more recent work from Finland has shown that the rapid increase does appear to be slowing or even declining¹⁰, potentially due to changes in the activity levels and general health of the population. The epidemiology of this injury has shown interesting changes over time. Between 1950 and 1980 the proportion of fractures occurring due to major trauma reduced whilst fractures due to sports in men increased¹¹.

1.2 Ankle anatomy

The ankle is a mortise joint comprising the tibial plafond, medial malleolus and posterior malleolus articulating with the body of the talus with the lateral malleolus completing it. A mortise is defined by the Oxford English Dictionary as “a hole...in a part which is designed to receive a corresponding projection (a tenon)...so as to join...the parts together”¹². The majority of weight bearing is through the tibia with the fibula bearing one sixth of the load¹³. The axis of the joint is 15 degrees externally rotated to the coronal plane due to the more anterior position of the medial malleolus with respect to the lateral malleolus.

The surrounding soft tissues are key to the stability of the ankle joint. Three ligamentous complexes have important roles to play; the medial collateral, lateral

collateral and syndesmotic ligaments¹⁴. The syndesmosis is stabilised by several ligaments: anteriorly, the anterior inferior tibiofibular ligament, posteriorly, the posterior inferior tibiofibular ligament, and centrally the interosseous membrane. The anterior inferior tibiofibular ligament originates from Chaput's tubercle on the distal tibia and inserts into the distal fibula anteriorly. The posterior inferior tibiofibular ligament in turn originates on Volkmann's tubercle inserting onto the posterior fibula. Medially the deltoid ligament provides this stability. It is a large, strong ligament comprised of two parts, the superficial and deep components. The deep part is thought to be the most important in ankle stability¹⁵ and arises from the posterior colliculus and the intercollicular groove of the medial malleolus inserting on the medial side of the talus. The superficial component extends in a fan shape from the anterior colliculus of the medial malleolus to the talus, navicular and calcaneus. Laterally the lateral collateral ligament is made up of three component ligaments. The anterior and posterior talofibular ligaments pass from the fibula to the anterior and posterior aspects of the talus with the fibulocalcaneal ligament passing in between from the fibula to the calcaneus.

In addition to the ligaments, the muscles crossing the ankle joint are important dynamic stabilisers particularly during gait. Tibialis anterior and posterior invert the ankle with tibialis anterior also dorsiflexing (with extensor digitorum longus, extensor hallucis longus and peroneus tertius) and tibialis posterior also plantar flexing (with peroneus longus, peroneus brevis, gastrocnemius, soleus, plantaris, flexor hallucis longus and flexor digitorum longus). These muscle groups provide significant stability to the ankle even in the absence of the medial and lateral

ligaments¹⁴ as has been shown when comparing the biomechanics of ankle injuries in cadavers to those in patients.

The ankle is traversed by neurovascular structures with the deep peroneal nerve and dorsalis pedis artery anteriorly, the superficial peroneal nerve anterolaterally, the sural nerve posterolaterally, the saphenous nerve and great saphenous vein anteromedially and the tibial nerve and posterior tibial artery medially. The knowledge of their locations combined with the ligaments and tendons is key to the surgical approaches to the ankle. The deep peroneal nerve and dorsalis pedis artery are found laterally to the tendon of extensor hallucis longus at the level of the ankle. The sural and saphenous nerves are more variable and therefore at risk in medial and lateral approaches to the ankle respectively.

1.3 The importance of ankle fractures

Ankle fractures can have a significant impact on daily activities post injury. A range of physiological, psychological and social consequences were reported by McPhail et al in their qualitative work¹⁶. Patients used phrases such as “could not do anything...could not even walk the dog” and “your social life is affected in such a way that you don’t want to go out”. High demand sports players can have their livelihood affected with Larsson et al finding ankle fractures to cause a median absence from football of 86 days in elite players¹⁷ with ankle fractures resulting in significant time off work for the majority of patients.

Open fractures can have more significant morbidity and even mortality. Earle in a very early paper from 1828, reported the death of a 53 year old patient following an open ankle fracture dislocation requiring amputation¹⁸. Further investigation into these injuries found ankle fractures to be the fifth most common open injury following finger phalangeal, tibia and fibula diaphyseal, distal radius and toe phalangeal fractures¹⁹.

Two major areas of interest in ankle fractures are their epidemiology and the outcomes for patients of sustaining these injuries. This thesis considers both areas in greater detail.

1.4 Classification

In order to describe the fractures contained within this thesis the use of a number of different classification systems has been necessary. The aim of an ankle fracture classification is for it to be reliable, reproducible and as Müller²⁰ described, “if it considers the severity of the bone lesion and serves as a basis for treatment and for the evaluation of the results”. As in many areas of orthopaedics, the number of systems available suggests that these aims have not yet been achieved.

The most simple ankle fracture classification is Pott’s²¹ which divides ankle fractures based on the number of fractures of the malleoli. Fractures of the lateral, medial and posterior malleoli can be classified as isolated unimalleolar, bimalleolar and trimalleolar fractures depending on the number of malleoli involved. A greater

number of malleolar fractures have been reported to result in a worsening prognosis²².

Building on this the Danis Weber^{23,24} classification system describes the lateral malleolar fracture in more detail, specifically in terms of its relationship to the syndesmosis. Infrasyndesmotic fractures are classified as type A, those at the level of the syndesmosis as type B and suprasyndesmotic as type C. This Danis Weber classification has been shown to have good inter and intra observer reliability²⁵ and has been described by Lindsjo²⁶ as a system that “even an exhausted doctor on emergency call at four in the morning should be able to apply without too much error”. However, this classification does not predict fracture stability accurately or prognostic information and does not address medial sided injuries which can be key^{22,27,28}.

A more exhaustive classification system is the Lauge Hansen classification described in 1950²⁹ based on previous work by Ashhurst and Bromer in 1922³⁰. This is a mechanistic classification system produced following experiments on cadaveric ankles. The system has three components: a word describing the position of the foot at the time of the fracture, another describing the rotation of the talus and finally a number describing the stage of the injury. This results in four groups of fractures each with between two and four stages; supination external rotation (SER), supination adduction (SAD), pronation abduction (PAB), pronation external rotation (PER). This classification has not been used in detail in this thesis but is referred to in several of the studies. Most ankle fractures can be classified using this system³¹ and it is of great assistance for surgical planning, but the reliability of the actual

mechanistic description has been called into doubt by studies using in-vivo videos of ankles at the time of fracture³².

1.5 The epidemiology of ankle fractures

Investigation into the epidemiology of fractures allows one to understand the injury far more completely than is possible than when treating the fractures of individuals. Fracture epidemiology has many practical and academic benefits³³. It can be used to plan the allocation of health care resources including staffing and operative materials. In addition it can provide understanding of the causes and patterns of injury allowing comparison with other injuries and localities. It can therefore help the needs of the community.

It is known that ankle fractures are common injuries treated by orthopaedic surgeons on a regular basis³. They are the second most often sustained lower limb fracture after hip fractures, but there has been little recent investigation into their epidemiology. Previously published data from Edinburgh has investigated the epidemiology of ankle fractures from 1988 to 1990² but there have been significant changes in the epidemiology of many fractures over the intervening years³⁴. In particular, social deprivation and ankle fractures has not previously been investigated in detail which is of increasing interest in the orthopaedic literature³⁵.

Open ankle fractures are significant injuries with a risk of morbidity and mortality¹⁸. Whilst a number of authors have described the epidemiology of ankle fractures and

how this has changed over time^{2,6,8,9,36,37}, very little has been published describing the epidemiology of open ankle fractures.

The literature regarding open ankle fractures has concentrated on the management of these injuries including the timing of surgery³⁸, the methods of fixation^{39,40} and the outcomes of management⁴¹. There has been minimal consideration of the patient groups affected and the mechanisms by which these fractures occur. Studies of ankle fractures as a whole are limited by the relative rarity of open fractures with only around 2.6% of all fractures being open injuries¹.

Fracture curves

One method that assists in investigation of fracture epidemiology is the use of fracture curves. Fracture curves were first described by Court-Brown and Caesar in 2006 to aid in studying fracture epidemiology³. They described eight different fracture distribution curves (Figure 1:1) which, it has been reported, can be applied to all fractures.

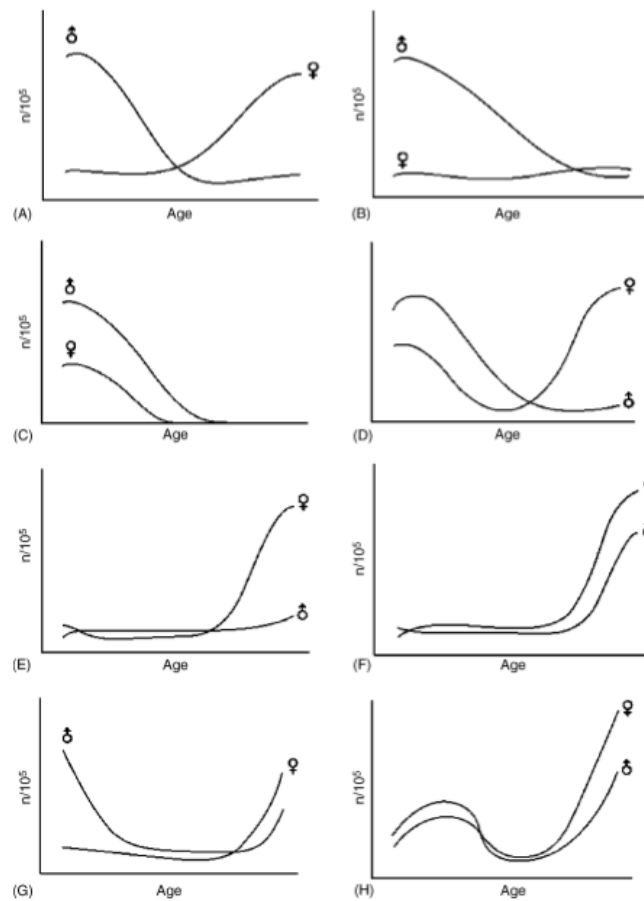


Figure 1:1 Fracture distribution curves. Taken from “Epidemiology of Adult Fractures: A review. Court-Brown CM, Caesar B. *Injury*. 2006; 691-697”.

These fracture curves can be summarised as seen in Table 1:1.

Table 1:1 Summary of fracture distribution curves.

<i>Fracture curve</i>	<i>Male</i>	<i>Female</i>
A	Unimodal young	Unimodal older
B	Unimodal young	-
C	Unimodal young	Unimodal young

D	Unimodal young	Bimodal
E	-	Unimodal older
F	Unimodal older	Unimodal older
G	Bimodal	Unimodal older
H	Bimodal	Bimodal

Further work from Court-Brown et al⁴² described six different patterns of fracture in the elderly, Figure 1:2. These line graphs can be summarised as seen in Table 1:2.

Table 1:2 Description of elderly fracture patterns.

<i>Fracture pattern</i>	<i>Male</i>	<i>Female</i>
I	Increasing	Increasing
II	Stable	Increasing
III	Increasing	Stable
IV	Decreasing	Stable
V	Stable	Decreasing
VI	Stable	Stable

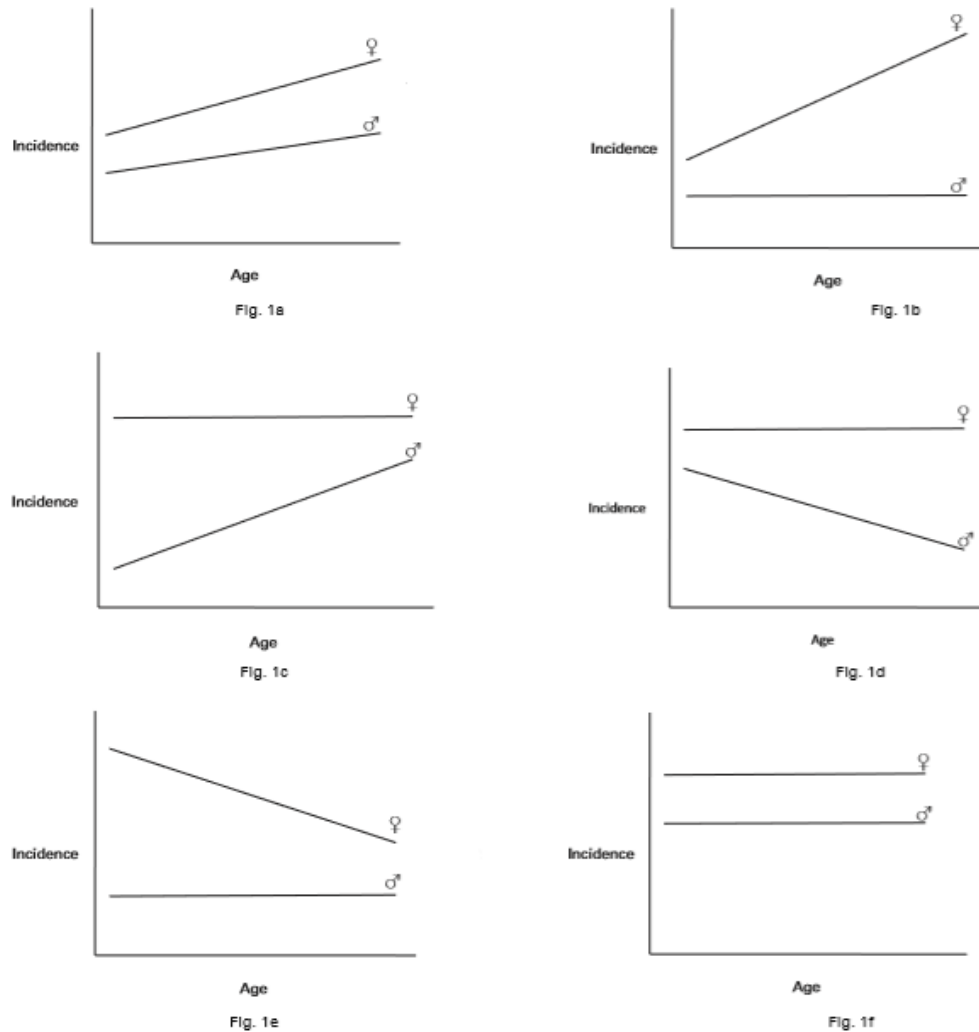


Figure 1:2 Elderly fracture pattern line graphs. 1a type I, 1b type II, 1c type III, 1d type IV, 1e type V, 1f type VI. Taken from "The spectrum of fractures in the elderly. Court-Brown, Clement, Duckworth, Aitken, Biant, McQueen. BJJ 2014, 96B, 366-372".

1.6 The outcomes of ankle fractures

The aim of a doctor is to do no harm⁴³ and even more so to “make the care of your patients your first concern”⁴⁴. In order to provide the best possible care to patients

one must know what that entails. To assess management, knowledge of the outcomes of care is essential. However, deciding how to assess the outcome of care can be challenging. The International Consortium for Health Outcomes Measurement defines outcomes as “the results of treatment that patients care about most”⁴⁵. This is evidently a broad framework and as a result, outcomes can be assessed in many ways. In this thesis clinical outcomes, radiographic outcomes and patient reported outcomes have been used.

Clinical outcomes

Clinical outcomes come in many forms from easily quantified objective outcomes such as mortality and readmissions to slightly less easily defined, more subjective measures such as complications and treatment success. In this thesis both types of clinical outcomes have been used.

Radiographic outcomes

Radiographic outcomes allow an objective assessment of treatment in orthopaedics. By looking at a radiograph one can evaluate both the initial fracture and the end result of treatment. Radiographic outcomes may be criticised as they may not necessarily correlate with the patient’s perception of the outcome. As a result radiographic outcomes are included in this thesis but are supplemented with other outcomes where possible.

Patient reported outcome measures (PROMs)

PROMs are increasingly used in health care to assess the outcomes of disease and treatment. They have the advantage of being able to ask the patient directly about the matters that affect them and therefore evaluate their perception of the treatment. Their disadvantage may lie in their subjectivity. It has been shown in orthopaedics that outcomes may be affected by factors such as comorbidities including mental health issues and back pain⁴⁶ as distinct to the injury in question.

Many different PROMs have been used to assess ankle fractures, reflecting their limitations. In this thesis a wide range of outcome questionnaires have been used to allow for this including ankle specific outcome measures and generalised quality of life outcome measures.

Ankle specific outcome measures

- The Olerud and Molander score (OMS)⁴⁷ is an ankle fracture specific outcome measure that includes questions on pain, stiffness, swelling, stair climbing, supports, activities of daily living, squatting, running and jumping. It may either be used in its entirety or in an abbreviated form for less physically able patients omitting the questions on running, jumping and squatting. The score is calculated by adding together the question scores to get a score out of 100 where 100 is the best possible score. The OMS is well used in the ankle fracture literature allowing for comparison with other studies and is also relatively easy to apply.

- The American Academy of Orthopaedic Surgeons (AAOS) questionnaire⁴⁸ is an assessment of foot and ankle pathology and its treatment. It is made up of 25 questions including those on shoe wear and work. The overall score is again calculated out of 100 with 100 the best score. The AAOS is broad ranging but the 25 questions included can be taxing for the patient to complete.
- The Manchester - Oxford (MOXFQ) score⁴⁹ is a 16 question assessment of foot and ankle function. Initially developed to assess outcomes after hallux valgus surgery⁴⁹ it has been further developed for use in foot and ankle pathology in general⁵⁰. The questions cover three dimensions of function: walking, pain and social interaction. The raw scores are converted to a metric from 0 to 100 with 100 being the most severe symptoms in contrast to the OMS and AAOS. The MOXFQ is frequently used in elective foot and ankle surgery outcomes but less commonly used following ankle fractures.

Generalised outcome measures

- The Short Form 12 (SF-12)⁵¹ is a 12 question, generalised quality of life outcome measure that provides normalised physical and mental component scores in relation to the general British population. The mean score for the population is 50.0 (SD 10.0) with 100 the best possible score. The 12 questions of the SF-12 can, at times, seem confusing to patients following trauma.
- The EuroQol five dimension scale⁵² (EQ-5D) is an alternative generalised quality of life outcome measure. It consists of five questions on mobility,

self-care, pain, activities and psychological status each scored from one to three as well as a health and pain score out of 100. The five questions permit calculation of a summary score ranging from -0.59 to one, with a maximum score of one indicating perfect health. The EQ-5D has been used in many conditions and is well accepted by patients.

- The University of California, Los Angeles (UCLA) activity score⁵³ is a one question score, most commonly used in hip and knee arthroplasty, that provides a score between one and 10 based on the activity level of the patient where 10 is the most active. The UCLA score is not often used in ankle fracture research but the concept is easy for patients to understand.

There are many areas of research into ankle fractures for which the outcomes are unknown or not fully understood. This thesis investigates four areas that cover the extent of ankle fractures. The investigation, surgical management, post injury mobilisation and post injury thromboprophylaxis of ankle fractures. The reasons for these choices are discussed in more depth below.

1.6.1 Outcomes of the use of gravity stress radiographs to assess ankle fracture stability

A key role as a surgeon is in decision making regarding which patients will benefit from intervention and which will be better left to heal without intervention in order to obtain the best possible outcomes. Operative treatments over the past 50 years have led to improved outcomes following unstable ankle fractures⁵⁴ but at times

identification of the patients that may benefit from surgical intervention remains controversial.

Assessment of stability in ankle fractures is key in deciding the most appropriate mode of treatment. However, ascertaining whether a particular ankle fracture is stable or unstable may be challenging. The vital structure required to maintain ankle stability appears to be an intact osteoligamentous complex, comprising an intact medial malleolus with an intact deep deltoid ligament⁵⁵⁻⁵⁷. SER II injuries with medial bony and ligamentous stability are considered stable whereas SER IV injuries with both medial and lateral instability are not. In SER IV fractures where the medial stability is lost due to a ligamentous rather than a bony injury, this assessment can be difficult as the standard radiographs on presentation may be indistinguishable from those of a SER II injury. Stable injuries can be successfully treated non-operatively⁵⁸ whereas unstable ones require operative, or very careful non-operative, management⁵⁹.

Several methods have been suggested to distinguish a stable SER II injury from an unstable SER IV injury. Early studies used clinical assessment of the medial soft tissues (including tenderness, swelling and bruising) to identify those with potential deltoid ligament injury⁶⁰⁻⁶⁴. The sensitivity and specificity of these signs were called into question by a number of authors^{65,66} and alternative options for assessment have subsequently been investigated.

Stress radiographs have been proposed as a potential method of assessing the competence of the deep deltoid ligament and therefore ankle stability in patients with apparently isolated lateral malleolar fractures⁶⁷. Stress may be provided by either manual force or gravity, with both involving the application of an external rotational force at the ankle, thus applying tension to the medial soft tissues. Gravity stress radiographs (GSRs) have been reported to be more acceptable to the patient and result in less radiographic exposure to the clinician⁶⁸⁻⁷⁰. Whilst stress radiographs have been found to be both sensitive and specific in cadaveric experiments^{56,57}, recent clinical studies have suggested that a widened medial clear space (MCS) on stress radiographs may not equate to a functionally unstable ankle⁷¹.

It is also unclear as to which parameters on the stress radiographs are best measured. Measurement of the MCS alone is the most frequently described parameter with values of four, five and six mm variously suggested as cut-off points for diagnosing instability^{56,65,66,72}. Other authors have recommended comparison of the MCS with a baseline value for the individual, most commonly the superior clear space (SCS)¹⁵. Some authors have combined both, with a requirement for the MCS to be greater than four or five mm and also larger than the SCS^{68,69,71,73}.

In this thesis the radiographic and patient reported outcomes of the use of the GSR to identify unstable ankle fractures have been used.

1.6.2 Outcomes of the use of the fibular nail

Operative management of ankle fractures has traditionally been undertaken with the use of open reduction and internal fixation⁵⁴. The technique of plating the lateral malleolus has changed little since the 1960s and has a complication rate that has been reported of up to 30% in specific patient groups⁷⁴. Wound infection has been seen in up to 26%⁷⁵, symptoms related to the metalwork in up to 50%⁷⁶ and mechanical failure in 14%⁷⁷. Even higher rates of complications are seen in the elderly⁷⁸ and in those with diabetes or neuropathy⁷⁹. This has led to the investigation of other fixation techniques and methods.

The fibular nail is an alternative method of fixing the lateral malleolus. It requires a smaller incision (1cm⁸⁰ compared with 8cm⁸¹ for lateral plating) and less soft-tissue dissection. It affords better mechanical stability in osteoporotic bone⁸² with less prominent metalwork, and has the potential to reduce the incidence of complications. Favourable short term outcomes of fibular nailing have been reported in small numbers of patients^{80,83,84}. A study of 37 patients had encouraging results with a mean OMS of 87, a good radiological outcome in 97% and a low complication rate, with only one case of loss of fixation and two of infection⁸⁰.

Clinical, radiographic and patient reported outcomes have been used to investigate the outcomes of the use of the fibular nail in this thesis.

1.6.3 Outcomes of early weight bearing following ankle fracture

Following an ankle fracture, patients commonly enquire as to when they can return to their normal day to day activities. Although the initial management of an ankle

fracture may be the primary concern to the treating orthopaedic surgeon, the rehabilitation protocol is highly important to the patient and their family. Patients may be permitted to weight bear either fully, partially or not at all whilst immobilized in a plaster cast, a moonboot⁶², an ankle foot orthotic (AFO), a stabilizing shoe⁸⁵ or elasticated support bandaging⁵⁸. Whilst surgeons may prefer the more conservative options due to fear of complications, patients and their families may derive significant benefit from a more active rehabilitation protocol.

Early weight bearing following ankle fracture has been extensively investigated; principally in the late 1980s and 1990s^{86,87,96,88-95}. Although these studies all showed that early weight bearing was safe following ankle fracture and that good outcomes could be achieved this does not appear to have become routine practice amongst orthopaedic surgeons^{97,98}.

In order to investigate the outcomes of early weight bearing following ankle fracture in both operatively and non-operatively treated patients clinical and radiographic outcomes have been obtained in this study.

1.6.4 Outcomes of current venous thromboembolic prophylaxis following ankle fracture

Historically, an ankle fracture could be a fatal injury¹⁸; this is thankfully no longer the case but post injury there is still a risk of venous thromboembolic events (VTEs) which can cause substantial morbidity and mortality⁹⁹. Recent emotive case reports of fatal pulmonary emboli following ankle fractures¹⁰⁰⁻¹⁰² have led to an increase in

awareness of VTEs following ankle fractures. Large numbers of VTEs have been reported following ankle fractures¹⁰³ but these range from asymptomatic deep venous thromboses (DVTs) to fatal pulmonary emboli (PEs). Whilst the morbidity and mortality following a PE can evidently be major, this is not the case for asymptomatic DVTs. By contrast the morbidity and mortality of pharmacological thromboprophylaxis can be significant^{104,105}.

Current NICE guidelines recommend consideration of pharmacological thromboprophylaxis in patients admitted to hospital subjected to lower limb plaster cast immobilisation¹⁰⁶. This has been interpreted by some orthopaedic surgeons to suggest that all patients with ankle fractures, particularly those treated operatively, should be provided with pharmacological thromboprophylaxis¹⁰⁷.

It is important, therefore, to understand the rates of clinically relevant PEs and DVTs following ankle fractures. This permits a comparison of the risk of VTEs to the risk of complications arising from pharmacological thromboprophylaxis.

In this study only the clinical outcomes of the current thromboprophylaxis following ankle fracture have been investigated, specifically the rates of VTEs which can cause significant morbidity and mortality.

1.7 Aims of this thesis

The aim of this body of work is to investigate the epidemiology and outcomes of ankle fractures. There is an initial consideration of the epidemiology of all ankle

fractures, followed by a more focussed examination of the epidemiology of open ankle fractures. The second half of the thesis considers the outcomes after ankle fracture. The outcomes of radiographic stress examination are then studied, moving on to an analysis of the outcomes of a novel management technique and an alternative post injury rehabilitation strategy, and concluding by an assessment of an important clinical complication in greater detail, that of VTE.

1.8 Chapter overview

Ankle fractures are common injuries, regularly treated by orthopaedic surgeons. This chapter has discussed the importance of a functioning ankle that is essential for locomotion. Ankle fractures therefore have the potential to significantly affect activities of daily living. As a result, investigation into ankle fractures is of great importance. This thesis investigates the epidemiology and outcomes of ankle fractures looking at several facets of these important topics.

Chapter 2: Methods

This chapter describes the research methods used for the investigation into the epidemiology and outcomes of ankle fractures.

2.1 Introduction

This thesis was undertaken using a range of research methods. The majority of the work was undertaken using a prospective database on all ankle fractures in Edinburgh and the surrounding areas presenting to the Royal Infirmary Edinburgh between 8/9/10 to 29/6/12. Additional sources of data were used for some studies.

Two major databases were collated. One included all ankle fractures over a 21-month time period and another looking in greater detail at open ankle fractures over a 23-year time period.

2.2 Database compilation

2.2.1 Ankle fracture database

All patients with ankle fractures presenting to the Royal Infirmary of Edinburgh (RIE) over a 21-month period between 8/9/10 and 29/6/12 were included in a

database. This included all ankle fractures, whether requiring inpatient or outpatient management, as all of these in the area are treated at the RIE.

Patients were identified initially from the fracture clinic and inpatient admission lists that were created in the orthopaedic department daily. To ensure that no patients were missed the local radiology portal was searched weekly for all ankle radiographs performed at the RIE. On reviewing these radiographs, it was possible to confirm that all patients in the database did have an ankle fracture (rather than a soft tissue injury) and to identify any missed patients.

Patients were excluded from the database if they were under the age of 15 years at the time of injury. In Edinburgh patients of 13 or 14 years can either present to the RIE or to the Royal Hospital for Sick Children. As a result, inclusion of patients of 13 and 14 years could have led to an incomplete data set.

To ensure that any further care of the patients was likely to occur at the RIE and to allow for calculation of fracture epidemiology, patients were only included in the database if they resided in the catchment area of the RIE. The RIE has a defined catchment area that comprises the City of Edinburgh, Midlothian and East Lothian. Patients from West Lothian may either present to the Royal Infirmary Edinburgh or to St John's Hospital, Livingston and were therefore excluded from the database. Patients who resided outside the region but were treated at the RIE were not included in the database. Patients that were domiciled within the region but that sustained their injury elsewhere and were transferred or followed up at the study centre were included.

As this study was undertaken between 2010 and 2012, the 2011 census was used accurately to define the local population numbers¹⁰⁸ in the City of Edinburgh, Midlothian and East Lothian, Table 2:1. The local population of 15 years or older at the time of the study was 559,841 comprising 290,551 women and 269,290 men¹⁰⁸.

Table 2:1 Population of council areas within the catchment of the RIE from Scotland's Census 2011¹⁰⁸.

<i>Council area</i>	<i>Population (aged 15 and above)</i>
City of Edinburgh	408,907
East Lothian	82,353
Midlothian	68,581
Total	559,841

In total 1,262 patients with ankle fractures were included in the database. Data were collected on several variables including age, gender, mechanism of injury, fracture classification, past medical history, drug history, body mass index (BMI), patient address (as a surrogate for social deprivation) and date of injury.

Mechanism of injury was recorded based on the patient's report of the event. To permit analysis, mechanism of injury was then classified into one of 7 groups: falls, sport, road traffic accidents (RTAs), assaults, direct blows, seizures and stress fractures. Falls were subdivided into three groups: falls from standing height (<1m), falls on the stairs or steps and falls from height (>1m). In those fractures sustained whilst playing sport, further detail was obtained from the patients as to the particular

sport involved. Identification of the mechanism of injury was not possible in 20 patients (1.6%).

Classification was undertaken prospectively using the Pott's and Weber classification systems as described in chapter 1. Any fractures that proved difficult to classify were discussed with Mr Tim White, Consultant Orthopaedic Surgeon.

The patient's address was used to calculate the social deprivation quintile using the Carstairs and Morris index. The Carstairs and Morris index is a method of quantifying deprivation in small areas developed in the 1980s in Edinburgh by Vera Carstairs and Russell Morris¹⁰⁹ and subsequently updated with each census. It uses four variables from the census: male unemployment, overcrowding, car ownership and low social class to rank areas within Scotland. This allows division of areas within Scotland into quintiles as used in this work. The Carstairs and Morris index was chosen over the Scottish Index of Multiple Deprivation as it does not include a "health" component in its calculation.

Carstairs postcode lookup data from the Scottish Government data allowed mapping of the postcodes of each patient to a deprivation quintile¹¹⁰ Note that this file describes quintiles with quintile one being most deprived (a recent update in order to put Carstairs data in line with Scottish Index of Multiple Deprivation data) which is at odds with most published work using Carstairs and as a result this has been reversed in this thesis to use the most commonly described quintile one as least deprived. In order to calculate the incidence of ankle fractures in each quintile Detailed Characteristic Postcode Sector data from Scotland's Census 2011 was used (DC1117SC) with census population numbers described by age and detailed

postcode sector. This enabled calculation of the population of each detailed postcode sector aged 15 years and older. A VLOOKUP within excel then mapped each of the detailed postcode sectors to a Carstairs quintile to allow calculation of the population within each quintile.

This database was then used to identify appropriate patients for individual investigations.

2.2.2 Open ankle fracture database

A further database was used to identify appropriate patients for the investigation into the epidemiology of open ankle fractures. This database was compiled in conjunction with Professor Court Brown. All patients presenting to the RIE between January 1988 and December 2010 with open ankle fractures, again as inpatients or outpatients, were included. This data was collected prospectively from 1988 to 2005 whilst from 2005 onwards patients were identified by retrospective review of the departmental computerised database.

Patients were only included if they were over the age of 16 and resided in the City of Edinburgh, Midlothian and East Lothian for the reasons described above. As this study was undertaken between 1988 and 2010 the 2001 census was used to accurately define the population numbers. The local population over the age of 16 at the time of the study was 517,555 (census www.scotland.gov.uk).

Information recorded included age, gender, address, date and mechanism of injury, other injuries, and Gustilo et al type^{111,112}.

The Injury Severity Score (ISS)¹¹³ was calculated retrospectively from the Abbreviated Injury Scale (AIS)¹¹⁴. Open ankle fractures score three on the AIS, whilst wounds less than 10cm score one and wounds greater than 10cm score two. Gustilo et al type one and two open injuries were given an AIS of one whilst type three open injuries were given an AIS of two. The ISS was then calculated as the sum of the squares of the three highest AIS scores.

The patient address was used to calculate the social deprivation quintile as described above.

2.3 Epidemiology

Investigation into the epidemiology of ankle fractures was undertaken using both the ankle fracture and open ankle fracture databases.

2.3.1 Epidemiology of ankle fractures

All the patients in the ankle fracture database were included to investigate the epidemiology of ankle fractures.

The incidence of ankle fractures over the study period was calculated by counting the period of data collection in days (8/9/10 to 29/6/12 = 23 + 31 + 30 + 31 (part of

2010) + 365 (whole of 2011) + 31 + 29 + 31 + 30 + 31 + 29 (part of 2012) = 661 days. This was then divided by 365 calculating the number of years as 1.81 years.

2.3.2 Epidemiology of open ankle fractures

The open ankle fracture database was used to investigate the epidemiology of open ankle fractures.

2.4 Outcomes

Investigation into the outcomes of ankle fractures was undertaken using patients identified from the ankle fracture database for all the studies except the investigation into the outcomes of operative management of ankle fractures. As discussed in chapter 1 a range of different outcome measures were used including clinical, radiographic and patient reported outcomes.

2.4.1 Outcomes of the use of gravity stress radiographs to assess ankle fracture stability

Investigation into the use of GSRs to identify unstable ankle fractures was undertaken using patients from the prospectively collected ankle fracture database described in detail in section 2.2.1. As patients were prospectively added to this database those with isolated Weber B lateral malleolar fractures and no apparent MCS widening on routine radiographs were invited to take part. These patients

underwent a GSR using specific radiographic protocol in either the emergency department or the orthopaedic fracture clinic.

The GSR was undertaken by placing the patient in the lateral decubitus position with the injured leg closest to the table and supported by the table up to the level of the midcalf with a bolster, Figure 2:1. The gravity acting on the foot creating an external rotation force across the ankle. Plantarflexion was not controlled.

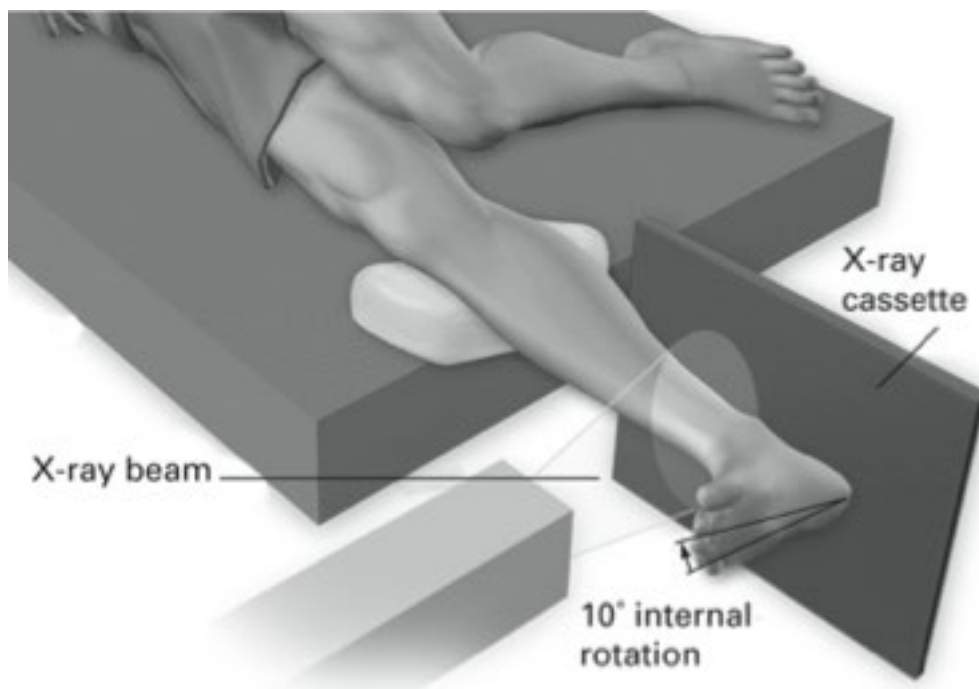


Figure 2:1 Positioning for a GSR. Taken from: The use of gravity or manual-stress radiographs in the assessment of supination-external rotation fractures of the ankle. Schock HJ, Pinzur M, Manion L, Stover M. JBJS (Br). 2007; 89(8), 1055-1059.

172 patients underwent GSRs. Seventeen of these patients were excluded from the study; eight patients with evidence of widening of the MCS at time of injury, eight patients erroneously treated operatively on the basis of the GSRs at the beginning of

the study when they were operated on as a result of displacement on the GSR, and one patient in whom the GSR resulted in displacement of the mortise that did not resolve on removal of the external rotation force application and required operative reduction and fixation.

The GSRs were not reviewed by the treating orthopaedic surgeon and patients were treated according to the routine ankle fracture management protocol at the RIE.

Patients were permitted to fully weight bear in either a below knee weight bearing cast or a moonboot and were reviewed clinically and radiographically at two- and six-weeks post injury.

The GSRs were measured using the patient archiving and communication system (PACs) software measuring tools. Measurements of the radiographic MCS and SCS were undertaken on the GSRs and compared with published criteria^{15,56,65,66,68,69,71–73}. The two- and six-week radiographs were reviewed to identify any evidence of displacement, obtaining radiographic outcomes.

In order to assess the PROMs of this cohort of patients, outcomes were obtained using postal and telephone questionnaires at a mean of six years post injury. Patients were initially sent out a paper questionnaire with help from Dr Deborah MacDonald. If there was no reply to this then patients were telephoned with help from Miss Lucy Olsen (medical student). Patients were telephoned three times at a range of times of day and days of the week to maximise opportunities for contact with them. Patients were asked a range of questions including recognised PROMs questionnaires OMS, as an ankle fracture specific tool, MOXFQ as a general foot and ankle tool, global quality of life scores (EQ5D) and the one question UCLA.

Of the 154 patients included in this study 12 were deceased at the time of follow up and three were suffering from dementia and were unable to answer questions. Of the remaining 139 patients, 78 were contacted and provided answers to the questionnaires (57%), six patients were contacted and declined to answer questions, 29 did not reply to either the postal or telephone questionnaires and 26 patients did not have any current contact details available.

2.4.2 Outcomes of the use of the fibular nail

Assessment of the outcomes of the use of the fibular nail was undertaken using a separate cohort of patients in order to identify a cohort of patients who had been treated with the use of the device. Between May 2002 and August 2010, the Acumed (Acumed, Hillsboro, Oregon, USA) fibular nail was used in 105 patients with an unstable fracture of the ankle. These were identified retrospectively from the electronic patient database.

The Acumed fibular nail is a solid titanium nail available in two diameters (3 mm and 3.6 mm) and three lengths (110 mm, 145 mm and 180 mm). Surgery is performed under general or spinal anaesthesia with the patient supine. A tourniquet is required only if open reduction of the medial side is anticipated. A closed reduction is performed, after which a 1 cm longitudinal incision is made over the tip of the lateral malleolus; the distal metaphysis is prepared with a cannulated 6.1 mm drill over a 1.6 mm guide wire. The diaphysis is reamed by hand using a 3.1 mm or 3.7 mm reamer as appropriate. The nail is then implanted.

Initially the nail was fixed to bone using a variety of techniques. These included distal locking screws to secure the distal fragment, placed either anterior-to-posterior or medial-to-lateral, with a proximal blocking screw to prevent proximal migration; distal locking screws alone; a ‘syndesmosis’ screw alone; or no fixation. Early evaluation of the results with these techniques revealed complications in a few patients, and consequently the technique was progressively modified. Currently an anterior-to-posterior distal locking screw is used which stabilises the distal fragment and reaches the dorsal fibular cortex but does not penetrate it, so as to avoid peroneal tendon irritation. The construct can then be distracted or rotated, under fluoroscopic guidance, to achieve an anatomical reduction of the mortise before the nail is locked with a transverse ‘syndesmosis’ screw, which prevents proximal migration, lateralisation and rotation (Figure 2:2).

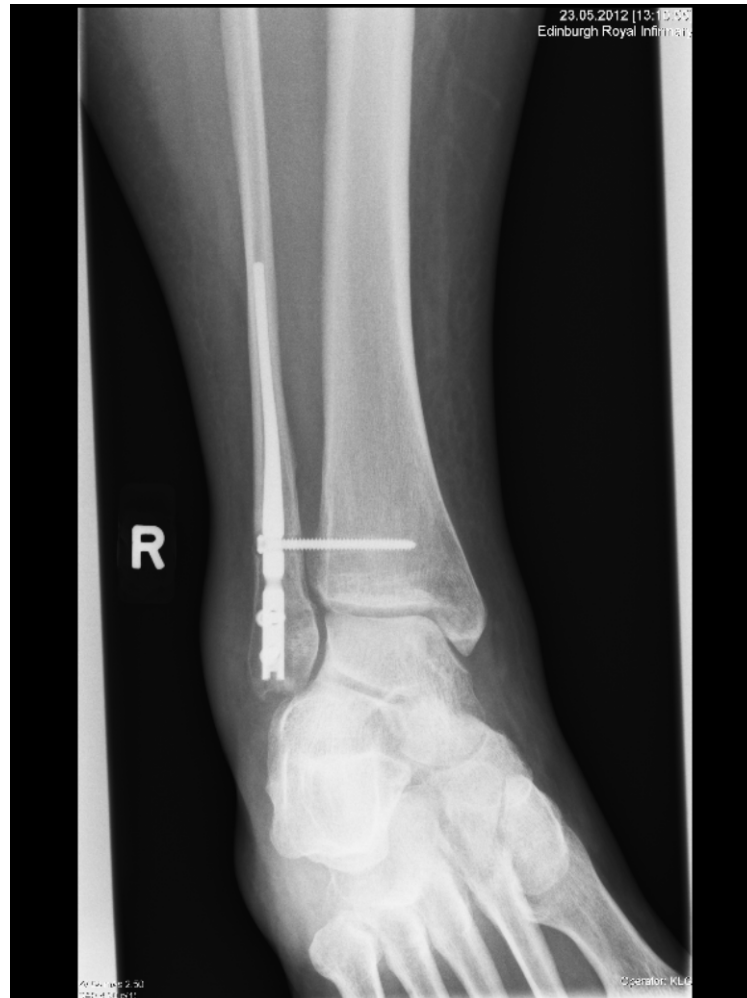


Figure 2:2 Radiograph showing the current technique of fixation of fibular nail to bone. The percutaneously inserted nail is fixed to the fibula with a distal anterior to posterior locking screw and a transverse screw across the syndesmosis.

Any fracture of the medial or posterior malleolus is then addressed as the surgeon prefers. Post-operatively, a walking cast is applied after 24 hours: patients are allowed to bear weight immediately provided there has been no diastasis.

The notes of all patients were reviewed to assess clinical outcomes. Radiographs were available for 80 patients to assess radiographic outcomes. I assessed the adequacy of reduction blinded using the method described below by McLennan and

Ungersma¹¹⁵. If the criteria were not clearly met, the radiographs were further reviewed by Mr Tim White, Consultant Orthopaedic Surgeon. McLennan and Ungersma defined good reduction as the fibula being out to length; <2mm posterior displacement; and <1mm increase in MCS. A fair reduction was described as fibular shortening of <2mm; 2mm to 4mm posterior displacement; 2mm lateral displacement; and 1mm to 3mm increase in MCS. A poor reduction was defined as fibular shortening >2mm; >4mm posterior displacement; >2mm lateral displacement; and >3mm increase in MCS. Routine radiological parameters were also measured, including the MCS, SCS and the talocrural angle.

After a mean of six years (one to nine), 52 of the original 105 patients completed functional questionnaires, including the SF-12, the abbreviated OMS and the AAOS questionnaire. As most patients in this cohort were not able to run, jump or squat before their injury the abbreviated OMS was used. Of the 53 patients who did not complete the questionnaires, 25 had died, eight were unable to do so because of dementia, three had emigrated and 17 declined.

2.4.3 Outcomes of early weight bearing following ankle fracture

Investigation of the outcomes of weight bearing following ankle fracture was undertaken using the ankle fracture database. Patients added to the database over a 15-month period of data collection were prospectively added to a separate weight bearing database. All patients were included, those with both stable and unstable ankle fractures undergoing either non-operative or operative management. In

addition to the details described above the management and weight bearing status of the patients in this database was also recorded.

Following assessment of fracture stability by the treating surgeon, fractures were treated either operatively or non-operatively. Patients were instructed to mobilise fully weight bearing as able, either immediately postoperatively (for those fractures considered unstable that underwent operative intervention), or at the first fracture clinic review (if stable and treated non-operatively). Post injury immobilisation was undertaken following discussion between the treating surgeon and the patient in either a plaster cast, moonboot or elasticated support bandaging. Patients were prospectively followed up until the time of fracture union in order to assess for fracture displacement on their radiographs, to record radiographic outcomes and to assess clinical outcomes.

Some groups of patients were excluded from the early weight bearing protocol on the basis of previously published evidence. These patient groups were also excluded from early weight bearing in this study, Table 2:2, due to concerns regarding the heightened risk of complications.

Table 2:2 Exclusion criteria for early routine weight bearing.

<i>Exclusion criteria</i>
Syndesmotic fixation ¹¹⁶
Unstable fixation ^{88,89}
Associated injuries requiring NWB ^{87,88,96}
Children with Salter Harris injuries ^{87,89,96}
Unable to comply with instructions ^{88,89}
Alcohol excess or drug abuse ^{87,96}

2.4.4 Outcomes of current venous thromboembolic prophylaxis following ankle fracture

Investigation into the outcomes of current VTE prophylaxis following ankle fracture was undertaken by including all patients in the ankle fracture database.

The local departmental protocol for pharmacological thromboprophylaxis was that non-operatively treated fractures did not receive pharmacological prophylaxis but were encouraged to be mobile and fully weight bearing in a supportive cast or orthosis as soon as possible following injury. Operatively treated fractures received subcutaneous low molecular weight heparin (LMWH) during their inpatient stay with no further pharmacological thromboprophylaxis following discharge. The majority of operatively treated patients were also permitted to mobilise fully weight bearing within a cast or orthosis.

Identification of VTEs within this cohort of patients was undertaken through use of Hospital Episode Statistics (HES) data¹¹⁷. Using the unique 10 character identifier of all patients in Scotland (Community Health Index number), all events that corresponded to the International Classification of Diseases (ICD) codes I801/I802 (ICD-10) and 4511 (ICD-9) for DVT and I260/I269 (ICD-10) and 4150/4151 (ICD-9) for PE between 1st January 1981 and 30th June 2014 were identified.

In order to confirm complete data capture, local hospital records were then scrutinised to confirm the diagnosis of VTE along with the date of diagnosis, and to identify the presence of any known risk factors for VTE¹¹⁸. As a result of this review, one patient who was coded as having had a PE was determined to have had an inconclusive computed tomography pulmonary angiogram (CTPA) and was ultimately determined not to have had a VTE, they were therefore removed from the figures.

No attempt was made to screen patients for subclinical VTEs. Patients presenting with symptoms suggestive of VTE were assessed through the standard Emergency Department protocol. Suspicion of VTE was assessed by use of a Wells Score¹¹⁹, venous thrombin assay, Doppler ultrasound and CTPA as appropriate. Patients diagnosed with VTEs were then treated as per the local hospital protocol and entered into the HES data.

The incidence of clinically recognised VTEs within the patient cohort at 30 and at 90 days after ankle fracture was calculated. This was compared with the background incidence for this population by reviewing all episodes of VTE within the study

cohort occurring prior to ankle fracture or at a remote time-point after injury, over a 33-year period from 1981 to 2014.

2.5 Statistics

Data analysis was undertaken using GraphPad Prism versions 7 and 8 (GraphPad Software, La Jolla, California, USA). Descriptive statistics were used with 95% confidence intervals (CIs) calculated where appropriate. Normality was checked using the Shapiro-Wilk and Kolmogorov-Smirnov tests. Chi-squared tests were used for categorical variables; unpaired two tailed t tests were used for continuous variables where the data showed a parametric distribution, Mann Whitney U tests were used otherwise. For the correlation between continuous variables the Pearson Coefficient (PC) was used. Kaplan-Meier survival curves¹²⁰ were produced to assess the survival of the fibular nail. A p value of <0.05 was considered significant.

Chapter 3: Epidemiology of ankle fractures

3.1 Introduction

Fractures of the ankle are common injuries treated by orthopaedic surgeons on a regular basis making up around 9% of the fractures seen by orthopaedic surgeons³.

Previous work into the epidemiology of ankle fractures has shown them to have a male preponderance with a bimodal fracture distribution². Increasing fracture incidence in elderly women has been seen⁹ but recently it has been suggested that this may have changed¹⁰.

Investigation into the epidemiology of fractures is important for our understanding of the injury and the planning of health care in amongst many other roles. This chapter considers the epidemiology of ankle fractures as a whole before moving on to investigation of the epidemiology of open ankle fractures in greater detail.

3.2 Epidemiology of ankle fractures

3.2.1 Summary

Ankle fractures are common injuries affecting patients throughout life. Investigation into the epidemiology of ankle fractures permits workforce and material planning for these common injuries.

All patients with ankle fractures presenting to the RIE over a 21-month period were prospectively added to a database, both inpatients and outpatients. Data were collected on age, gender, mechanism of injury, fracture classification, social deprivation and date of injury.

Ankle fractures were found to have an incidence of 124.5 per 100,000 per year with a significantly higher incidence in women ($p=0.007$). The mean age was 48.5 years with women significantly older than men ($p<0.001$). A fall from a standing height was the most common mechanism of injury (65.2%) with football the most common sporting mechanism (41.8% of sporting injuries). The majority were isolated lateral malleolar Weber B fractures with Weber C, medial and posterior malleolar fractures occurring in distinct, different patient groups. Ankle fractures were found to be associated with social deprivation with the incidence highest in the most deprived quintile in society.

This study has found that ankle fractures are now predominantly injuries occurring in women with an association with social deprivation. This provides important information for service planning in orthopaedics.

3.2.2 Aims

The aim of this study is to investigate the current epidemiology of ankle fractures to identify the demographics of patients sustaining ankle fractures, the common mechanisms of injury, the most common fracture patterns and the changes in the epidemiology of ankle fractures over time.

3.2.3 Methods

This study investigating the current epidemiology of fractures was undertaken using the entire ankle fracture database described in chapter 2. This comprised all patients with ankle fractures presenting to the RIE over a 21-month time period, both inpatients and outpatients.

3.2.4 Results

Incidence

1,262 ankle fractures were included in the study. The incidence of ankle fractures was 124.5/100,000/year (95% CI 117.9 to 133.6). The overall incidence peaked in late middle age with the highest incidence in those aged 65 to 69 years (193.6/100,000/year) and the lowest incidence in the 35 to 39 year age group (84.3/100,000/year), Figure 3:1. 55.7% of the ankle fractures were in women.

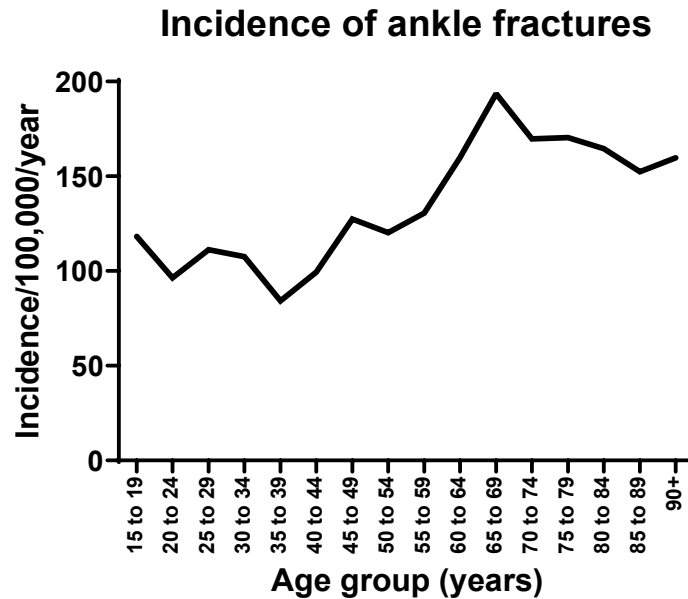


Figure 3:1 Changes in age specific ankle fracture incidence with age.

The mean age of patients sustaining ankle fractures was 48.5 years (range 15 to 100, 95% CI 47.4 to 49.6) with a significant difference in the mean age between men and women at 41.3 years and 54.2 years respectively ($p < 0.001$, Mann Whitney U test). The overall incidence of ankle fractures in women of 133.6/100,000/year was also significantly higher than the incidence in men of 114.6/100,000/year ($p = 0.007$, Fishers exact test). The incidence in women increased with age until the seventh decade followed by a decrease whilst the male incidence remained relatively stable throughout life, Figure 3:2. This was found to fit most closely to fracture curve E³ although the decrease in incidence in the super-elderly women has not previously been shown.

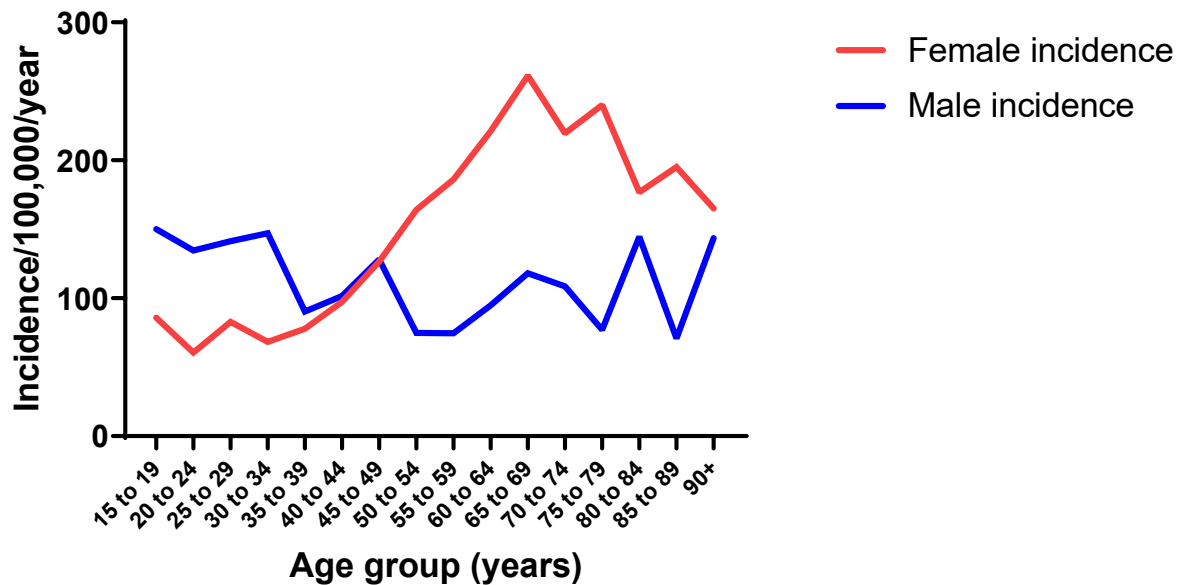


Figure 3:2 Male and female age specific incidence of ankle fractures.

Mechanism of injury

Ankle fractures were found to be predominantly low energy injuries, Table 3:1, with over 70% due to a fall from a standing height or on the stairs. Those fractures sustained due to high energy mechanisms of injury, comprising 23.6% of fractures, shared many similarities. They were predominantly sustained by men (75% in men compared to 35% of the low energy fractures), with a significantly younger mean age than the low energy mechanisms of injury, 34.2 and 52.8 years respectively ($p < 0.001$ Mann Whitney U test).

Further analysis of the mechanism of injury in younger patients found that a large number were associated with the ingestion of alcohol, particularly in women. In patients under the age of 30, ankle fractures were associated with the ingestion of

alcohol in 7.3% of cases in men and 17.0% in women (Chi squared with Fishers exact test $p = 0.018$).

Table 3:1 Mechanisms of injury in 1,262 patients sustaining ankle fractures. Showing frequency as a percentage of all fractures. Mechanisms in red are high energy, those in blue are low energy and those in black account for very small numbers.

<i>Mechanism</i>	<i>Frequency (%)</i>	<i>Mean age (years)</i>	<i>Female (%)</i>	<i>Mean female age (years)</i>	<i>Mean male age (years)</i>
Fall standing	65.2	52.4	64.6	55.9	46.0
Sport	16.5	31.7	23.6	35.4	30.5
Fall stairs	8.5	56.0	68.2	55.7	56.5
Fall height	3.2	43.1	37.5	52.0	37.8
RTA	2.2	42.5	32.1	42.1	42.6
Assault	1.8	31.7	8.6	33.5	31.6
Direct blow	0.4	47.4	80.0	52.5	27.0
Seizure	0.4	59.0	40.0	67.5	53.3
Stress	0.2	52.0	100.0	52.0	-
Unknown	1.6	55.8	70.0	59.3	47.7

The second most common mechanism of injury was sport. Of the 208 ankle fractures sustained due to sport the majority were sustained whilst playing football or rugby, Table 3:2. The mean age for those fractures sustained due to sport was substantially younger than the overall mean for all ankle fractures, 31.7 and 48.5 years respectively ($p < 0.001$ Mann Whitney U test). The only sport with a higher mean age than the overall mean was golf with a mean of 65.5 years, which may be due to the low energy nature of many of these fractures.

Table 3:2 Ankle fractures sustained due to sport. Frequency represented as a percentage of all ankle fractures sustained playing sport.

<i>Mechanism</i>	<i>Frequency (%)</i>	<i>Mean age (years)</i>	<i>Female (%)</i>
Football	41.8	26.7	1.1
Rugby	12.0	22.5	20.0
Running	8.2	40.9	58.8
Golf	4.3	65.5	11.1
Cycling	3.8	37.4	25.0
Roller blading/skating	3.4	28.0	42.9
Horse riding	2.4	43.6	100.0
Ice skating	2.4	31.4	60.0
Skateboarding	2.4	22.0	40.0
Basketball	2.4	30.4	20.0

The peak incidence of sports-related ankle fractures was in the youngest age group with incidence decreasing with age, Figure 3:3. There was a significant difference in the incidence of sports related ankle fractures between men and women at 32.6 and 9.3/100,000/year respectively (Fisher's exact test $p < 0.001$). In men in the third decade sport was the most common mechanism of injury.

Incidence of sports related ankle fractures

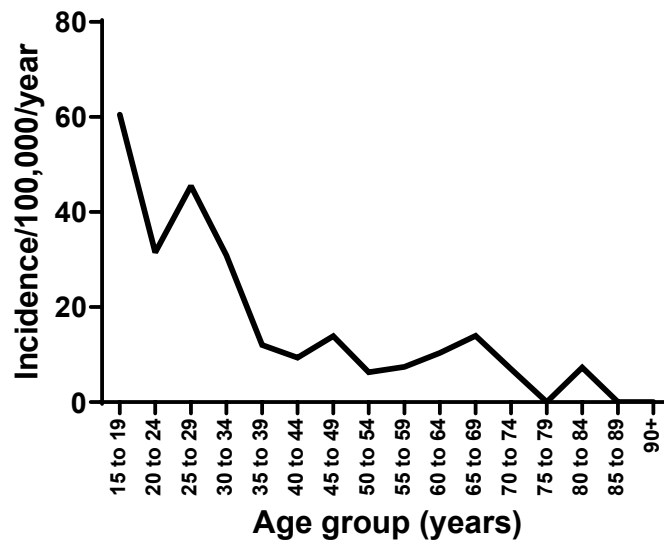


Figure 3:3 Change in incidence in sports related ankle fractures with age.

Fracture classification

Pott's classification permitted classification of all but two fractures (99.8% of fractures) which were excluded as they were paediatric fracture configurations, Table 3:3. Isolated lateral malleolar fractures were the most commonly sustained injury (68.5% of fractures) with isolated medial and posterior malleolar fractures the least commonly sustained ankle fractures. Analysis of the isolated medial and posterior malleolar fractures revealed that both injuries were sustained by a predominantly male patient group (58.5%) with a significantly younger mean age than the other fracture types, 35.3 years and 49.5 years respectively ($p < 0.001$, Mann Whitney U test) and they were significantly more likely to be sustained playing sport, 29.3% vs 15.5% ($p = 0.003$, Fishers exact test). Of note no isolated posterior malleolar fracture was sustained by a patient older than 50 years of age.

Table 3:3 Epidemiology of Pott's classification of ankle fractures, n = 1260.

<i>Fracture type</i>	<i>Frequency (%)</i>	<i>Mean age (years)</i>	<i>Female (%)</i>	<i>Fall from standing (%)</i>	<i>Sport (%)</i>
Lateral malleolar	68.5	47.8	55.2	69.1	17.4
Bimalleolar	14.5	54.5	61.7	68.3	10.9
Trimalleolar	10.5	53.1	60.6	66.7	8.3
Medial malleolar	5.1	36.2	42.2	39.1	26.6
Posterior malleolar	1.4	32.1	38.9	61.1	38.9

Fracture curves were created for the three most common fractures, Figure 3:4. The bi and trimalleolar fractures showed a typical type E distribution with a peak incidence in the oldest women and a fairly stable fracture incidence in men. The lateral malleolar fractures however were not found to fit with any particular fracture curve due to a decrease in incidence in the super-elderly women as previously discussed.

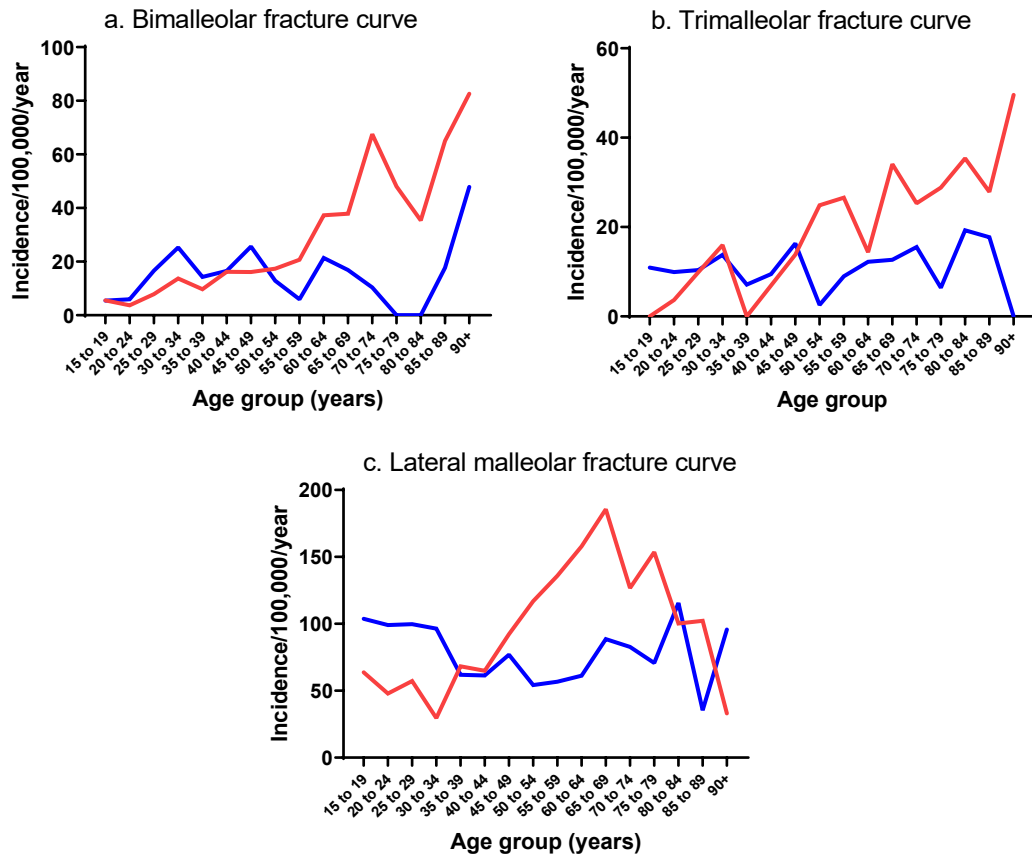


Figure 3:4 Pott's classification fracture curves, red line indicates female incidence, blue line indicates male incidence. a. Bimalleolar fractures showing a type E distribution. b. Trimalleolar fractures showing a type E distribution. c. Lateral malleolar fractures showing a distribution that does not fit with any previously described fracture curve.

The Weber classification allowed for further analysis of the lateral malleolar and trimalleolar fractures as well as those bimalleolar fractures that included the lateral malleolus (98%), Table 3:4. This resulted in 1174 fractures included, 93.0% of fractures. The majority of these were Weber B type fractures at the level of the syndesmosis (67.2%) with the Weber C suprasyndesmotomic fractures the least common. Weber C fractures had a significantly younger mean age than the other fracture types (41.3 versus 50.5 years, $p < 0.001$ Mann Whitney U test), a significantly

greater proportion of fractures occurring in men (56.0% versus 41.4%, $p < 0.001$ Chi squared test) and a significantly greater percentage occurring due to sport (28.4% versus 13.9%, chi squared test).

Table 3:4 Epidemiology of Weber's classification of ankle fractures, n = 1174.

<i>Fracture type</i>	<i>Frequency (%)</i>	<i>Mean age (years)</i>	<i>Female (%)</i>	<i>Fall from standing (%)</i>	<i>Sport (%)</i>
A	21.4	50.5	64.9	63.0	17.5
B	67.2	50.6	56.5	70.6	12.7
C	11.4	41.3	44.0	51.5	28.4

Creation of fracture curves showed a type E distribution for the Weber B fractures, a type B fracture curve for the Weber C fractures and, once again, a fracture curve not previously described with a lower incidence in super-elderly women for the Weber A fractures, Figure 3:5.

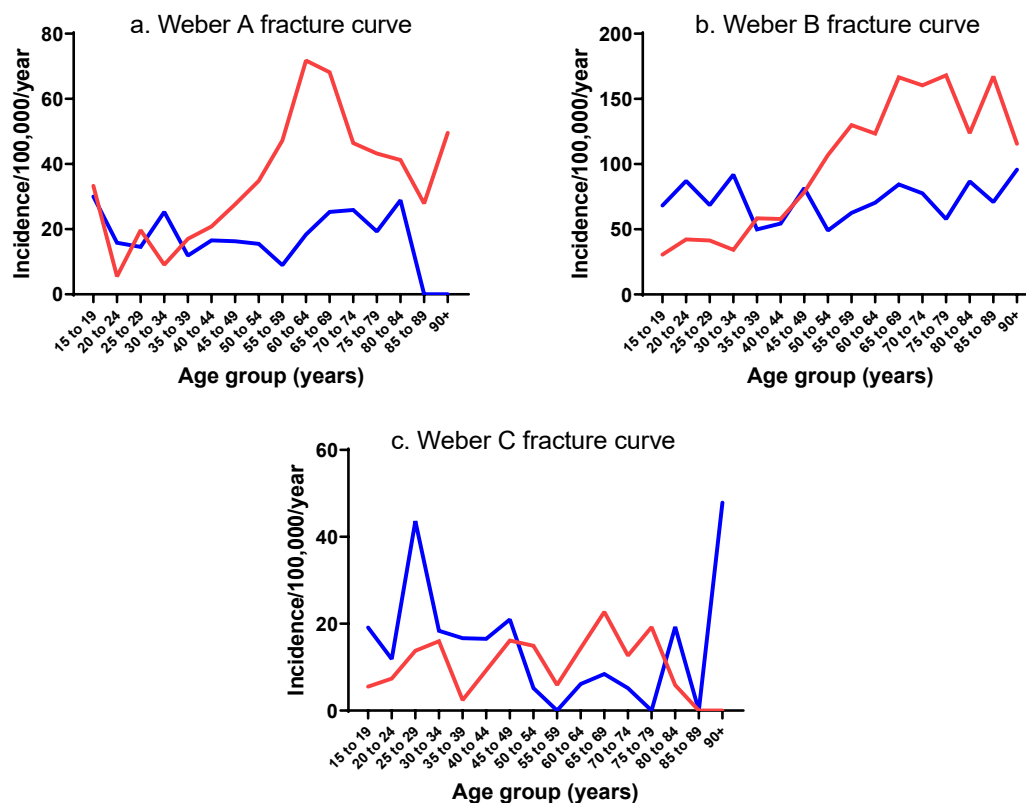


Figure 3:5 Weber classification fracture curves, red line indicates female incidence, blue line indicates male incidence. a. Weber A fractures showing a distribution that does not fit with any previously described fracture curve. b. Weber B fractures showing a type E distribution. c. Weber C fractures showing a type B distribution.

Social deprivation

Social deprivation using the Carstairs and Morris index was calculated for 1,247 patients for whom a current postcode was available (98.8% of patients). The highest incidence was in the most deprived quintile, Table 3:5, although due to the local population demographics the highest frequency was in the third quintile.

Table 3:5 Social deprivation and incidence of ankle fractures.

<i>Deprivation quintile</i>	<i>Incidence (10⁵/year)</i>
1 (least deprived)	125.5
2	113.5
3	127.1
4	115.9
5 (most deprived)	133.1

Those in the most deprived quintile had a significantly younger mean age at which they sustained ankle fractures than those in the other quintiles ($p < 0.001$ Mann Whitney U test) and the ankle fractures sustained by those in quintile five were significantly more likely to occur in men ($p = 0.011$, Chi squared test), Table 3:6.

Table 3:6 Social deprivation and ankle fractures details

<i>Deprivation quintile</i>	<i>Mean age (years)</i>	<i>Female (%)</i>	<i>Fall from standing (%)</i>	<i>Sport (%)</i>
1 (least deprived)	54.2	65.2	73.4	13.5
2	47.8	57.1	65.2	17.0
3	50.4	55.1	59.8	18.9
4	46.0	51.8	67.1	17.1
5 (most deprived)	42.9	47.9	59.7	16.8

3.2.5 Discussion

This study of the epidemiology of 1,262 consecutive ankle fractures has described the detailed epidemiology of ankle fractures in the 21st century. The overall incidence of 124.5 ankle fractures/100,000/year found in this study is broadly in line with previously published rates of between 71 and 184 ankle fractures/100,000/year^{6,37,121,122}. Higher incidences of 168.7 and 184/100,000/year were reported by Elsoe¹²¹ and Daly³⁷ respectively but both authors included all ages in their studies whilst the current study only includes adults. This may have resulted in a higher overall incidence as Elsoe¹²¹ found the second highest incidence in the 10 to 19 age group. Daly³⁷ also had difficulty defining their population size whereas a census was carried out locally during the period of data collection allowing for accurate calculation of the population size¹²³. Lower incidences of 107 and 71/100,000/year were reported by Jensen⁶ and Thur¹²² respectively but Thur only included those patients admitted with ankle fractures excluding all patients treated as outpatients whilst the work by Jensen only included 212 fractures and only those admitted through the ED which may account for the difference.

A study of the same geographic population looking at fractures from 1988 to 1990² found a very similar incidence of 122.0/100,000/year. This stabilisation of the incidence of ankle fractures has been described elsewhere. Although Kannus previously reported an increasing incidence of fall related ankle fractures between the 1970s and 1990s⁹ further work from his group found that after a peak incidence in the late 1990s¹⁰ the incidence of fall related ankle fractures in the elderly has begun to decrease in the last 10 to 15 years. They have found the current incidence

and the incidence in the late 1980s to be very similar, as found here. Two other authors looking at similar years have also found no change or only a very small change in the incidence in the 1990s and early 2000s^{121,122}.

This study has found ankle fractures to be significantly more common in women and that the women sustaining ankle fractures are significantly older than the men sustaining these injuries. Other recent studies have also found ankle fractures to be predominantly sustained by women¹²¹ in contrast to Court-Brown² and Daly³⁷ who found the reverse in studies carried out in the 1970s and 1980s. This is supported by Bengner who reported a change from predominantly male fractures to female over the 30 years of their study¹¹.

Ankle fractures have been found in this study to have a fracture curve with a stable incidence in men and a unimodal distribution in women with a peak in the seventh decade. This is very similar to the findings of Thur looking at 91,410 ankle fractures in Sweden between 1987 and 2004¹²² but in contrast to previous work which found a type A fracture curve with a unimodal younger male and unimodal older female distribution³. It may be that this reflects the changing ankle fracture epidemiology with a reduction in ankle fractures in younger men. Looking in greater detail at the fractures in the elderly a decreasing incidence with age can be seen in women with a stable incidence in men, a type V fracture pattern. This is also in contrast to previous work which described a type IV pattern⁴² and work from Finland which found a type II pattern¹⁰. The differences between the current study and the work from Finland may be due to differences within the population. Ankle fractures are predominantly injuries seen following a fall from a standing height requiring a level of mobility,

Finland has seen large increases in life expectancy¹²⁴ and health improvements¹²⁵ in the past decade which may have increased the activity levels of the elderly whilst Scotland has not yet seen this change.

The bimalleolar and trimalleolar and Weber B fracture curves do not show a drop in incidence in the super elderly suggesting that these may be osteoporotic fractures as previously described by Court-Brown³. This agrees with Koval who found a higher mortality rate in these fractures than unimalleolar ankle fractures¹²⁶. It has also been previously shown that the microarchitecture of the trabecular bone in elderly patients sustaining ankle fractures is altered compared with controls⁷.

In common with most other authors this study has found lateral malleolar fractures to be the most commonly sustained of the Pott's classification system¹²¹ and Weber B² the most common of the Danis Weber types. Thur¹²² found a higher incidence of bi and trimalleolar fractures but their study only included inpatients, likely resulting in the exclusion of large numbers of conservatively treated isolated lateral malleolar fractures.

The epidemiology of the medial and posterior malleolar fractures and the Weber C fractures has been found to be very different from the other fracture types in this study. These all shared similar fracture curves and all occur in the young men with higher proportions due to sport. Others have also found this with medial malleolar fractures reported to be more common in younger patients^{2,121} and Weber C fractures to be high velocity injuries². This difference in the epidemiology may be due to the difference in the bone density of the lateral malleolus in younger men such that a mechanism potentially causative of a lateral malleolar Weber B injury instead causes

a soft tissue injury. This is supported by the high incidence of ankle sprains in this age group¹²⁷. Alternatively, the mechanism of sustaining ankle fractures may be different in younger men due to their biomechanics and activities such that they fall in a different way leading to pronation type injuries causing these fracture types.

Ankle fractures have been shown to be more common in the most deprived quintile in Edinburgh. This is in common with a large range of other fractures in both adults³⁵ and children¹²⁸. This study has also shown that those sustaining ankle fractures in the most deprived quintile were significantly more likely to be men, with a significantly younger mean age.

This study was undertaken on ankle fractures over a 21-month period and as such is not able to investigate changes in the epidemiology of ankle fractures over time in detail. However a previous study in the same geographic area does permit some comparisons² as discussed. This study is however able to investigate the 1,262 ankle fractures in a great degree of detail due to the prospective nature of the study with data collection undertaken by the researcher. In addition, the census carried out in the local area during the time of data collection allows accurate measurement of the population to calculate the incidence.

3.2.6 Conclusion

This study of the epidemiology of ankle fractures has found ankle fractures to be common injuries with an incidence of 124.5/100,000/year. They are predominantly sustained by women with a stable incidence in men and a unimodal distribution in women. Lateral malleolar and Weber B ankle fractures are the most commonly

sustained with medial and posterior malleolar and Weber C fractures sustained by a significantly younger, predominantly male group of patients. Ankle fractures are most common in the most deprived quintile in whom they occur at a significantly younger age.

3.3 Epidemiology of open ankle fractures

This study was published in 2015 in Archives of Orthopedic Trauma Surgery¹²⁹, appendix 1.

3.3.1 Summary

Open ankle fractures present a significant clinical challenge. The management and outcome of these injuries has been extensively reported, but there have been no reports of the epidemiology and how this has changed over time.

This study reports on 178 adult patients with open ankle fractures presenting to the RIE over a twenty-three year period. The RIE is the only hospital receiving adult orthopaedic trauma in the region and has a defined population.

The incidence of open ankle fractures was 1.5/10⁵/year, representing 1.5% of all ankle fractures. The mean age was 55 years (range 16 to 96), with the highest incidence occurring in women over the age of 90. The most common mechanism was a simple fall with only 26% of cases due to a RTA. 82% of cases were isolated

injuries. Social deprivation had no significant influence on the incidence, but there was a difference in the mechanism with the majority of injuries in the most deprived quintile caused by RTAs and significantly fewer due to simple falls ($p=0.047$).

Over the twenty-three years there was a significant increase in the mean age from 44 to 64 years ($p=0.03$). The overall incidence remained constant over the two decades.

In common with many traumatic injuries, open ankle fractures are increasingly low energy insufficiency fractures affecting elderly patients, particularly older women.

This has implications for service planning and training as well as the surgical intervention in these patients.

3.3.2 Aims

The aim of this study is to investigate the epidemiology of open ankle fractures. To identify the patients affected, the prevalent modes of injury and the associated injuries as well as whether the epidemiology of open ankle fractures has changed during the last two decades.

3.3.3 Methods

The open ankle fracture database described in chapter 2 was used for this study. This comprised all open ankle fractures presenting to the RIE between 1988 and 2010.

3.3.4 Results

Incidence

During the twenty-three-year study period 178 patients presented to the RIE with open ankle fractures. This represents an incidence of 1.49/100,000/year within the local population of 517,555.

The mean age of these patients was 55 years, ranging from 16 to 96 years. Women made up 54% of these patients with an incidence of 1.52/100,000/year and a mean age of 64, whilst there were 82 men with a mean age of 45 and an incidence of 1.46/100,000/year (Figure 3:6).

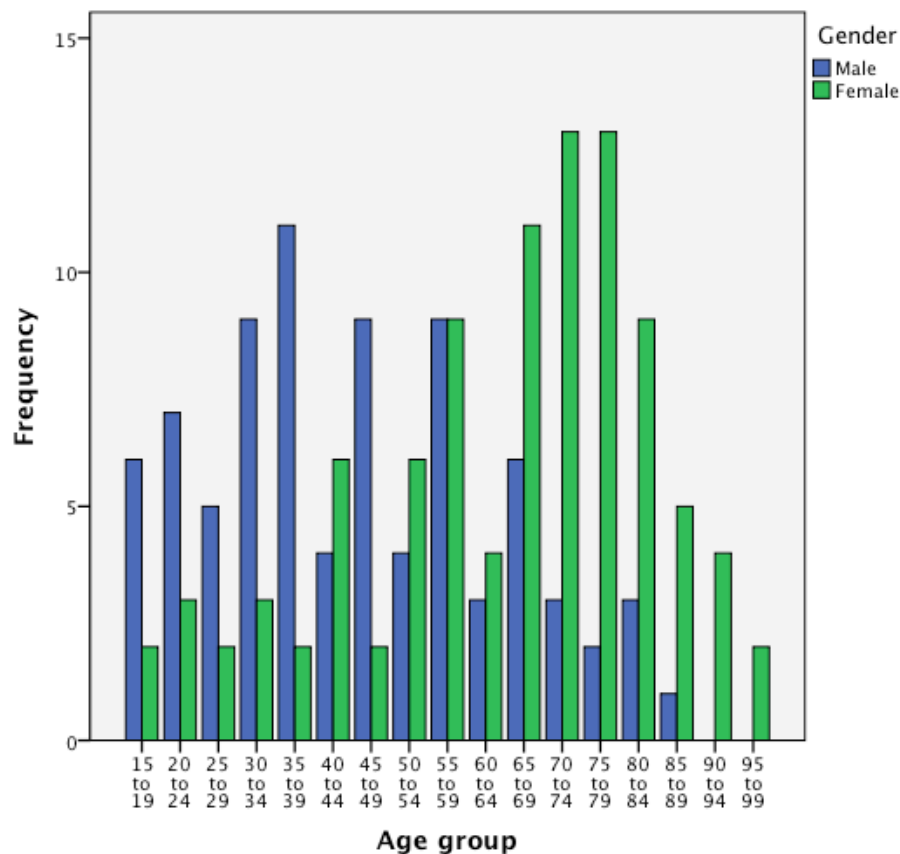


Figure 3:6 Age and gender distribution of open ankle fractures 1988 to 2010.

The mean ages of men and women were significantly different ($p < 0.001$) but there was no significant difference in the incidence with gender. The incidence of open ankle fractures increased in men with age from 1.41/100,000/year in patients under 65 to 1.68/100,000/year in patients over 65 but this was not significant ($p = 0.86$). However, a significant change was observed in women with an incidence of 0.78/100,000/year in patients under 65 increasing to 4.26/100,000/year in patients over 65 (PC $r = 0.87$, $p < 0.001$). This is shown in Figure 3:7.

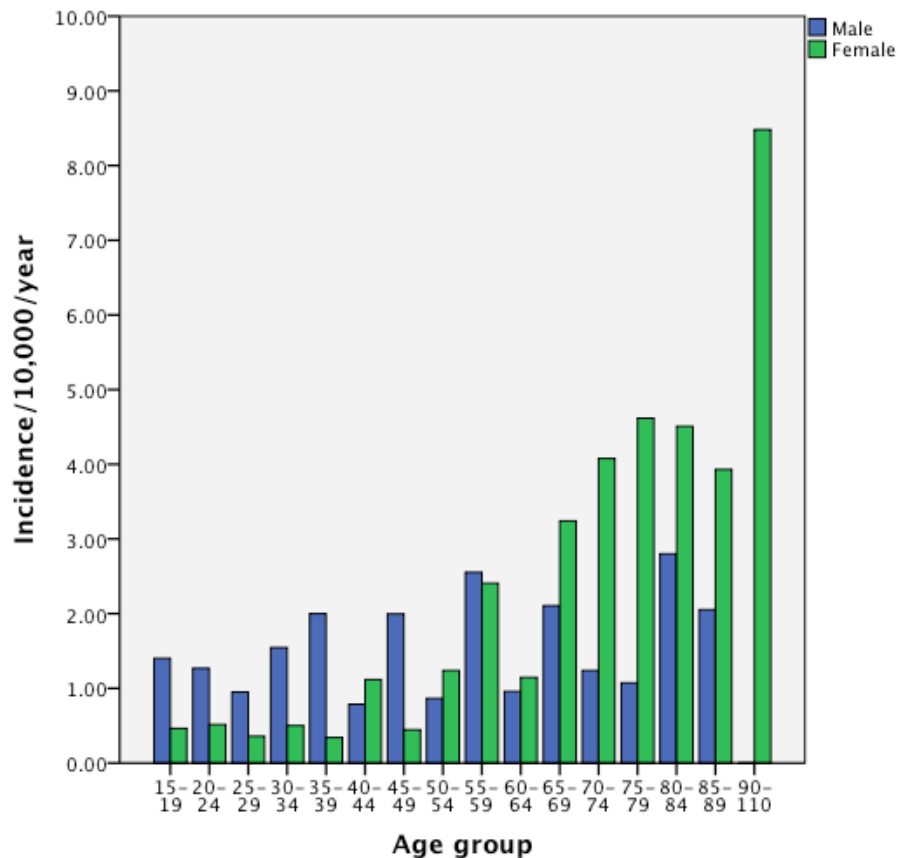


Figure 3:7 Change in incidence of open ankle fractures with age.

Mechanism of Injury

The most common mechanism of injury was a simple fall, accounting for just under half of the fractures (Table 3:7) with RTAs second and accounting for 26% of fractures. When the age of the patients was taken into consideration 74% of fractures in elderly patients were due to simple falls whilst in patients under the age of 65 simple falls accounted for only 32% of fractures ($p < 0.001$, odds ratio 5.91) with RTAs accounting for a further 33%. The addition of gender to the analysis found that the majority of fractures sustained as a result of simple falls or falls on the stairs

occurred in women; in contrast those sustained in RTAs, falls from height or whilst playing sport which occurred more commonly in men.

<i>Mechanism of injury</i>	<i>Number of patients</i>	<i>Mean age (years)</i>	<i>Percentage female</i>	<i>Mean ISS</i>
Simple fall	87	66	75%	11
RTA	46	47	33%	16
Fall from height	15	40	27%	12
Fall from stairs	11	64	82%	11
Sport	8	32	13%	12
Direct blow/assault	5	31	20%	14
Crush	3	47	0	11
Unknown	3	52	33%	13

Table 3:7 Mechanism of injury of open ankle fractures

The open ankle fractures sustained in RTAs were largely due to pedestrian versus car incidents (Figure 3:8). The patients sustaining their injury as passengers were predominantly female with a mean age of 59, and ISS of 19, whilst those involved as drivers were all male with a mean age of 36 and mean ISS of 35. The 5% of injuries due to sport occurred almost exclusively in male patients which included a number of sports: rugby, 38%, football, 25%, and horse riding, 13%.

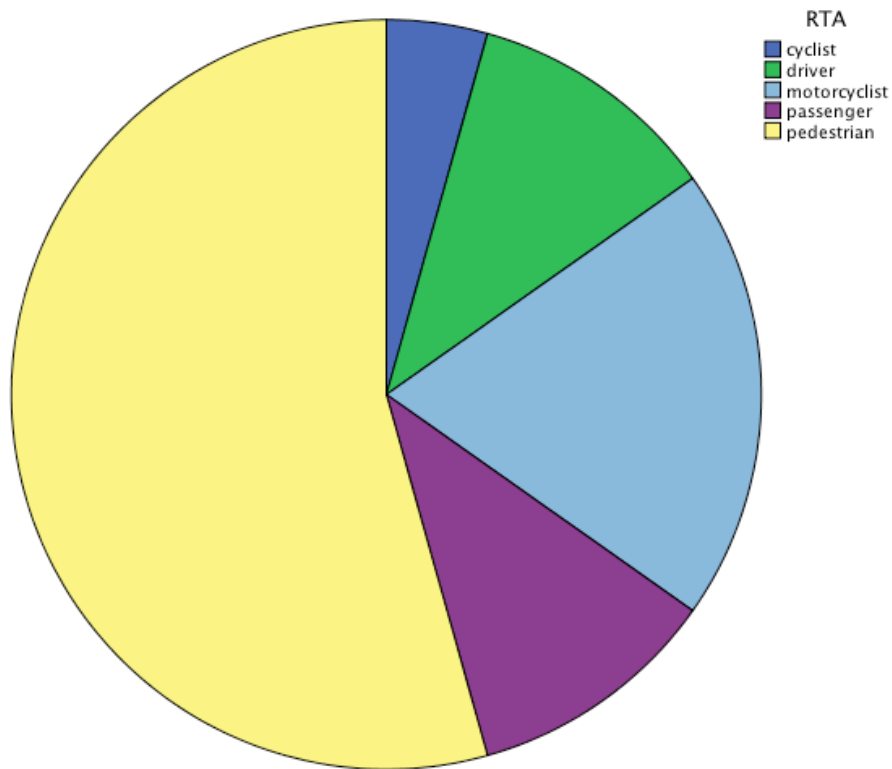


Figure 3:8 Open ankle fractures with an RTA as the mechanism of injury.

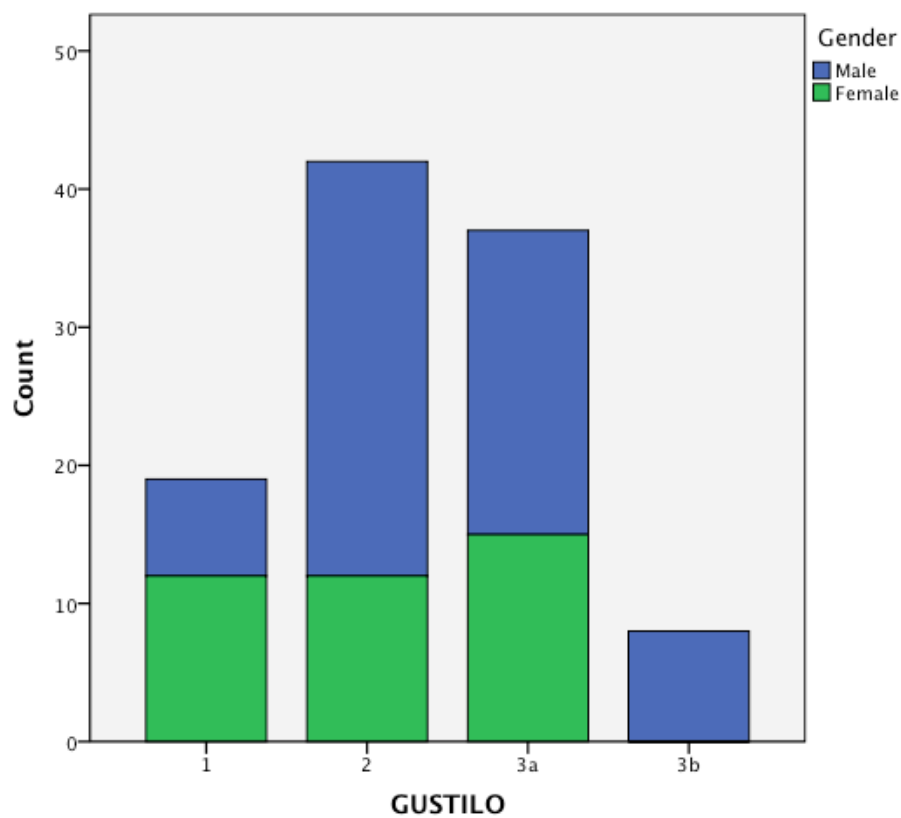
Gustilo et al Classification

The distribution of fractures by the Gustilo et al classification is shown in Table 3:8.

The most frequent type of injury was IIIa, which accounted for 40% of cases. The mean age of these patients was higher than the other types of injury at 61 years ($p=0.005$) with the majority of these cases occurring due to a simple fall. Type IIIa fractures were most prevalent in the elderly, whilst in patients under the age of 65 type II fractures were more common (Figure 3:9 and Figure 3:10). The mean ISS increased as the Gustilo et al type increased (PC $r=0.15$, $p=0.02$), when the one patient with a Gustilo et al type IIIc fracture was excluded.

Table 3:8 Gustilo et al type of open ankle fractures

<i>Gustilo et al</i>	<i>Patients</i>	<i>Mean Age</i>	<i>Injuries due to simple fall</i>	<i>Mean ISS</i>
Type I	31 (17%)	54.8	48%	11.9
Type II	64 (36%)	51.2	45%	12.1
Type IIIa	72 (40%)	61.4	57%	13.6
Type IIIb	10 (6%)	39.6	20%	15.1
Type IIIc	1 (1%)	76.0	0%	13.0

**Figure 3:9 Gustilo et al type of open ankle fractures in patients under the age of 65.**

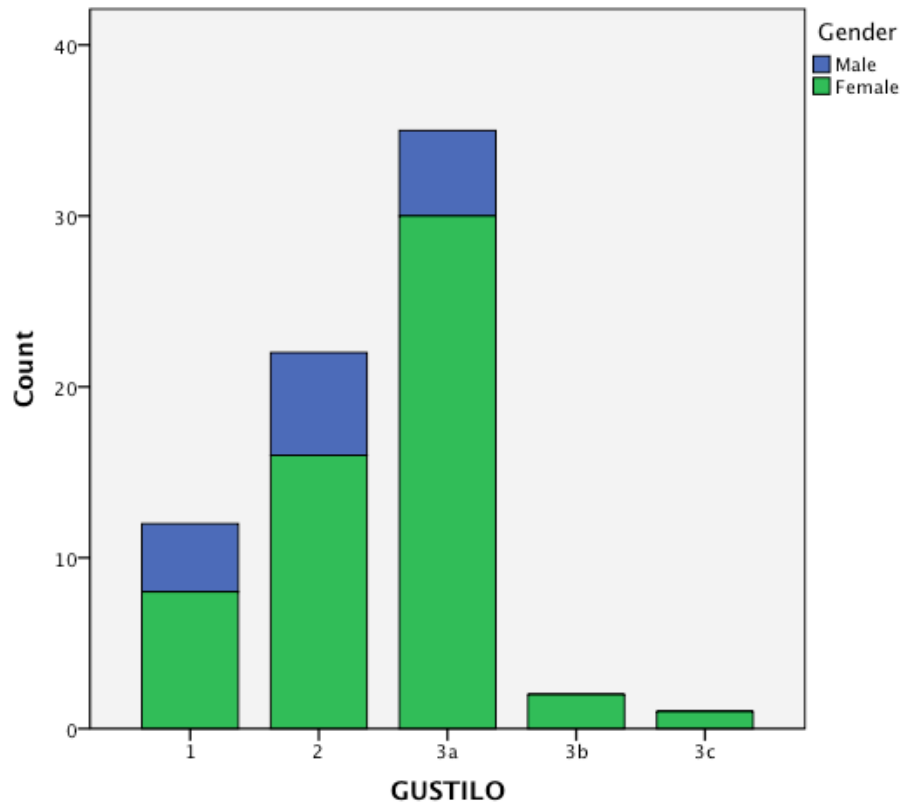


Figure 3:10 Gustilo et al type of open ankle fractures in patients over the age of 65.

Other injuries

The majority of patients with open ankle fractures (82%) sustained this as an isolated injury. Of the 18% of patients that sustained their open ankle fracture in conjunction with other injuries additional orthopaedic injuries were the most common associated injuries (88%) as shown in Table 3:9. These other fractures were predominantly of the lower limbs (80%) with a small number affecting the upper limbs (14%) and spine (6%). Most patients sustained only one open fracture however 6% of patients sustained two open fractures, two patients sustained three open fractures and one elderly female patient sustained six open fractures (distal femur, proximal tibia,

middle, ring and little fingers). The median ISS was 13 with a range from 10 to 57; 92% of patients had an ISS of 10 or 13. All of the patients with an ISS of greater than 13 sustained their open ankle fracture as a result of a high energy injury; 87% were due to RTAs with one sustained after a fall from height and one as a result of an assault.

Table 3:9 Other injuries sustained at the same time as the open ankle fracture. Some patients sustained multiple other injuries.

<i>Other injuries</i>	<i>Number of patients</i>	<i>Percentage</i>
Orthopaedic	29	88%
Chest	8	24%
CNS (including head injuries)	7	21%
Abdominal	4	12%

Social Deprivation

There was no correlation between social deprivation and the incidence of open ankle fractures, Table 3:10. The largest proportion of patients was in quintile one and the smallest was in quintile five but as the local population is skewed towards affluence the highest incidence of open ankle fractures was in quintile five at 1.80/100,000/year. Simple falls were the most common cause of injury in all quintiles except quintile five. In this quintile the majority of injuries were caused by

RTAs with simple falls only causing 30% of injuries ($p=0.047$). Quintile five also had the lowest mean age of patients and the highest mean ISS but this was not significant ($p=0.26$ and 0.48).

Table 3:10 Social deprivation and open ankle fractures.

<i>Carstairs quintile</i>	<i>Patients</i>	<i>Incidence (10⁵/year)</i>	<i>Mean age</i>	<i>Mean ISS</i>	<i>Percentage female</i>	<i>Modal Gustilo et al type</i>
1	56	1.73	57	13.7	61%	IIIa
2	30	1.31	54	12.2	53%	II
3	37	1.55	57	12.7	59%	II
4	35	1.47	55	11.3	43%	II
5	20	1.80	50	14.3	45%	IIIa

Change with time

Over the twenty-three years the incidence of open ankle fractures remained stable with between two and 14 fractures presenting to the unit each year (Table 3:11).

Table 3:11 Year of injury of open ankle fractures.

<i>Year of</i>	<i>Patients</i>	<i>Mean</i>	<i>Most common</i>	<i>Mean ISS</i>	<i>Percentage</i>
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Epidemiology and Outcomes of Ankle Fractures

<i>injury</i>		<i>age</i>	<i>mechanism</i>		<i>female</i>
1988	6	44.17	RTA (100%)	19.17	50%
1989	8	42.63	RTA (50%)	13.88	63%
1990	10	52.30	RTA (60%)	10.90	20%
1991	8	45.75	RTA (63%)	13.50	0
1992	4	57.25	RTA (50%)	12.25	50%
1993	2	78.00	Simple fall (100%)	11.50	100%
1994	8	56.50	Simple fall (75%)	11.50	63%
1995	6	40.33	Simple fall (50%)	12.50	50%
1996	6	56.50	RTA (50%)	14.50	50%
1997	6	46.33	Simple fall (50%)	10.50	50%
1998	6	62.17	Simple fall (66%)	11.50	66%
1999	11	52.45	RTA (45%)	17.18	36%
2000	11	52.45	Simple fall (55%)	10.82	45%
2001	14	63.43	Simple fall (69%)	14.43	71%
2002	8	55.25	Simple fall (38%)	12.25	88%
2003	7	55.29	Simple fall (71%)	11.29	71%
2004	7	59.14	Simple fall (71%)	10.86	71%
2005	9	62.56	Simple fall (66%)	11.67	56%
2006	7	58.71	Simple fall (57%)	12.14	86%
2007	4	69.25	Simple fall (75%)	12.25	75%
2008	11	52.27	Simple fall (55%)	13.82	36%
2009	12	61.92	Simple fall (75%)	11.00	42%

2010	7	64.14	Simple fall (57%)	13.86	71%
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However, there were two major changes over this time period. The prevalent mechanism of injury showed a marked change; 100% of open ankle fractures in 1988 were due to RTAs but there were none caused by RTAs from 2008 to the end of the period of data collection (Figure 3:11). The mean patient age has also changed, with a rise from 44 years in 1988 to 64 years in 2010 ($r=0.21$, $p=0.03$). Finally, when patients over the age of 65 years are analysed separately (Figure 3:12) it can be seen that there has been a marked increase in the incidence of open ankle fractures in elderly women, but not elderly men, since 1988.

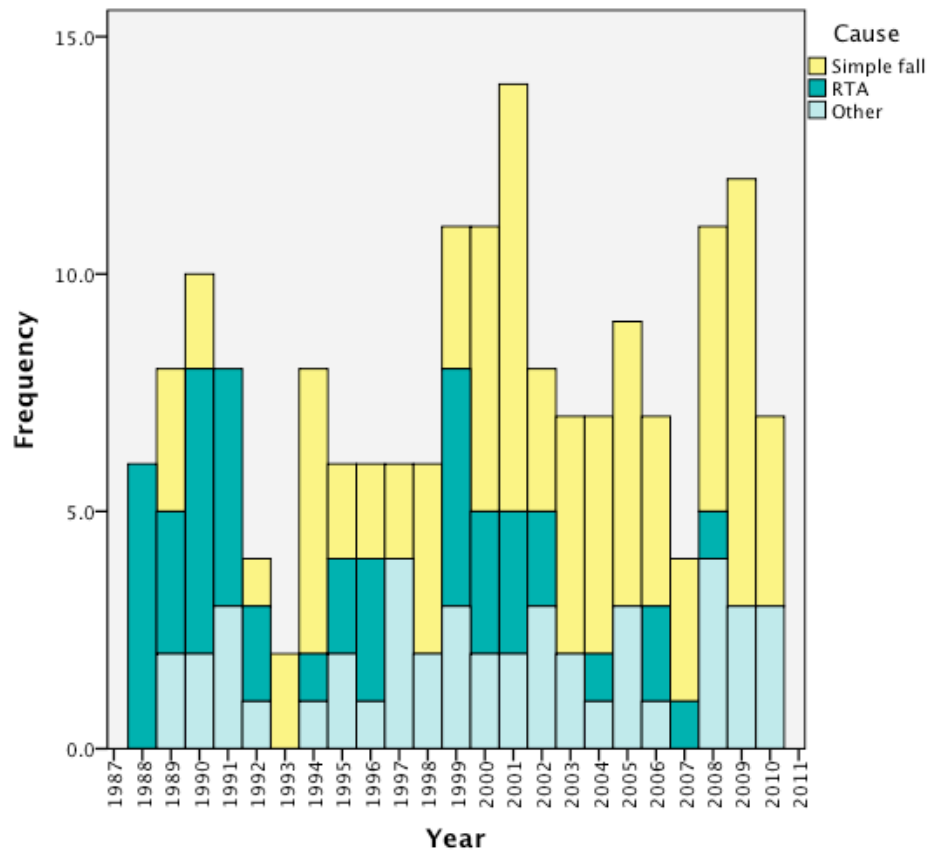


Figure 3:11 Change in mechanism of injury of open ankle fractures over the twenty-three-year study period.

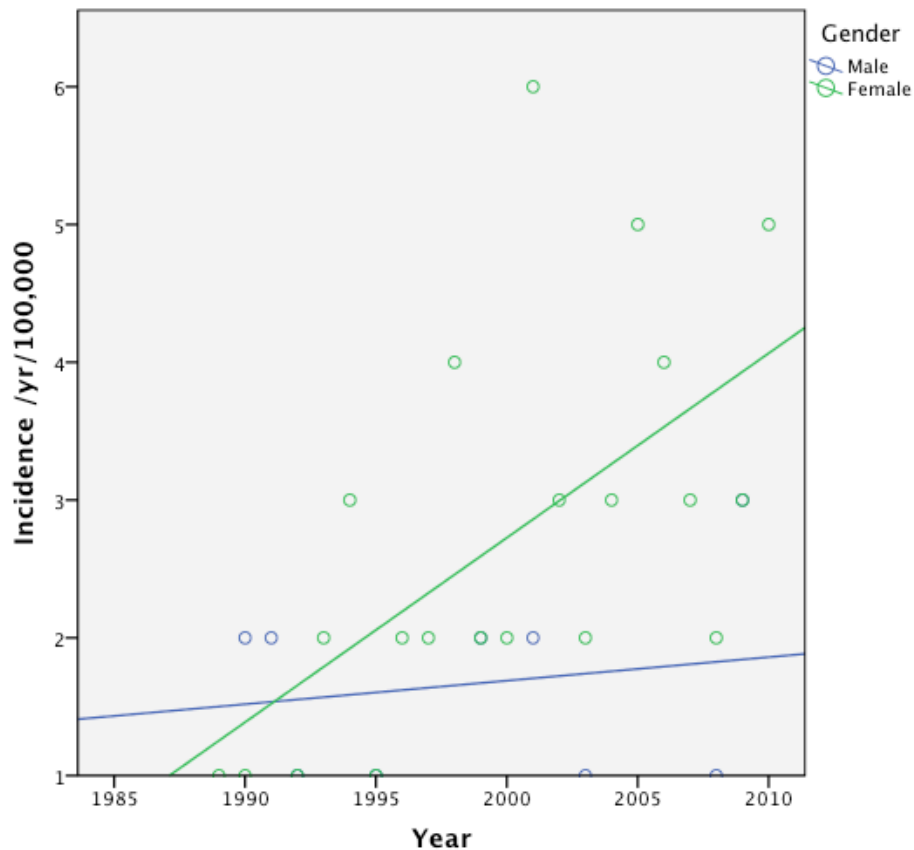


Figure 3:12 Change in incidence of open ankle fractures in patients over the age of 65.

3.3.5 Discussion

This study has demonstrated the overall incidence of open ankle fractures to be 1.49/100,000/year. The incidence of all ankle fractures for the study centre in 2000³ was 100.8/100,000/year therefore it can be estimated that open ankle fractures comprise 1.5% of all ankle fractures locally which is lower than previously reported rates, ranging from 2% to 5%^{2,130}. These higher reported rates of open fractures may be due to analysis of inpatient data only; as many closed ankle fractures can be

managed on an entirely outpatient basis this would underestimate the true number of ankle fractures.

The mean age of 55 years in this cohort of patients is a decade older than the mean age of 1500 ankle fractures previously reported², whilst the highest age specific incidence is in patients over the age of 90. This is higher than that seen in closed ankle fractures; Koval et al¹³¹ reported 33,704 patients over the age of 65 with ankle fractures and found a peak incidence between 80 and 84 years of age followed by a decrease in patients over the age of 85. This decade advance in peak incidence and mean age for open ankle fractures, in comparison to all ankle fractures, may be due to a change of the condition of the soft tissues as patients' age¹³² such that the same fracture in a patient in their eighties may be closed but in a patient in their nineties becomes open as the soft tissue envelope deteriorates.

In this study there were a similar number of open ankle fractures in women, 54%, and in men. The overall incidence of open fractures has previously been shown to be higher in men than in women¹³³ whilst ankle fractures as a whole have been found to be roughly evenly spread between the genders^{2,6,37}. However, this has shown a change in recent decades with Bengner reporting a reduction in the male female gender ratio from 1.16 to 1.07 between 1950 and 1980¹¹. The change in the gender ratio over time is also seen in our cohort of ankle fractures with the male female gender ratio changing from 1 in 1988 to 0.4 in 2010 but this is not significant ($r=0.259$, $p=0.122$).

The reduction in the male female gender ratio appears to be predominantly due to the increasing incidence in elderly women. Open ankle fractures do not fit with the most

common fracture distribution curve; unimodal young male patient, unimodal older female: the distribution that ankle fractures as a whole were thought to fit. Instead open ankle fractures have a unimodal older female patient distribution in common with closed fractures of the pelvis, distal humerus and distal femur. The incidence in young men is double that seen in young women, as has previously been reported for all ankle fractures⁶, but the incidence then remains relatively stable in men whilst showing a large increase in women with age. The highest age specific incidence for both men and women is older than for closed injuries. Of particular note is the highest incidence in men is in the age group 80 to 84 whilst in closed ankles this peak occurs in young men. Again, this is likely to be due to the changes in the soft tissue envelope with age.

The open ankle fractures in this study occurred due to a simple fall in 49% of cases and RTAs in 26%. As expected the mechanism of injury is skewed towards higher energy modes than in all ankle fractures where between 8 and 10% of injuries have been attributed to RTAs^{2,6,37}. However, in elderly patients 74% of the open fractures did occur due to low energy mechanisms of injury and overall the proportion of open ankle fractures due to high energy mechanisms of injury is low compared to all open fractures where 58% have been attributed to RTAs¹³³. Open ankle fractures therefore appear to be predominantly low energy injuries. This may be due to the limited soft tissue coverage around the ankle with little excess available to allow for deformation, hence, in a susceptible patient, relatively little force may be required to cause a large wound over the medial malleolus.

The majority of open ankle fractures were classified as Gustilo et al type III injuries. In comparison to all open fractures the proportion of fractures that were Gustilo et al type I was lower¹³³. This may be due to both the limited soft tissue envelope and the increased age of the patients predisposing to poorer soft tissues. When the type III fractures are further analysed the spread is rather different to all open fractures, as by far the majority of type III open ankle fractures are IIIa in comparison to an equal spread between IIIa and IIIb in all open fractures. The lower energy mechanisms of injury seen in open ankle fractures in comparison to all open fractures may explain why relatively few IIIb and IIIc open ankle fractures were observed.

Elderly patients are more likely to sustain open ankle fractures that are Gustilo et al type IIIa than type I or II. As previously discussed, elderly patients are also more likely to sustain their injuries as a result of a low energy mechanism. It therefore seems counterintuitive that the ISS should rise as the Gustilo et al type increases. However, the higher ISS with Gustilo et al type IIIa fractures than type I may be explained by the method of calculating the ISS. Wounds greater than 10cm are assigned an AIS of two whilst wounds less than this are assigned an AIS of one. Patients with a type IIIa fracture will therefore have obtained a higher ISS from their open ankle fracture rather than from any further injury. In fact, when their open fracture contribution to the ISS is subtracted the mean ISS for other injuries is less than one in both type I and IIIa injuries but higher in type II and IIIb injuries.

Over the twenty-three years of data collection the most striking change was in the prevalent mechanism of injury. This change from RTAs to simple falls may be due to a number of factors. The number of casualties due to RTAs has decreased over

this time period¹³⁴ which may be attributed to a number of factors including improvements in road safety and awareness of the dangers of driving whilst under the influence of alcohol¹³⁵. This may explain the reduction in open ankle fractures sustained as a result of RTAs but does not explain the increasing number of fractures due to simple falls.

As the mean age of the patients has increased so too has the number of fractures due to simple falls, the proportion of the fractures that occur in women and the proportion that are Gustilo et al type IIIa. It appears that elderly female patients are sustaining type III open fractures as a result of simple falls. Overall open ankle fractures were equally distributed throughout the study period with no significant change in incidence over time, however, there was an increase in the incidence of open ankle fractures in elderly women. This could be explained by intrinsic changes within the elderly population¹³⁶. This increased incidence in elderly women has also been observed for closed ankle fractures. Kannus et al demonstrated the incidence⁹ of ankle fractures in patients over the age of 60 changed from 66/100,000/year in 1970 to 174/100,000/year in 2000.

The major limitation of this study is the small number of fractures included over a prolonged period of study. Although this does limit the strength of the conclusions that can be made this is due to the rarity of these injuries and may help to explain why no previous studies have been undertaken.

3.3.6 Conclusion

In conclusion open ankle fractures are becoming a low energy open fracture that occurs predominantly in elderly women after a simple fall. One may therefore expect to see an increase in the number of open ankle fractures over the coming years as the elderly population continues to increase.

Chapter 4: Outcomes of ankle fractures

4.1 Introduction

The assessment of outcomes is key to improving care for patients. This chapter investigates the outcomes of a number of different interventions into ankle fracture care; their investigation, surgical management, post injury mobilisation and post injury thromboprophylaxis.

4.2 Outcomes of investigation of ankle fractures

4.2.1 Summary

Assessment of stability in ankle fractures is key in deciding the most appropriate mode of treatment. In SER IV fractures where the medial stability is lost due to a ligamentous rather than a bony injury this assessment can be difficult. Stress radiographs have been suggested as a potential method for assessing the competence of the deep deltoid ligament and therefore ankle stability in patients with apparently isolated lateral malleolar fractures. Whilst stress radiographs have been found to be both sensitive and specific in cadaveric experiments, recent clinical studies have suggested that a widened medial clear space on stress radiographs may not equate to a functionally unstable ankle. These previous studies have used manual stress radiographs and have included an operative arm in which patients were selected for surgical intervention based on empirical clinical criteria. The aim of this study was to

assess whether patients with an apparently isolated lateral malleolar fracture on presentation but with a positive gravity stress radiograph could be successfully managed non-operatively.

A prospective study of all patients with isolated Weber B lateral malleolar fractures presenting to the RIE was undertaken. Patients with an oblique distal fibular fracture pattern and no obvious medial clear space widening on routine radiographs underwent a gravity stress radiograph. Measurements of the radiographic medial clear space and superior clear space were made and compared with published criteria: measurement of medial clear space alone is the most frequently described parameter with values of 4, 5 and 6mm variously suggested as cut-off points for diagnosing instability whilst some previous authors have recommended additional comparison of the medial clear space with the superior clear space.

154 patients underwent GSRs and were treated non-operatively fully weight bearing in either a cast or removable boot. Following fracture union all patients had both anatomical alignment of the ankle mortise and good or excellent function.

Measurement of the medial clear space and baseline superior clear space found that 79% of the 154 patients that were treated conservatively and had no evidence of late displacement had a medial clear space of greater than 4mm on the gravity stress radiographs.

The currently used criteria for measurements on stress radiographs result in high numbers of false positive cases. This may lead to unnecessary surgery. Further investigation is required in order to identify other clinical or radiographic criteria that may be of use in the assessment of functional ankle stability after fracture.

4.2.2 Aims

The aim of this study was to investigate the use of the GSR in clinical practice and to identify whether patients with an apparently isolated lateral malleolar fracture on presentation but with a positive GSR could be successfully managed non-operatively.

4.2.3 Methods

This study was undertaken using patients identified from the prospectively collected ankle fracture database as described in detail in chapter 2, section 2.2.1.

4.2.4 Results

This study included 155 patients with isolated Weber B lateral malleolar fractures and no apparent MCS widening on routine radiographs. The mean age of the patients was 46 years (range 16 to 89), 85 patients were female (55%) and the remaining 70 male. The majority of the patients sustained their injuries as the result of a simple fall (57%) with only 1% of ankle fractures in this study due to an RTA.

Of the 155 patients who underwent gravity stress radiographs taken in A&E or at first fracture clinic review only one was found to have an unstable ankle fracture with evidence of talar shift on radiographs taken at two weeks post injury. The remaining 154 (99.4%) patients were treated non-operatively fully weight bearing. None of these patients had any evidence of late displacement of the talus at two weeks or at final radiographic review at six weeks post injury.

Measurement of the MCS and baseline SCS found that 77% of the 154 patients that were treated conservatively and had no evidence of late displacement had an MCS of greater than 4mm on the gravity stress radiographs. Further breakdown of the values for MCS and SCS can be seen in Table 4:1.

Table 4:1 Number (percentage) of patients with talar shift exceeding the given measurement, i.e. false positives on gravity stress radiographs.

	<i>4mm</i>	<i>5mm</i>	<i>6mm</i>
Absolute MCS only assessed	118 (77%)	60 (39%)	28 (18%)
MCS > 1mm more than SCS	78 (51%)	53 (34%)	27 (18%)
MCS > 2mm more than SCS	28 (18%)	26 (17%)	22 (14%)

PROMs were obtained for 57% of patients. Comparison of those patients in whom outcomes were obtained with those in whom it was not possible to obtain outcomes found that those patients in whom outcomes were obtained were slightly but significantly older (mean age 49.9 and 42.9 years respectively, $p=0.029$ Mann Whitney U test) with a higher proportion of women (60.9% in those for whom outcomes were obtained versus 42.4%, $p=0.024$ Fishers exact test).

The majority of patients reported good outcomes, Table 4:2. The patients were also asked about their pre-operative UCLA score with the patients having a mean reduction in their activity score of 0.59 (range: improvement of 3 to reduction of 8 levels). There was no significant correlation between any of the outcome measures and the MCS measurements.

Table 4:2 PROMs following ankle fractures

	<i>Mean score</i>	<i>SD</i>	<i>Range</i>
Olerud and Molander score	83.3	22.8	5 - 100
Manchester Oxford	11.00	21.69	0 – 82.81
Walking	12.38	25.69	0 – 100
Pain	12.84	23.74	0 – 85
Social	7.43	17.27	0 - 75
UCLA score	6.5	2.5	2 - 10
EQ-5D score	0.90	0.21	-0.18 - 1

4.2.5 Discussion

This study has found that patients with an apparently isolated lateral malleolar fracture on presentation but with a positive GSR can be successfully managed non-operatively with good PROMs and good radiographic outcomes. In this prospectively collected cohort of 154 patients, 118 (77%) were found to have positive GSRs using the most generous criteria for a positive radiograph (MCS greater than 4mm); when even the most strict criteria were used (MCS greater than 6mm and more than 2mm greater than SCS) 22 (14%) remained positive. None of these ankle fractures were managed operatively and despite early weight bearing none showed late displacement and had good longterm PROMs.

It therefore appears that GSRs cannot be used to assess stability of ankle fractures and that further investigation is required to ascertain which ankle fractures are isolated lateral SER II injuries and which are in fact SER IV injuries with medial ligamentous instability. The patients included within this study were typical of those presenting with ankle fractures² and it seems reasonable that these results could be extrapolated to all patients with SER II injuries.

These results agree with those of Koval et al who previously investigated 21 patients of their patients with positive manual stress radiographs with MRI⁷¹. Of the 21 patients included only two were shown to have deep deltoid ligament rupture on MRI investigation and felt to require surgical intervention. The remaining 19 patients were treated conservatively in a walking boot with good patient reported outcomes. Further investigation comparing the results of GSRs to MRI (as a gold standard)¹³⁷ found that using a cut off of greater than 6mm on GSRs resulted in 100% sensitivity for deep deltoid ligament rupture but only a 50% positive predictive value whilst a cut off of greater than 5mm on GSRs led to a positive predictive value of 23.1%, showing again the risk of over treatment when using GSRs.

Comparison of GSRs to weight bearing radiographs¹³⁸ also found that GSRs appear to overdiagnose instability. In their study of 104 patients with isolated lateral malleolar fractures 56% of patients would have undergone surgery if all patients with an MCS of greater than 4mm on GSRs had been operated on. Instead they used weight bearing radiographs to decide on the necessity of operative intervention and obtained good outcomes with only 13% of patients undergoing surgery.

A randomised controlled trial comparing outcomes of patients with an MCS of greater than 5mm randomised to operative or non-operative management found no difference in one year functional results between groups¹³⁹. A further retrospective study of 51 patients found good clinical and radiographic outcomes in a cohort of patients with a mean MCS of 4.42mm on GSRs¹⁴⁰ again highlighting the risk of over treatment when relying on GSRs.

Differences between results in this study and those found by cadaveric studies^{56,57}, which have found predictable increases in measurements taken from stress radiographs with ligament sectioning, may be due to the additional effect of the musculotendinous units actively crossing the ankle joint in the live patient. This may help to explain why this study has not found any particular measurement of the MCS, with or without reference to a baseline, to be diagnostic for medial instability.

Further investigation is therefore required to achieve a reproducible, sensitive and specific method for identifying those ankle fractures that are unstable and require operative intervention, and to distinguish them from those that are stable and can be treated conservatively. In the light of the results presented here it appears that stress radiographs should not be considered the gold standard by which all other methods are compared. As a result further investigation of clinical signs as a method distinguishing between the two may merit further investigation.

Many other options for investigation have been considered and a recent study from Holland found a range of options in use there¹⁴¹. The most popularly used option was repeat of the mortise view at a week post injury (43.9% of respondents) with 16.6% of respondents using a weight bearing radiograph. Weight bearing

radiographs may have some clinical application, a recent study from Switzerland¹⁴² found weight bearing radiographs taken at three to ten days post injury to be a reliable and safe method for assessing stability and need for operative management. However, a cadaveric study¹⁴³ has found no significant MCS widening seen on weight bearing radiographs taken on ankles with an osteotomised fibula and disrupted deltoid ligament.

This work could be criticised for short-term follow up with these patients having the potential to develop late osteoarthritis. However, as recent work has suggested that the latency period between ankle fracture and subsequent development of osteoarthritis may be as much as 21 years¹⁴⁴ this will require extensive follow up of these patients. In addition the radiographs were only measured by one researcher, however, Pitakveerakul et al¹⁴⁵ have found excellent intraclass correlation coefficients when comparing measurements of the MCS and SCS on GSRs. Those patients in whom PROMs were obtained were not entirely reflective of the entire cohort as the young, male patients were under-represented in the follow up cohort. This is a recognised problem in patient follow up with certain groups significantly harder to obtain follow up in¹⁴⁶. Finally plantarflexion was not controlled for with the GSR which may help to explain some of the large values for the MCS due to the frustral shape of the talus.

4.2.6 Conclusion

Current use of GSRs to assess for stability may be resulting in significant over treatment of patients with stable ankle fractures that could be safely managed non-operatively. This study has demonstrated that many patients with positive GSRs may successfully be managed conservatively with good patient reported and radiographic outcomes.

4.3 Outcomes of ankle fractures treated with fibular nails

This study was published in the Journal of Bone and Joint Surgery (British) in 2012¹⁴⁷, appendix 2.

4.3.1 Summary

Techniques for fixation of fractures of the lateral malleolus have remained essentially unchanged since the 1960s, but can be associated with complication rates of up to 30% in certain patient groups. The fibular nail is an alternative method of fixation requiring a minimal incision and tissue dissection, and has the potential to reduce the incidence of complications.

This study reviewed the results of 105 patients with unstable fractures of the ankle that were fixed between 2002 and 2010 using the Acumed fibular nail. The mean age of the patients was 64.8 years (22 to 95), and 80 (76%) had significant systemic medical comorbidities. Various different configurations of locking screw were assessed over the study period as experience was gained with the device. Nailing

without the use of locking screws gave satisfactory stability in only 66% of cases (4 of 6). Initial locking screw constructs rendered between 91% (10 of 11) and 96% (23 of 24) of ankles stable. Overall, seven patients had loss of fixation of the fracture and there were five post-operative wound infections related to the distal fibula. This led to the development of the current technique with a screw across the syndesmosis in addition to a distal locking screw. In 21 patients treated with this technique there have been no significant complications and only one superficial wound infection. Good fracture reduction was achieved in all of these patients. The mean physical component Short-Form 12, Olerud and Molander score, and American Academy of Orthopaedic Surgeons Foot and Ankle outcome scores at a mean of six years post-injury were 46 (28 to 61), 65 (35 to 100) and 83 (52 to 99), respectively. There have been no cases of fibular nonunion.

Nailing of the fibula using the current technique gives good radiological and functional outcomes with minimal complications, and should be considered in the management of patients with an unstable ankle fracture.

4.3.2 Aims

The aim of this study was to evaluate the early experience of treating unstable ankle fractures with the fibular nail and to assess the outcomes of this method of treatment.

4.3.3 Methods

This study was undertaken using a cohort of patients who had been treated using the fibular nail over an eight-year period at the RIE. The methods are described more fully in chapter 2, section 2.4.2.

4.3.4 Results

In total, 105 patients were included in this study. Their demographics and medical comorbidities are shown in Table 4:3. Most had significant comorbidities, often multiple, and were treated with a fibular nail because of previously described good outcomes in this sometimes challenging group of patients⁸⁰. There were only 11 young patients without comorbidity or associated soft tissue injury. These were treated with a fibular nail on the basis of surgeon preference.

Table 4:3 Demographics and comorbidities of the 105 patients with an unstable fracture of the ankle

<i>Demographics</i>	
Mean age (range) (yrs)	64.8 (22 to 95)
Number of female patients (n, %)	86 (82)
Domicile at time of injury (n, %)	
Own home	92 (88)
Own home with help	11 (10)
Residential home	1 (1)
Nursing home/Institution	1 (1)
Comorbidities (n, %)	
Hypertension	28 (27)
Ischaemic heart disease	16 (15)
Diabetes mellitus	12 (11)
Psychiatric disorders	11 (10)
COPD/Asthma	10 (10)
Cerebrovascular accident	9 (9)
Cardiac failure	7 (7)
Hypothyroidism	6 (6)
Neuropathy	6 (6)
Renal failure	5 (5)
Rheumatoid arthritis	5 (5)
Number of comorbidities (n, %)	
≥ 5	6 (6)
4	6 (6)
3	10 (10)
2	21 (20)

1	37 (35)
0	25 (24)
Smoking (n, %)	
Yes	21 (20%)
No	53 (50%)
Ex	11 (10%)
Unknown	20 (20%)
Alcohol use (n, %)	
None	32 (30%)
0 to 21 units/week	36 (34%)
> 21 units/week	12 (12%)
Unknown	25 (24%)

The mechanism of injury is shown in Table 4:4 and the type of ankle fracture in Table 4:5. Bimalleolar fixation was needed in 78 cases and trimalleolar fixation in three. Three patients needed fixation of the lateral and posterior malleoli and 21 a fibular nail on the lateral side only. Patients who needed fixation of the medial malleolus were treated with screws (n = 50), a tension-band wire (n = 15), Kirschner (K)-wires (n = 12) or a plate and screws (n = 4). Surgery was carried out by one of ten consultant surgeons in 56 cases, by a fellow in 19 cases and by a registrar in 30 cases. Most operations (32%) were carried out on the first day after injury (interquartile range one to three days); only five were performed more than a week after injury.

Table 4:4 Mechanism of injury

<i>Mechanism of injury</i>	<i>n, (%)</i>
Simple fall	81 (77)
Fall from low height	11 (10)
Fall from height	6 (6)
Motor vehicle collision	3 (3)
Direct blow	2 (2)
Unrecorded	2 (2)

Table 4:5 Fracture type

<i>Fracture type</i>	<i>n, (%)</i>
Bimalleolar	60 (57)
Trimalleolar	29 (28)
Isolated lateral malleolus	14 (13)
Pilon	2 (2)

Mortality

Overall, 25 patients (24%) died during the follow-up period, 11 in the first year. This gives a standardised mortality ratio (SMR) of 3.29 (95% CI 1.93 to 6.37, $p < 0.001$), which means that this cohort was more than three times as likely to die within one

year than an age- and gender-matched population. As no deaths were due either directly or indirectly to the ankle fixation, it is clear that the observed cohort was significantly less well than the age-matched general population. Moreover, the SMR for all patients with ankle fractures treated in the RIE in 2008 was 1.89 (95% CI 1.14 to 2.96, $p = 0.008$) and the odds ratio (OR) for death of this cohort compared with all patients with ankle fractures was 4.9 (95% CI 2.22 to 10.77). This indicates that the observed cohort was also significantly less well than other patients with the same injury ($p < 0.0001$).

Overall clinical outcomes

A total of 82 patients (78%) did not experience any complications from the fixation of the lateral malleolus. However, the construct failed in seven patients, five of whom (5%) underwent revision surgery. There were five patients with a lateral wound infection, of whom four also had an infection of the medial wound. The metalwork was removed from 16 patients (15%): the fibular nail in seven and locking screws only in nine (Table 4:6). The Kaplan-Meier survival curve for the fibular nail is shown in Figure 4:1.

Table 4:6 Technique of fixation of the fibular nail to bone and complications experienced with each technique

	<i>Locking screw constructs</i>				<i>Current technique</i>
	None	Distal locking screw	Proximal blocking screw + distal locking screw	Syndesmosis screw alone	Syndesmosis screw + distal locking screw
Number of patients	6	24	43	11	21
Failure of fixation	2	1	3	1	0
Removal of fibular nail	0	2	4	1	0
Removal of medial metalwork	3	3	9	2	1
Removal of locking screws	0	1	7	n/a	1
Medial wound infection	1	1	4	0	1
Lateral wound infection	0	0	1	0	0
Both sides wound infection	0	2	1	1	0
Patients with complications related to lateral fixation (n, %)	2 (33)	5 (21)	14 (32.5)	1 (9)	1 (5)

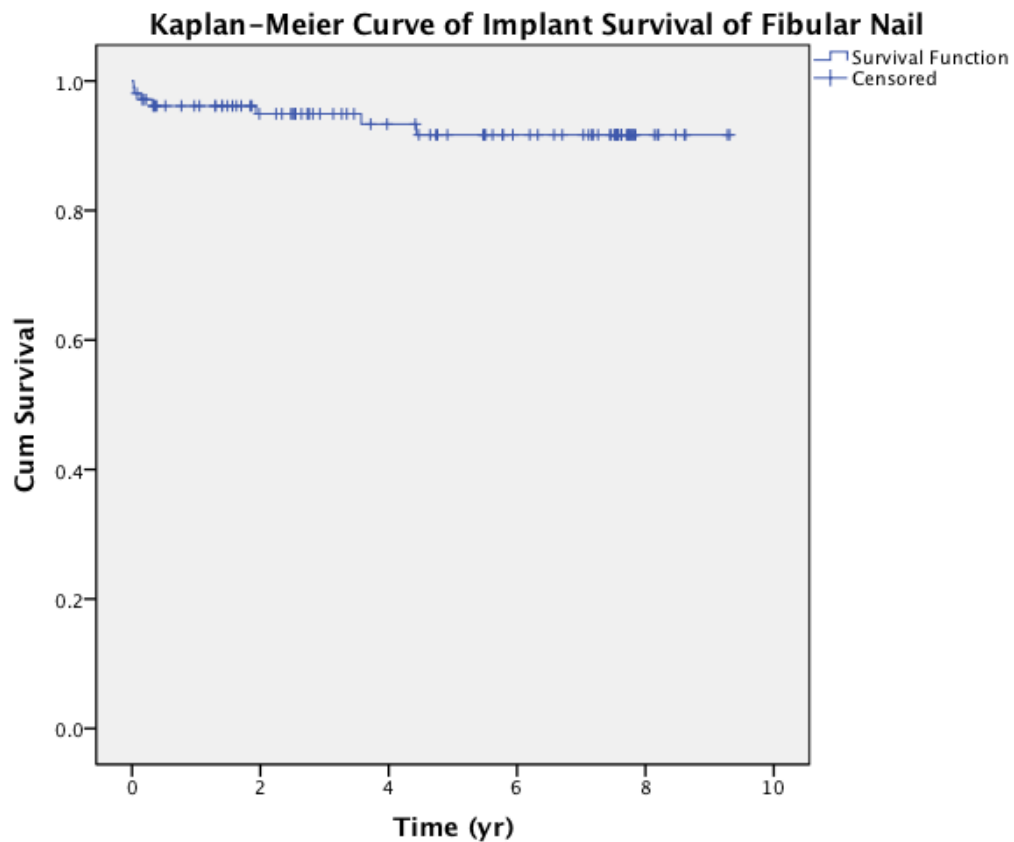


Figure 4:1 Kaplan-Meier curve showing survival of the fibular nail.

Clinical outcomes of initial locking screw constructs

In six patients the fibular nail was implanted without either proximal or distal locking screws, somewhat in the manner of a Rush nail. Significant failure of fixation occurred in two, with shortening of the fibula and lateral subluxation of the talus. One patient died from myocardial infarction shortly afterwards; the other needed an ankle fusion.

In order to improve the fixation, 24 patients had a fibular nail implanted with distal locking screws but with no syndesmosis or blocking screw: 23 (96%) went on to

satisfactory union. One construct failed in a similar manner to that described above, with lateral talar subluxation, and the patient required a fusion.

A total of 43 nails were implanted with a distal locking screw and an additional proximal blocking screw, in an attempt to maintain length. Of these, 40 fractures (93%) united without complication. The other three constructs, all in elderly patients, failed. One required revision surgery and ultimately an amputation. It became apparent that the talus still had the potential to subluxate laterally with this technique, as it was possible for the fibular nail to bypass the blocking screw (Figure 4:2). In addition, the distal locking screws irritated the soft tissues in seven patients and were removed electively after the fracture had united.

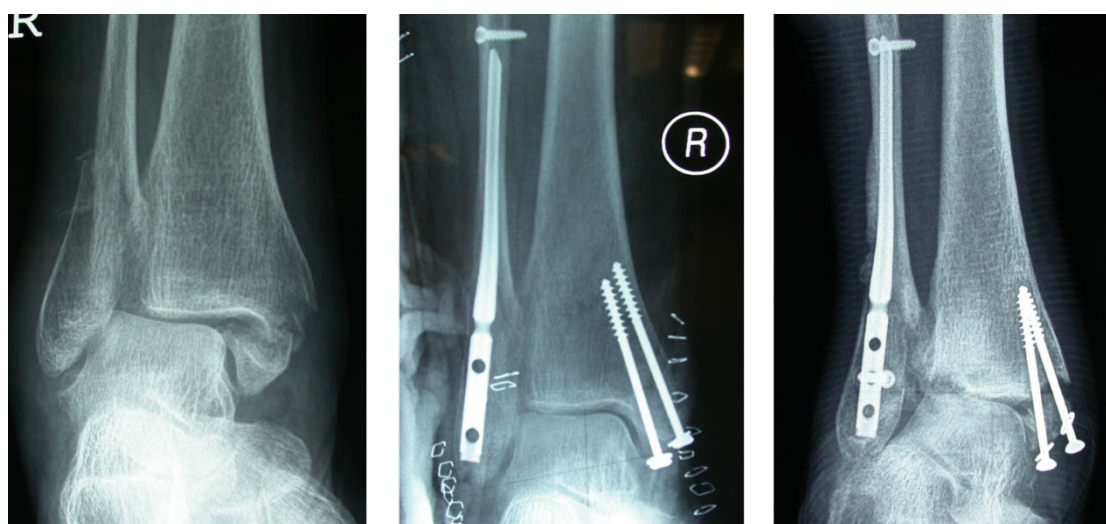


Figure 4:2 Radiographs of a bimalleolar ankle fracture in a 71 year-old female patient with multiple comorbidities, a) at presentation, b) immediately post-operatively showing the lateral malleolar fracture managed with a fibular nail fixed to bone with a distal locking screw and proximal blocking screw, and c) at six weeks post-operatively showing failure of fixation, with the fibular nail moving proximally past the blocking screw, resulting in lateral talar shift due to inadequate lateral buttressing.

There were also 11 patients who underwent fixation with a fibular nail which incorporated a proximal locking screw but no distal locking screw. Most experienced no further problems, but the fixation failed in one, who ignored medical advice to avoid weight-bearing, and required a revision operation. Another patient developed osteoarthritis after anatomical union and underwent ankle replacement seven years later. As a result of this experience the current technique was developed, which incorporates both proximal and distal locking.

This uses a 'syndesmosis' screw and a distal locking screw which reaches the dorsal cortex of the fibular. 21 patients have been treated in this manner and all their fractures have gone on to heal anatomically and uneventfully. In one case, however, a morbidly obese patient with a body mass index of 40.1 kg/m^2 and a complete diastasis did bear full weight through the affected ankle immediately, and although the fracture united uneventfully, the diastasis recurred after ten weeks; it was treated successfully by further reduction and the placement of a second diastasis screw. No syndesmosis screws have been removed electively, and with the exception of the patient described above, none have displaced or broken to date.

Radiographic outcomes

An anatomical reduction was achieved in 77 patients (96%) according to the criteria previously described. There was no increase in MCS and no fibular shortening. The other 3 patients (4%) had a fair reduction. In one case the length of the fibula was not completely restored, although the talocrural angle was $> 0^\circ$ and the fibular shortening $< 2 \text{ mm}$. In the other two cases the MCS was $> 1 \text{ mm}$ greater than the tibiotalar space. The OMS in those patients with only a fair reduction was 40 in one, 30 in

another, and unobtainable in the third as the result of a cerebrovascular accident. No patients had a poor reduction.

PROMs

The PROMs are shown in Table 4:7 PROMs scores. There was a trend to a higher score for patients treated with the current technique, but this was not significant ($p \leq 0.26$). The mean SF-12 scores were within 1 SD of the mean for the normal population, the mean of the mental component being slightly higher than the mean for the population. Of the 52 patients who completed the OMS, 24 (46%) had a good outcome, 21 (40%) had a fair outcome and the remaining seven (14%) had a poor outcome. The mean AAOS score was 79.0 (26.3 to 100) for all patients and 82.5 (51.8 to 98.7) for those treated with the current technique.

Table 4:7 PROMs scores, mean score (range)

	<i>All techniques</i>	<i>Current technique</i>
Olerud and Molander score	62.2 (0 to 100)	65.2 (35 to 100)
Short-Form 12		
Physical component	41.5 (17.7 to 60.6)	45.7 (27.9 to 60.6)
Mental component	53.1 (26.7 to 66.3)	55.2 (45.3 to 63.1)
AAOS score	79.0 (26.3 to 100)	82.5 (51.8 to 98.7)

4.3.5 Discussion

Unstable ankle fractures are most commonly treated by ORIF using techniques that have not changed significantly for many years and have a high rate of complications, particularly in osteoporotic bone. Metalwork and scarring can be troublesome and require secondary surgery. The complication rate following ORIF in the elderly is up to 40%⁷⁸. It is also considerably higher in patients with systemic disease, particularly diabetes and neuropathy⁷⁹, and in those with compromised local soft tissues and those who smoke¹⁴⁸. A proportion of those patients who avoid initial complications will later require removal of metalwork^{76,81,149}.

Suggested alternatives to traditional lateral plating techniques include the use of locking plates and minimally invasive plating techniques. Although locking plates have been shown to be biomechanically advantageous in osteoporotic bone¹⁵⁰, this benefit may be negated by a higher rate of wound complications¹⁵¹. Minimally invasive plating techniques allow surgery to be carried out through marginally smaller wounds (3 cm to 4 cm in a recent report¹⁵²) but are more technically challenging than traditional techniques¹⁵².

Intramedullary fixation of the fibula minimises dissection. Successful results have been reported for a variety of implants, including the Rush nail and other types of fibular nail^{83,84,153}. Two groups^{83,84} have reported their results using the Biomet SST fibular nail (Biomet Inc, Indiana, USA), an intramedullary nail which is fixed to bone with a distal anteroposterior locking screw only. In total, they report 35 patients with good functional and radiological results. However, this nail does not allow for placement of a screw across the syndesmosis, and Ramasamy et al⁸³ reported failure of fixation with lateral talar subluxation in one patient (9%). Rajeev et al⁸⁴ do not

report any cases of failure of fixation but the post-operative radiograph included does show evidence of talar shift.

The Acumed fibular nail is unique in allowing secure cross-locking of the fracture fragments, thereby maintaining tibiotalar congruence as well as fibular length and rotation. The technique is conceptually straightforward and involves the skills used to nail other long bones. Almost half of the fractures presented here were fixed by fellows or registrars, with good outcomes.

This study presents the results with this device in 105 patients over eight years. The surgical technique has evolved as the experience has grown: the finding that whereas an unlocked (or partially locked) construct remains potentially unstable, the new preferred technique, using a syndesmosis screw and a distal locking screw, has so far proved entirely stable. Overall, anatomical reduction was possible in 97% of patients, and satisfactory fracture healing occurred in 93%. Lateral wound problems occurred in five patients, four of whom also had a medial infection. This wound complication rate of 3.8% compares favourably with that of lateral plating techniques^{81,151}.

PROMs also suggest a satisfactory subjective outcome: the psychological domain score of the normalised SF-12 was slightly better than the population mean (53.1 (range 26.7 to 66.3) *vs* 50.0), and the mean physical function score was only slightly less than that of the healthy population (41.5 (17.7 to 60.6) *vs* 50.0). These are comparable with the results reported by Shah et al¹⁵⁴ of 85 ankle fractures in patients with a much younger mean age of 50 years treated with lateral plating augmented with lag screw fixation, who had a mean psychological domain score of 49.9 and a physical score of 45.6. The mean abbreviated Olerud and Molander joint-specific

scores (62.2 for the entire cohort) were also comparable to those reported for similar patient groups. Yang et al¹⁵⁵ reported a mean score of 61 in patients over the age of 50 within their cohort of supination external rotation type IV Lauge Hansen ankle fractures. The mean AAOS score for patients treated by the current technique was 82.5. This is within 1 SD of the mean score for a healthy population¹⁵⁶ (mean 93.2 (SD 12.3)) and comparable to results found in other cohorts of patients sustaining ankle fractures. Bois et al¹⁵⁷ in their cohort of 17 patients with posterior malleolar fractures, found a mean score of 87, and Gardner et al¹⁵⁸ found a mean score of 79 at a follow-up of eight months in another cohort of patients with posterior malleolar fractures and a mean age of 45 years.

Like most retrospective cohort studies, this study can be criticised for incomplete follow-up. Several sets of radiographs could not be located and outcome scores were only recorded for half of the original cohort. However, 62% of those cases without outcome scores had either died or had dementia, reflecting the age and comorbidities of these patients. This series comes from a single hospital with an academic interest in trauma management, but experience with the technique suggests that it can be generalised. Finally the reliance on radiographic outcomes may mask displacement that might be better visualised with CT or MRI.

4.3.6 Conclusion

In conclusion, this study has found the fibular nail to be an attractive alternative for the fixation of unstable ankle fractures. The technique allows for accurate reduction

of the ankle mortise, early weight-bearing and predictable bone healing, with a low rate of wound complications.

4.4 Outcomes of early weight bearing following ankle fracture

4.4.1 Summary

Early weight bearing of patients with ankle fractures is associated with good outcomes. There are a number of potential advantages to early mobilisation including reduced hospital stay, and earlier return to work and return to regular daily activities. However, many surgeons have not incorporated this into their routine ankle fracture protocol, particularly for patients managed operatively, potentially due to concerns regarding loss of reduction. The hypothesis of this study was that ankle fractures managed fully weight bearing would have good outcomes and a low rate of loss of reduction.

All ankle fractures presenting to the RIE over a 15-month period were studied prospectively. Patients were instructed to mobilise fully weight bearing as able, either immediately postoperatively (for those fractures considered unstable that underwent operative intervention), or at the first fracture clinic review (if stable and managed conservatively). Only patients with syndesmotic injuries and those with neuropathy or psychiatric illness were excluded. The effectiveness of this management protocol was assessed by clinical and radiographic review following fracture union.

847 patients were included, with a mean age of 48.1 years. 33.2% of fractures were unstable and therefore managed operatively, 66.8% were stable and managed in casts

or with functional bracing. In 99.4% of cases the radiographs showed maintenance of anatomical mortise and fracture reduction at the time of union.

Early weight bearing of patients with ankle fractures, whether managed conservatively or operatively, results in very low rates of loss of reduction and should be considered routine management for the majority of patients.

4.4.2 Aims

The aim of this study was to investigate the outcomes of patients managed with routine early weight bearing both those managed non-operatively and operatively.

4.4.3 Methods

This study included a cohort of patients from 15 months of the ankle fracture database as described in chapter 2, section 2.4.3.

4.4.4 Results

This study included 847 patients with ankle fractures treated both operatively and non operatively. The mean age of the patients was 48.1 years with a range from 15 to 100 years; 482 of the patients were female (56.9%). The majority of the patients sustained their injuries due to a simple fall (55.7%) with sports injures accounting for 20.4% of fractures.

Non operatively managed fractures

566 (66.8%) of these fractures were judged to be stable and therefore managed non-operatively. Early weight bearing was permitted in 97.0% of these patients. Those excluded included four patients with associated injuries that necessitated a period of non or partial weight bearing, three paediatric patients with Salter Harris injuries, two patients with plaster cast issues that required a brief period of non-weight bearing mobilisation and one patient who underwent a period of follow up elsewhere and was instructed by the institution to mobilise non weight bearing. In addition there were four cases where there was a deviation from departmental protocol without clinical reason.

Immobilisation undertaken following discussion between patient and surgeon resulted in 58% of patients immobilized in a plaster cast, 34% in a moonboot and 8% in elasticated support bandaging. All patients showed good fracture reduction at final radiographic review with maintenance of the anatomical mortise.

A small number of patients sustained fractures that were judged to be unstable but the patients were not able to undergo surgical intervention due to significant comorbidities (five patients, 0.59%). These patients with unstable ankle fractures managed non-operatively were not permitted to weight bear early.

Operatively managed fractures

276 (32.6%) of the fractures were judged to be unstable and managed operatively. Fixation of the fracture was dependent upon the fracture type and at the discretion of the operating surgeon. Early weight bearing was permitted in 162 patients (58.7%).

The 114 patients not permitted to bear weight fully through their fixation early are shown in Table 4:8. A small number of patients were not permitted to partake in early routine weight bearing due to deviations from the protocol by the operating surgeon near the beginning of the study, in addition three patients underwent a portion of their follow up care at other institutions that did not permit early routine weight bearing.

Table 4:8 Reasons why early weight bearing was not permitted in operatively treated ankle fractures.

<i>Reason for non-weight bearing</i>	<i>Frequency (%)</i>
Syndesmotic fixation	60 (53%)
Unstable fixation	24 (21%)
Associated injury	19 (17%)
Unable to comply	1 (0.3%)
Deviation from protocol	7 (6%)
Treated at other institution	3 (3%)

At final radiographic review reduction had been maintained in all but five of the patients permitted early weight bearing. These five patients should all have been excluded from early weight bearing due to either the nature of their injury or their comorbidities. Two of these patients were permitted to weight bear through syndesmotic injuries that had been fixed with late recurrence of the diastasis and the other three were unable to comply with instructions due to psychological issues, alcohol excess and peripheral neuropathy respectively.

4.4.5 Discussion

This study has found early routine weight bearing following ankle fracture to be a safe rehabilitation protocol. When the protocol was conscientiously applied there were no cases of loss of reduction. Careful patient selection is important, however, to ensure that patients are not permitted to weight bear early if their injury, fixation or comorbidities do not permit this.

Early routine weight bearing in operatively managed patients was first shown to be safe by Ahl et al in 1986⁹⁶ and 1987⁸⁷. In these two RCTs Ahl showed that early weight bearing was safe with no significant increase in complications and good patient reported outcomes. In total 99 patients were included with a comparison between those permitted to bear weight through their ankle at the end of the first postoperative day and those only permitted to bear weight from the end of the fourth postoperative week. No difference in swelling, displacement or patient reported results was found between the groups. Further work by Finsen et al⁸⁸ in a RCT of 56 patients comparing three groups; no immobilisation but no weight bearing, non-weight bearing in cast and weight bearing in cast, found no significant differences in complications, clinical results or time to return to work. A further RCT of 81 patients in 1996⁸⁹ compared the no immobilisation non-weight bearing option with weight bearing in a below knee cast. Once again there was no difference in complications, range of movement or patient reported outcomes between groups. A more recent RCT published in 2016 from Canada¹⁵⁹ found no difference in loss of reduction, failure of fixation, wound complications or infection at six weeks post

operatively. These results were replicated in an RCT from Holland that was terminated early due to slow patient recruitment and funding issues¹⁶⁰.

Despite these RCTs weight bearing following ankle fracture has not been universally taken up. A recent BONE audit⁹⁸ found that 19% of non-operatively treated ankle fractures and 79% of operatively treated fractures in the United Kingdom were not permitted unrestricted weight bearing until greater than three weeks post injury.

Work from the United States found that 4.9 weeks was the mean amount of time surgeons would recommend non-weight bearing for even a young, healthy patient with an SER4 injury⁹⁷.

In this study certain groups of patients were not permitted to weight bear based on the inclusion criteria of the RCTs from the 1980s and 1990s. Syndesmotic fixation resulted in 60 patients being denied early weight bearing. A retrospective study of 86 patients with ankle fractures requiring syndesmotic fixation¹⁶¹ found no evidence of syndesmotic diastasis in patients permitted early weight bearing. In the current study, however, two patients did develop a post operative diastasis when weight bearing through a fixed syndesmosis.

There may be some criticism of this study as an observational study rather than a randomised controlled trial. However, based on the results discussed above it was not felt appropriate to submit a group of patients with ankle fractures to a period of non weight bearing when weight bearing had previously been shown to be safe. It may also be argued that the mode of immobilisation was not standardized across our patients. However, investigation of both operatively and non operatively managed ankle fractures has found no significant differences in outcomes between patients

immobilised in any particular form of immobilisation^{162,163}. Finally it has been reported that compliance with weight bearing following fracture is low and as such the treating surgeon's advice may have little bearing on the weight bearing of the patient¹⁶⁴.

4.4.6 Conclusion

In conclusion this study has shown that early routine weight bearing of appropriately selected patients does not lead to loss of reduction at final radiographic review and should be considered routine management for the majority of patients.

4.5 Outcomes of venous thromboembolic prophylaxis following ankle fractures

4.5.1 Summary

There are concerns regarding the rates and significance of DVT and PE following ankle fracture. Published rates of VTEs after ankle fracture vary widely, although there are isolated case reports of fatal PEs in the post-injury period. The aim of this study was to identify the incidence of VTE in patients with ankle fractures and to compare this with the background risk of VTE in these patients.

1,262 consecutive patients with ankle fractures presenting to the RIE were studied prospectively. The local policy is that all patients with non-operatively managed ankle fractures are encouraged to mobilise weight-bearing, but are not provided with

pharmacological thromboprophylaxis, whilst operatively-managed ankle fractures are only prescribed pharmacological thromboprophylaxis during their in-patient stay. Both hospital and national episode data were searched to identify VTEs occurring in this cohort between 1981 and 2014. Over this 34-year period there were 17 PEs and 5 DVTs. Of these, 55% occurred prior to the ankle fracture, 18% greater than 90 days after the ankle fracture and only 27% in the 90 days following injury, with no fatal PEs in this cohort. The incidence of VTEs among non-operatively managed ankle fractures within 30 and 90 days was 0.12% and 0.35% respectively. Operatively treated fractures were at greater risk, at 0.48% within 30 days and 0.72% at 90 days.

This study has found that the incidence of VTEs is low after ankle fracture: approximately two to three times lower than the risk after major joint arthroplasty. The efficacy of systemic anticoagulation remains controversial, and given that the rate of major haemorrhagic complications with systemic anticoagulation is 1.6%, it remains to be determined whether this is either effective or appropriate after ankle fracture.

4.5.2 Aims

The primary aim of this study was to identify the rate of clinically relevant VTEs following ankle fractures treated both operatively and non operatively to assess the outcomes of the current thromboprophylaxis. The secondary aims were to compare this to the background rate of VTE in these patients and the population as well as comparing this to the outcomes of pharmacological thromboprophylaxis.

4.5.3 Methods

This study was undertaken using the prospectively collected ankle fracture database described in chapter 2. This included all patients presenting to the RIE over a 21 month period with no patients excluded on the basis of known risk factors for VTE. Further details of the methods are included in chapter 2, section 2.4.4.

4.5.4 Results

A consecutive cohort of 1,262 patients with ankle fractures presenting to the study centre was identified and included in this study. The majority (847 patients, 67.1%) were judged to be stable and were managed non operatively. The remaining 415 (32.9%) were treated operatively. The patients had a mean age of 48.5 years (range 15 to 100 years) were predominantly female (703, 55.7%), and the majority had sustained their fractures in a fall from a standing height (823, 65.2%) or during sport (208, 16.5%).

In total, 22 patients were diagnosed with VTEs during the 33 years of data collection (1.7% of patients). This comprised 13 patients with isolated PEs (59.1% of events), five patients with isolated DVTs (22.7% of events) and four patients who were diagnosed as having both a PE and a DVT during the same admission (18.2% of events). Only six (27%) of these VTEs occurred in the 90 days following the ankle

fracture. The remainder were either prior to the ankle fracture or greater than 90 days following the fracture, Table 4:9.

Table 4:9 Timing of VTEs in the current study

<i>Timing</i>	<i>Frequency (%)</i>
Prior to ankle fracture	12 (55%)
Within the 90 days following ankle fracture	6 (27%)
>90 days following ankle fracture	4 (18%)

This permitted calculation of the 30-day and 90-day incidences of VTEs following ankle fracture, Figure 4:3. The 30-day incidence in those managed operatively was 0.48%, higher than in those managed non-operatively (0.12%) but this was not significant ($p=0.253$, Fishers exact test). The 90-day incidence in operatively managed patients of 0.72% was also higher than in those managed non-operatively, 0.35%, again this was not significant ($p=0.401$, Fishers exact test).

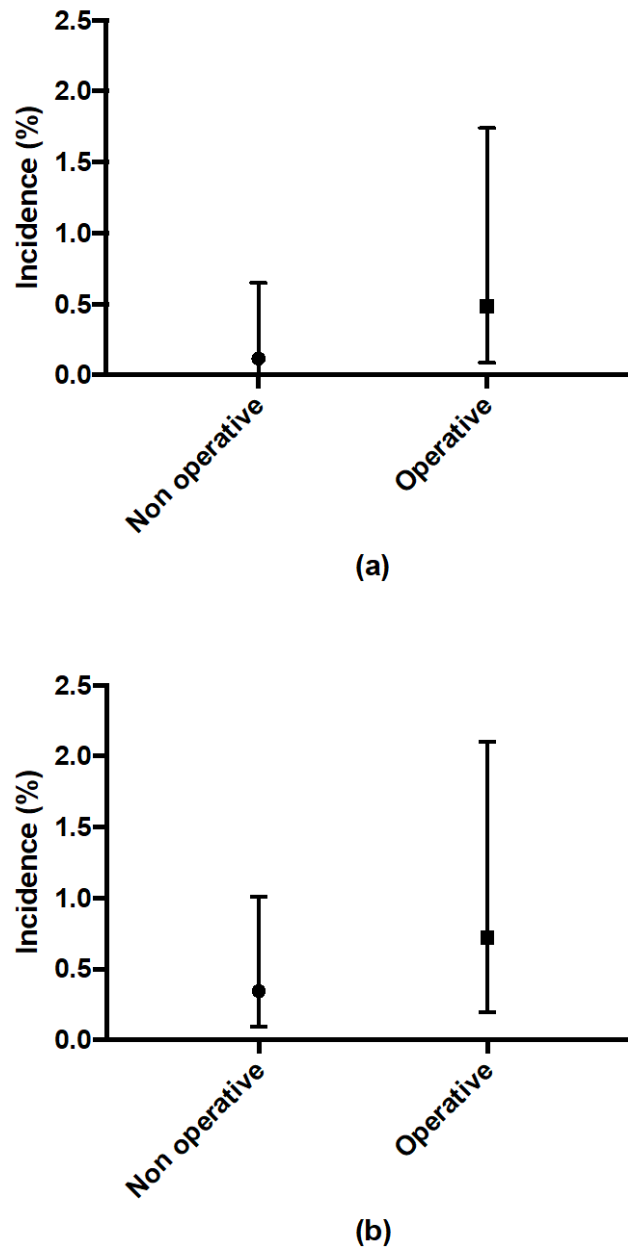


Figure 4:3: Incidence of VTE following ankle fracture. (a) 30 day incidence: non operative 0.12% (95% CIs 0.01 to 0.65%), operative 0.48% (0.09 to 1.74%). (b) 90 day incidence: non operative 0.35% (95% CIs 0.09 to 1.01%), operative 0.72% (95% CIs 0.20 to 2.10%).

Of those VTEs occurring in the 90-days following ankle fracture the majority were PEs, none of which were fatal. Five of the six patients were diagnosed with PEs with

one of the patients diagnosed with a concurrent PE and DVT. No patients were diagnosed with DVTs without a diagnosis of PE in the post-injury period.

Further analysis of the patients sustaining VTEs in the 90 days following fracture revealed only a very small number of previously identified risk factors for VTE^{165,166}. One of the six patients was aged greater than 60 years (62 years at time of injury) and one other patient had a BMI of greater than 30 (BMI 30.83).

Calculation of the background rate of VTE in this cohort of patients was undertaken by looking at the 16 patients diagnosed with VTEs outside of the 90-day period following ankle fracture. Twelve of these patients were diagnosed prior to the fracture. Of these, only one patient sustained a further VTE post fracture, with this occurring 25 months post fracture. One patient suffered three PEs prior to their ankle fracture and another suffered two DVTs.

The remaining four patients were diagnosed with VTEs more than 90 days (mean 19, range 13 to 29 months) following the fracture with no previous VTEs and no VTEs during the peri-fracture period. One of these patients suffered two DVTs during this time.

This led to a background rate in our patient cohort of 0.0094% per 90-day period (95% CIs 0.0058% to 0.0152%). Comparison of this to the rate in the 90 days post injury found it to be 37.7 times higher than the rate in non-operatively managed fractures and 76.9 times higher than the rate in operatively managed fractures.

Published rates of VTE in the 90-day period following hip and knee arthroplasty from the Royal Infirmary Edinburgh¹⁶⁷ are 2.27% for total hip arthroplasty and

1.79% for total knee arthroplasty. Comparison of these to the rate following ankle fracture found an increase of 3.1 times when total hip arthroplasty was compared to operatively managed ankle fractures and 2.5 times when compared with total knee arthroplasty.

A literature review of the risks of major bleeding with pharmacological thromboprophylaxis for VTE found a risk of major bleeding with dalteparin of 1.4%^{168,169} which is 1.94 times higher than the risk of VTE following operative management and 3.95 times higher than that following non-operative management.

4.5.5 Discussion

This study has identified six VTEs in the 90 days following ankle fracture with no fatal PEs. This equates to a clinical VTE risk of 0.72% in operatively managed patients and 0.35% in non operatively managed patients with ankle fractures. This study, of 1,262 consecutive patients, is the largest of its kind to assess the rate of VTEs in patients following ankle fracture. The patients included were representative of those commonly sustaining ankle fractures with a similar age and mechanism of injury to those previously reported². No significant difference between operatively and non operatively managed patients may be due to thromboprophylaxis but more likely to be a type II error due to the rarity of these events.

This rate of clinical VTEs in non operatively managed ankle fractures agrees with a number of smaller studies including work from Toronto¹⁷⁰ where non operatively managed knee to foot fractures were managed without pharmacological

thromboprophylaxis and a rate of 0.6% of clinically relevant VTEs was identified. Although a large number of fractures were included in this study only 39% of the 1200 fractures were ankle fractures, equating to only 468 patients. A far larger study using HES data¹⁶⁵ found a PE rate of 0.22% in 14,777 non operatively treated ankle fractures which is very similar to the rate of 0.35% in the present study. This large study was limited by the HES data and was unable to define the use of pharmacological thromboprophylaxis in this patient group.

Other studies in the UK have identified higher rates of clinical DVTs with Thomas and van Kampen¹⁷¹ reporting a rate of 1.84% following 381 various lower limb injuries immobilised in a cast. Four of these patients then went on to develop a PE. Of note all of the patients in this study were mobilised non-weightbearing. Venous stasis does promote formation of VTEs but this is not necessary following ankle fractures, the majority of patients can be permitted to weight bear which allows some calf muscle movement hence maintaining venous pump function and muscle mass. This may help to explain the higher reported rate of VTE in this study compared to our findings and those from Canada.

The VTE risk of 0.72% of following operatively managed ankle fractures is also similar to previously published figures. Analysis of English HES data¹⁷² on 45,949 operatively managed ankle fractures found a rate of DVTs of 0.12% and PEs of 0.17%. Of these six of the PEs were fatal. Although this is the largest paper to provide an idea of the frequency of VTE following ankle fracture the HES data does not include details of any thromboprophylaxis used and makes interpretation of these figures difficult. They did identify risk factors for VTE following operatively

managed ankle fractures however, with higher rates in the over 50s and those with Charlson scores of greater than or equal to two.

Further analysis of the 90 day VTEs revealed six PEs with only one patient also diagnosed with a concurrent DVT. This may be explained by the cast immobilisation. It seems likely that a large number of DVTs were missed due to the plaster immobilisation preventing observation of the calf swelling. This surprising finding has been found in a number of studies with higher rates of PEs than DVTs^{172,173}.

The background rate in this study using the same patient group found a rate of 0.0094% per 90 day period. This is slightly lower than others have found with Sweetland¹⁷⁴ reporting a background rate of 0.017% per 90 day period. Some of this disparity may be due to the patients included in their study compared to the current study. Sweetland only included middle aged women whereas the lower background rate in the current study includes all patients. If the background rate of 0.017% is used then the increase in rate of VTE following ankle fracture is 42.5 and 20.8 for operatively and non-operatively managed fractures respectively. These rates and those found in the current study are far higher than the background rate but this must be viewed with consideration of the rate in arthroplasty and the risks of pharmacological thromboprophylaxis.

Rates of VTE following hip and knee arthroplasty at the Royal Infirmary Edinburgh are 3.1 and 2.5 times higher than those following operatively treated ankle fractures. This comparison with arthroplasty is important as there is a great deal of research investigating VTE following hip and knee arthroplasty¹⁷⁵. A range of

pharmacological prophylaxis has been found to reduce rates of symptomatic VTE following arthroplasty however there is no evidence that this reduces mortality. As a result it is unlikely that one will be able to show this in ankle fractures as the rates are far lower.

In order to power a study looking at mortality following VTE in operatively managed ankle fractures to 80% one would need 742,808 patients considering a mortality rate of 0.4%¹⁷² at 90 days following ankle fracture with a 10% reduction in this, with a p value of 0.05. 742,808 patients would take 30 years assuming full enrolment of every ankle fracture in the United Kingdom.

Two RCTs have considered VTEs following ankle fracture. Selby et al¹⁷⁶ in Canada recruited 258 patients to a trial comparing two weeks of dalteparin to placebo following operatively treated isolated lower leg fractures. Recruitment to the trial was stopped at the first interim analysis with no evidence of a significant risk reduction in those patients treated with dalteparin. This trial included patients with tibia and fibula fractures as well as ankle fractures and therefore had a far higher rate of VTE at 1.5% in the dalteparin group and 2.3% in the placebo group but despite these higher rates were unable to find a significant difference. A further RCT in Holland¹⁷⁷ compared nandroparin or fondaparinux to no chemical thromboprophylaxis in patients with a non-operatively managed ankle or foot fracture requiring cast immobilisation for a minimum of four weeks. They found a significantly higher rate of asymptomatic DVTs in the control group but no significant difference in clinically relevant outcome points.

The most clinically relevant risk with pharmacological thromboprophylaxis is major bleeding. The risk of major bleeding is difficult ascertain particularly in ankle fracture patients but in hip and knee arthroplasty the rate has been estimated at 1.4%^{168,169}. As a result the risk of major bleed is far higher than the risk of VTE.

Current guidelines (NICE) suggest discussion with the patients on the benefits of pharmacological thromboprophylaxis following all inpatients with lower limb plaster cast immobilisation but this has been interpreted by some to suggest that pharmacological thromboprophylaxis should be provided¹⁰⁷.

There are some limitations to this work. There are only small numbers of VTEs in this cohort of 1,262 patients with ankle fractures due to their rarity. However, due to the relatively small numbers the data can be explored in greater detail. The method of collection relies on patients continuing their care in Scotland. Whilst patients may move in the long term as only locally residing patients are included the 30 and 90 day incidences are likely to be correct. Finally questions have previously been raised about the accuracy of HES data¹⁷⁸ particularly regarding VTEs but recent work has shown good validity particularly for data after 2008¹⁷⁹.

4.5.6 Conclusions

In conclusion this study has found a low rate of VTE following ankle fractures. The risks of pharmacological prophylaxis have been found to be higher than the risks of VTE and as a result pharmacological thromboprophylaxis cannot be recommended following ankle fracture. However, there are some cases of VTE in the current study

and discussion is required with patients regarding the risks and benefits of their own situation as well as their own wishes.

Chapter 5: Conclusions

This thesis has investigated the epidemiology and outcomes of ankle fractures. Two of the studies have been published prior to submission of this thesis and there has been further work in the literature since their release. This chapter summarises the findings of the studies in this thesis and the changes in the literature since the two studies were published.

5.1 Epidemiology of ankle fractures

5.1.1 Epidemiology of ankle fractures

This study has found ankle fractures to comprise a range of injuries with distinct epidemiology. Whilst isolated lateral malleolar Weber B fractures may be considered osteoporotic injuries, fractures of the medial and posterior malleoli as well as Weber C fractures occur in younger patients often with higher energy mechanisms. Further work to identify individualised management protocols for these quite different injuries may improve outcomes in both patient groups.

The finding of an association of ankle fractures with social deprivation also merits further investigation. The patients in the most deprived quintile are significantly younger and significantly more likely to be men sustaining their ankle fractures. This cohort of patients may also benefit from further investigation of prevention and management strategies.

5.1.2 Epidemiology of open ankle fractures

Since publication of this study on the epidemiology of open ankle fractures a small amount of further epidemiological evidence has been published, principally investigating older patients with low energy open ankle fractures. Ovaska et al¹⁸⁰ identified 137 patients with open ankle fractures over a 5-year period treated surgically. They found a mean age of 60 years with 56% of the patients women and 31% of injuries Gustillo III. This is very similar to the findings presented here. Wijendra et al¹⁸¹ reported on 61 patients with low energy open ankle fractures presenting to their unit in Oxford. They found an older mean age of 73 years, a greater proportion of female patients (82% versus 54%) and a lower median ISS than found in the current study. This is likely due to their exclusion of high energy injuries from their retrospective review. The current study found a mean age of 66 years with 75% of patients female when only low energy injuries were analysed.

Due to the rarity of these injuries further research to describe the epidemiology in greater detail may require the undertaking of large centres working together to provide the number of cases required.

5.2 Outcomes of ankle fractures

The outcome measures used in this thesis have been varied with clinical, radiographic and PROMs used. The PROMs used in this thesis have been numerous, whilst the OMS is consistently used there is no current standardised outcome set for ankle fractures which reflects the current lack of standardisation in ankle fracture

PROMs. Work is ongoing to produce an outcome set which would allow for easier compilation of results and comparisons across centres.

5.2.1 Outcomes of investigation of ankle fractures

This study has shown that GSRs have a high false positive rate that may lead to over treatment of stable ankle fractures. A recent review by Toth et al has agreed with this describing them as “truly insufficient in determining ankle instability”¹⁸².

Further investigation should therefore concentrate on investigating alternatives for identifying those ankle fractures that are stable and can safely be treated conservatively and those that will benefit from intervention. MRI has been suggested by some as an option but does have its downsides: expense and time. Currently many centres use a dynamic protocol¹. Patients with apparently stable ankle fractures are permitted to weight bear in an orthosis for one week following injury and then the radiographs are repeated. Any displacement at this stage indicates an unstable injury that is likely to benefit from intervention whilst those fractures that have not displaced are likely stable and can be treated non-operatively.

5.2.2 Outcomes of ankle fractures treated with fibular nails

Since this work was published in 2012, further work on the use of the fibular nail has built on it to confirm the role of the fibular nail in treating ankle fractures. Several randomised controlled trials have found encouraging outcomes for the use of the

fibular nail. Asloun¹⁸³ found significantly fewer complications and better PROMs at one year follow up in patients randomised to the fibular nail than those in the plate fixation group in their randomised controlled trial. White et al¹⁸⁴ also reported significantly fewer complications and more cost effectiveness in their randomised controlled trial of the use of the fibular nail in elderly patients with no difference in PROMs between the two groups.

Good outcomes have also been reported with the use of the fibular nail in diabetic patients with a retrospective study from Canada and the UK¹⁸⁵ reporting good clinical outcomes with the use of the fibular nail in this challenging patient group. Other groups have also reported on refinements to the technique of fibular nailing described here. Thevendran et al¹⁸⁶ have used arthroscopy to aid in reduction with the fibula nail in another cohort of diabetic patients.

There have been some concerns regarding the potential for iatrogenic injury with the use of the fibular nail due to its percutaneous insertion. Goss et al¹⁸⁷ performed a study on 10 cadavers and found that in all cases the peroneus brevis tendon was within 5mm of the distal skin incision and that the superficial peroneal nerve was at high risk in seven of the specimens when inserting the distal locking screws. However, they did not injure any structures during their study.

Finally, biomechanical studies have investigated the fibular nail in cadavers. Smith et al⁸² found a greater torque to failure in cadaveric SER IV fractures treated with the fibular nail compared to those fixed with a lag screw and neutralisation plate. Whilst Switaj et al compared the fibular nail to a distal fibular locking plate in Weber C

ankle fractures finding the syndesmotic diastasis to be maintained within acceptable limits with the fibular nail but inferior external rotation stiffness¹⁸⁸.

Further work to look at the outcomes of the fibular nail in comparison to traditional ORIF in younger patients is needed to fully assess the role of the fibular nail in ankle fractures as well as investigation into its use in other centres around the UK and around the world to assess its generalisability. In addition, further investigation into the outcomes of the use of the fibular nail in those patients at highest risk of complications following ankle fracture would assist in the perennial debate as to whether the risks of operative intervention in some patients with ankle fracture are too great.

5.2.3 Outcomes of early weight bearing following ankle fracture

This prospective cohort study builds on previous RCTs comparing weight bearing to non-weight bearing following operative management of ankle fractures. This adds to the evidence suggesting that weight bearing is an appropriate rehabilitation strategy following ankle fracture for the majority of patients and should confirm this to the large numbers of surgeons who are reticent to change their rehabilitation protocols.

5.2.4 Outcomes of venous thromboembolic prophylaxis following ankle fractures

This study has shown low rates of VTEs with the current management protocol following ankle fractures managed both operatively and non-operatively. Further work on VTE thromboprophylaxis in other areas of orthopaedics and medicine in general will provide more information to orthopaedic surgeons managing ankle fractures particularly in identifying the very small subset of patients who might benefit from prophylaxis.

5.3 Conclusions

This thesis has investigated the epidemiology and outcomes of ankle fractures. It has confirmed that ankle fractures are common injuries with a stabilisation of the overall incidence. Open ankle fractures comprise around 1.5% of all ankle fractures and are predominantly low energy injuries with the highest incidence in elderly women. Gravity stress radiographs have been shown to have a high rate of false positives and further research is required to identify alternative methods for identifying occult instability. Fibular nailing of unstable ankle fractures, early weight bearing and current limited VTE prophylaxis have all been shown to have good outcomes in large cohorts of patients.

Appendix 1

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ORTHOPAEDIC SURGERY

Open ankle fractures: who gets them and why?

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Abstract Open ankle fractures present a significant clinical challenge. The management and outcome of these injuries has been extensively reported, but there have been no reports of the epidemiology and how this has changed over time. We report 178 adult patients with open ankle fractures presenting to our unit over a twenty-three year period. The study centre is the only hospital receiving adult orthopaedic trauma in the region and has a defined population. The incidence of open ankle fractures was $1.5/10^5$ year, representing 1.5 % of all ankle fractures. The mean age was 55 years (range 16–96), with the highest incidence occurring in women over the age of 90. The most common mechanism was a simple fall with only 26 % of cases due to a motor vehicle collision (MVC). 82 % of cases were isolated injuries. Social deprivation had no significant influence on the incidence, but there was a difference in the mechanism with the majority of injuries in the most deprived quintile caused by MVCs and significantly fewer due to simple falls ($p = 0.047$). Over the twenty-three years, there was a significant increase in the mean age from 44 to 64 years ($p = 0.03$). The overall incidence remained constant over the two decades. In common with many traumatic injuries, open ankle fractures are increasingly low-energy insufficiency fractures affecting elderly patients, particularly older women. This has implications for service planning and training as well as the surgical intervention in these patients.

Keywords Ankle · Fracture · Malleolar · Trauma · Epidemiology · Open · Compound

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Introduction

Ankle fractures are a major component of the trauma workload, representing 9 % of fractures seen by orthopaedic surgeons [1]. Whilst a number of authors have described the epidemiology of ankle fractures and how this has changed over time [1–6], little has been published describing the epidemiology of open ankle fractures. The literature regarding open ankle fractures has concentrated on the management of these injuries including the timing of surgery [7], the methods of fixation [8, 9] and the outcomes of treatment [10]. There has been minimal consideration of the patient groups affected and the mechanisms by which these fractures occur. This information would allow for planning of care in this group of patients and for training to be targeted appropriately.

The primary aim of this study was to investigate the epidemiology of open ankle fractures; to identify the patients affected, the prevalent modes of injury and the associated injuries. The secondary aim was to identify whether the epidemiology of open ankle fractures has changed during the last two decades.

Methods

All patients presenting to the study centre between January 1988 and December 2010 with open ankle fractures, as inpatients or outpatients, were entered into a trauma database. These data were collected prospectively from 1988 to 2005 whilst from 2005 onwards patients were identified by retrospective review of the departmental computerised database. Information recorded included name, age, gender, address, date and mechanism of injury, other injuries, and Gustilo Anderson grade [11, 12].

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The study centre is the only hospital receiving adult (>15 years old) orthopaedic trauma in the City of Edinburgh, Midlothian and East Lothian. Paediatric orthopaedic patients may either be treated here or at the local paediatric hospital; as a result, these patients were excluded from the analysis. The local population over the age of 16 is 517,555 [13]. Any patients that were from outside the region but that were treated at the study centre were not included in the database. Patients that were domiciled within the region but that sustained their injury elsewhere and were transferred or followed up at the study centre were included.

The Injury Severity Score [14] (ISS) was calculated retrospectively from the Abbreviated Injury Scale (AIS) [15]. Open ankle fractures score three on the AIS, whilst wounds less than 10 cm score one and wounds greater than 10 cm score two. Gustilo Anderson grade one and two open injuries were given an AIS of one, whilst grade three open injuries were given an AIS of two. The ISS was then calculated from the sum of the squares of the three highest AIS scores.

The address was used to assess the level of social deprivation of the patient using the Carstairs and Morris index [16] which provides a score for each postcode sector in Scotland. From this score, the population can be divided into quintiles with one representing the least deprived areas and five the most deprived.

Statistical analysis was performed with SPSS version 19 (SPSS Inc., Chicago, IL, USA). Chi-squared tests were used for categorical variables; two-tailed t tests were used for continuous variables. For the correlation between continuous variables, the Pearson Coefficient (PC) was used. Spread of data was evaluated by use of standard deviation (SD). A *p* value of <0.05 was considered significant.

Results

During the twenty-three-year study period, 178 patients presented to the Royal Infirmary Edinburgh with open ankle fractures. This represents an incidence of $1.49/10^5$ /year within our local population of 517,555.

The mean age of these patients was 55 years, ranging from 16 to 96 years. Females made up 54 % of these patients with an incidence of $1.52/10^5$ /year and a mean age of 64, whilst there were 82 males with a mean age of 45 and an incidence of $1.46/10^5$ /year (Fig. 1). The mean ages of males and females were significantly different ($p < 0.001$), but there was no significant difference in the incidence with gender. The incidence of open ankle fractures increased in males with age from $1.41/10^5$ in patients under 65 to $1.68/10^5$ in patients over 65 but this was not significant ($p = 0.86$). However, a significant change was observed in

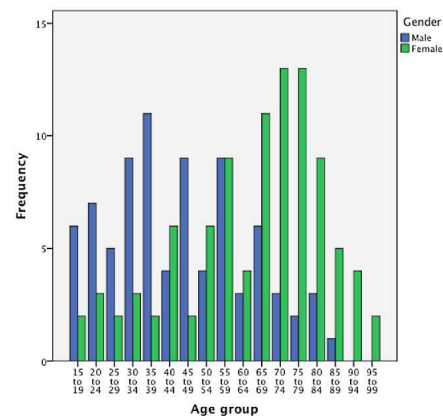


Fig. 1 Age and gender distribution of open ankle fractures 1988–2010

females with an incidence of $0.78/10^5$ in patients under 65 increasing to $4.26/10^5$ in patients over 65 (PC $r = 0.87$, $p < 0.001$). This is shown in Fig. 2.

Mechanism of injury

The most common mechanism of injury was a simple fall, accounting for just under half of the fractures (Table 1) with motor vehicle collisions (MVCs) second and accounting for 26 % of fractures. When the age of the patients was taken

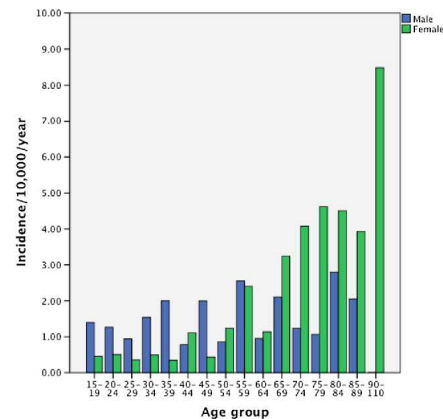


Fig. 2 Change in incidence of open ankle fractures with age

Table 1 Mechanism of injury of open ankle fractures

Mechanism of injury	Number of patients	Mean age (years)	Percentage female	Mean ISS
Simple fall	87	66	75	11
MVC	46	47	33	16
Fall from height	15	40	27	12
Fall from stairs	11	64	82	11
Sport	8	32	13	12
Direct blow/assault	5	31	20	14
Crush	3	47	0	11
Unknown	3	52	33	13

into consideration, 74 % of fractures in elderly patients were due to simple falls, whilst in patients under the age of 65 simple falls accounted for only 32 % of fractures ($p < 0.001$, odds ratio 5.91) with MVCs accounting for a further 33 %. The addition of gender to the analysis found that the majority of fractures sustained as a result of simple falls or falls on the stairs occurred in women; in contrast, those sustained in MVCs, falls from height or whilst playing sport occurred more commonly in men.

The open ankle fractures sustained in a MVC were largely due to pedestrian vs. car incidents (Fig. 3). The patients sustaining their injury as passengers were predominantly female with a mean age of 59, and ISS of 19, whilst those involved as drivers were all male with a mean age of 36 and mean ISS of 35. The 5 % of injuries due to sport occurred almost exclusively in male patients which included a number of sports: rugby, 38 %, football, 25 %, and horse riding, 13 %.

Gustilo Anderson classification

The distribution of fractures by the Gustilo Anderson classification is shown in Table 2. The most frequent grade

of injury was IIIa, which accounted for 40 % of cases. The mean age of these patients was higher than the other grades of injury at 61 years ($p = 0.005$) with the majority of these cases occurring due to a simple fall. Grade IIIa fractures were most prevalent in the elderly, whilst in patients under the age of 65 grade II fractures were more common (Figs. 4, 5). The mean ISS increased as the Gustilo Anderson grade increased (PC $r = 0.15$, $p = 0.02$), when one patient with a Gustilo Anderson grade IIIc fracture was excluded.

Other injuries

The majority of patients with open ankle fractures (82 %) sustained this as an isolated injury. Of the 18 % of patients that sustained their open ankle fracture in conjunction with other injuries, additional orthopaedic injuries were the most common associated injuries (88 %) as shown in Table 3. These other fractures were predominantly of the lower limbs (80 %) with a small number affecting the upper limbs (14 %) and spine (6 %). Most patients sustained only one open fracture; however, 6 % of patients sustained two open fractures, two patients sustained three open fractures and one elderly female patient sustained six open fractures (distal femur, proximal tibia, middle, ring and little fingers). The median ISS was 13 with a range from 10 to 57; 92 % of patients had an ISS of 10 or 13. All of the patients with an ISS of greater than 13 sustained their open ankle fracture as a result of a high-energy injury; 87 % were due to MVCs with one sustained after a fall from height and one as a result of an assault.

Social deprivation

There was no correlation between social deprivation and the incidence of open ankle fractures (Table 4). The largest proportion of patients was in quintile one and the smallest was in quintile five but as the local population is skewed towards affluence, the highest incidence of open ankle fractures was in quintile five at $1.80/10^5$ /year. Simple falls were the most common cause of injury in all quintiles

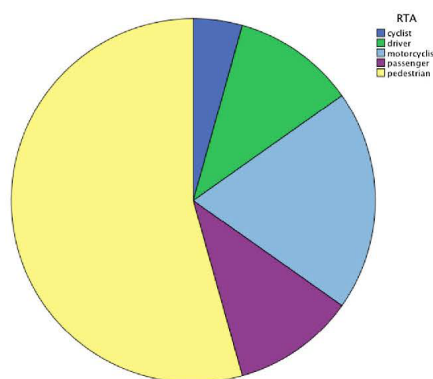
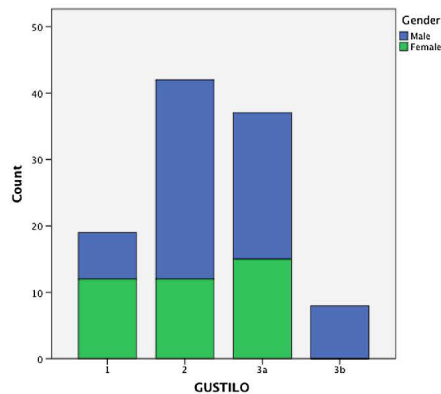
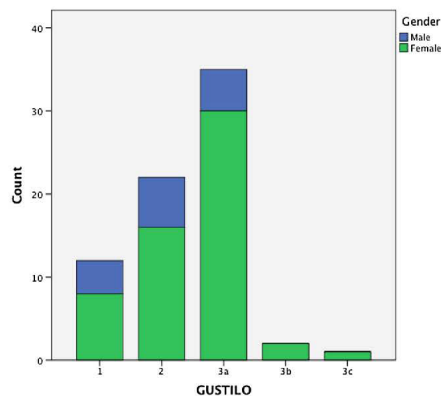
**Fig. 3** Open ankle fractures with a MVC as the mechanism of injury

Table 2 Gustilo Anderson grade of open ankle fractures

Gustilo Anderson	Patients	Mean age	Injuries due to simple fall (%)	Mean ISS
Grade I	31 (17 %)	54.8	48	11.9
Grade II	64 (36 %)	51.2	45	12.1
Grade IIIa	72 (40 %)	61.4	57	13.6
Grade IIIb	10 (6 %)	39.6	20	15.1
Grade IIIc	1 (1 %)	76.0	0	13.0

**Fig. 4** Gustilo Anderson grade of open ankle fractures in patients under the age of 65**Fig. 5** Gustilo Anderson grade of open ankle fractures in patients over the age of 65

except quintile five. In this quintile, the majority of injuries were caused by MVCs with simple falls only causing 30 % of injuries ($p = 0.047$). Quintile five also had the lowest

Table 3 Other injuries sustained at the same time as the open ankle fracture

Other injuries	Number of patients	Percentage
Orthopaedic	29	88
Chest	8	24
CNS (including head injuries)	7	21
Abdominal	4	12

Some patients sustained multiple other injuries

mean age of patients and the highest mean ISS but this was not significant ($p = 0.26$ and 0.48).

Change with time

Over the twenty-three years, the incidence of open ankle fractures remained stable with between two and 14 fractures presenting to the unit each year (Table 5). However, there were two major changes over this time period. The prevalent mechanism of injury showed a marked change; 100 % of open ankle fractures in 1988 were due to MVCs but there were none caused by MVCs from 2008 to the end of the period of data collection (Fig. 6). The mean patient age has also changed, with a rise from 44 years in 1988 to 64 years in 2010 ($r = 0.21$, $p = 0.03$). Finally, when patients over the age of 65 years are analysed separately (Fig. 7), it can be seen that there has been a marked increase in the incidence of open ankle fractures in elderly women, but not elderly men, since 1988.

Discussion

We have demonstrated the overall incidence of open ankle fractures to be $1.5/10^5/\text{year}$. The incidence of all ankle fractures for the study centre in 2000 [17] was $100.8/10^5/\text{year}$; therefore, it can be estimated that open ankle fractures comprise 1.5 % of all ankle fractures locally which is lower than previously reported rates, ranging from 2 to 5 % [1, 18]. These higher reported rates of open fractures may be due to analysis of inpatient data only; as many closed ankle fractures can be managed on an entirely outpatient

Table 4 Carstairs quintile

Carstairs quintile	Patients	Incidence (per year/10 ⁵)	Mean age	Mean ISS	Percentage female	Modal Gustilo Anderson grade
1	56	1.73	57	13.7	61	IIIa
2	30	1.31	54	12.2	53	II
3	37	1.55	57	12.7	59	II
4	35	1.47	55	11.3	43	II
5	20	1.80	50	14.3	45	IIIa

Table 5 Year of injury

Year of injury	Patients	Mean age	Most common mechanism	Mean ISS	Percentage female
1988	6	44.17	MVC (100 %)	19.17	50
1989	8	42.63	MVC (50 %)	13.88	63
1990	10	52.30	MVC (60 %)	10.90	20
1991	8	45.75	MVC (63 %)	13.50	0
1992	4	57.25	MVC (50 %)	12.25	50
1993	2	78.00	Simple fall (100 %)	11.50	100
1994	8	56.50	Simple fall (75 %)	11.50	63
1995	6	40.33	Simple fall (50 %)	12.50	50
1996	6	56.50	MVC (50 %)	14.50	50
1997	6	46.33	Simple fall (50 %)	10.50	50
1998	6	62.17	Simple fall (66 %)	11.50	66
1999	11	52.45	MVC (45 %)	17.18	36
2000	11	52.45	Simple fall (55 %)	10.82	45
2001	14	63.43	Simple fall (69 %)	14.43	71
2002	8	55.25	Simple fall (38 %)	12.25	88
2003	7	55.29	Simple fall (71 %)	11.29	71
2004	7	59.14	Simple fall (71 %)	10.86	71
2005	9	62.56	Simple fall (66 %)	11.67	56
2006	7	58.71	Simple fall (57 %)	12.14	86
2007	4	69.25	Simple fall (75 %)	12.25	75
2008	11	52.27	Simple fall (55 %)	13.82	36
2009	12	61.92	Simple fall (75 %)	11.00	42
2010	7	64.14	Simple fall (57 %)	13.86	71

basis, this would underestimate the true number of ankle fractures.

The mean age of 55 years in this cohort of patients is a decade older than the mean age of 1,500 ankle fractures previously reported [1], whilst the highest age-specific incidence is in patients over the age of 90. This is higher than that seen in closed ankle fractures; Koval et al. [19] reported 33,704 patients over the age of 65 with ankle fractures and found a peak incidence between 80 and 84 years of age followed by a decrease in patients over the age of 85. This decade advance in peak incidence and mean age for open ankle fractures, in comparison to all ankle fractures, may be due to a change of the condition of the soft tissues as patients age [20] such that the same fracture in a patient in their eighties may be closed but in a patient in their nineties becomes open as the soft tissue envelope deteriorates.

In this study, there were a similar number of open ankle fractures in women, 54 %, and in men. The overall incidence of open fractures has previously been shown to be higher in men than in women [21], whilst ankle fractures as a whole have been found to be roughly evenly spread between the genders [1, 4, 6]. However, this has shown a change in recent decades with Bengner reporting a reduction in the male/female gender ratio from 1.16 to 1.07 between 1950 and 1980 [22]. The change in the gender ratio over time is also seen in our cohort of ankle fractures with the male:female ratio changing from 1 in 1988 to 0.4 in 2010 but this is not significant ($r = -0.259$, $p = 0.122$).

The reduction in the male to female ratio appears to be predominantly due to the increasing incidence in elderly women. Open ankle fractures do not fit with the most common fracture distribution curve; unimodal young male,

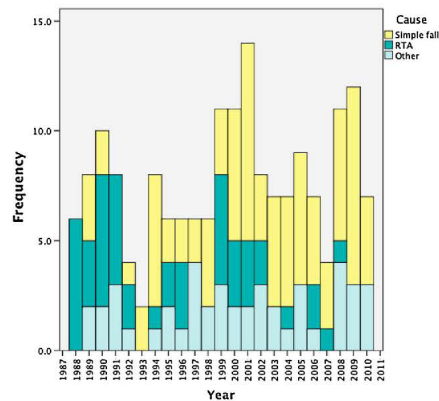


Fig. 6 Change in mechanism of injury of open ankle fractures over the twenty-two-year study period

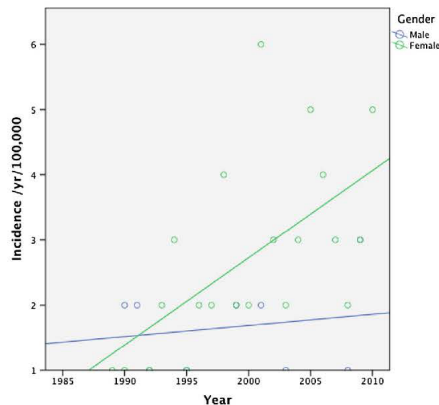


Fig. 7 Change in incidence of open ankle fractures in patients over the age of 65 from 1988 to 2010. The far greater increase in women than in men can be seen

unimodal older female: the distribution that ankle fractures as a whole fit. Instead open ankle fractures have a unimodal older female distribution in common with closed fractures of the pelvis, distal humerus and distal femur. The incidence in young men is double that seen in young women, as has previously been reported for all ankle fractures [6], but the incidence then remains relatively stable in men whilst showing a large increase in women with age. The highest age-specific incidence for both men and women is

older than for closed injuries. Of particular note is the highest incidence in men in the age group 80 to 84 whilst in closed ankles this peak occurs in young men. Again this is likely to be due to the changes in the soft tissue envelope with age.

The open ankle fractures in this study occurred due to a simple fall in 49 % of cases and MVCs in 26 %. As expected, the mechanism of injury is skewed towards higher energy modes than in all ankle fractures where between 8 and 10 % of injuries have been attributed to MVCs [1, 4, 6]. However, in elderly patients, 74 % of the open fractures did occur due to low-energy mechanisms of injury and overall the proportion of open ankle fractures due to high-energy mechanisms of injury is low compared to all open fractures where 58 % have been attributed to MVCs [21]. Open ankle fractures, therefore, appear to be predominantly low-energy injuries. This may be due to the limited soft tissue coverage around the ankle with little excess available to allow for deformation, hence, in a susceptible patient, relatively little force may be required to cause a large wound over the medial malleolus.

The majority of open ankle fractures were classified as Gustilo Anderson grade III injuries. In comparison to all open fractures, the proportion of fractures that were Gustilo Anderson grade I was lower [21]. This may be due to both the limited soft tissue envelope and the increased age of the patients predisposing to poorer soft tissues. When the grade III fractures are further analysed, the spread is rather different to all open fractures, as by far the majority of grade III open ankle fractures are IIIa in comparison to an equal spread between IIIa and IIIb in all open fractures. The lower energy mechanisms of injury seen in open ankle fractures in comparison to all open fractures may explain why relatively few IIIb and IIIc open ankle fractures were observed.

Elderly patients are more likely to sustain open ankle fractures that are Gustilo Anderson grade IIIa than grade I or II. As previously discussed, elderly patients are also more likely to sustain their injuries as a result of a low-energy mechanism. It therefore seems counterintuitive that the ISS should rise as the Gustilo Anderson grade increases. However, the higher ISS with Gustilo Anderson grade IIIa fractures than grade I may be explained by the method of calculating the ISS. Wounds greater than 10 cm are assigned an AIS of two whilst wounds less than this are assigned an AIS of one. Patients with a grade IIIa fracture will therefore have obtained a higher ISS from their open ankle fracture rather than from any further injury. In fact, when their open fracture contribution to the ISS is subtracted, the mean ISS for other injuries is less than the one in both grade I and IIIa injuries but higher in grade II and IIIb injuries.

Over the twenty-three years of data collection, the most striking change was in the prevalent mechanism of injury. This change from MVCs to simple falls may be due to a number of factors. The number of casualties due to MVCs has decreased over this time period [23] which may be attributed to a number of factors including improvements in road safety and awareness of the dangers of driving whilst under the influence of alcohol [24]. This may explain the reduction in open ankle fractures sustained as a result of MVCs but does not explain the increasing number of fractures due to simple falls.

As the mean age of the patients has increased so too has the number of fractures due to simple falls, the proportion of the fractures that occur in women and the proportion that are Gustilo Anderson grade IIIa. It appears that elderly female patients are sustaining grade III open fractures as a result of simple falls. Overall, open ankle fractures were equally distributed throughout the study period with no significant change in incidence over time; however, there was an increase in the incidence of open ankle fractures in elderly women. This could be explained by intrinsic changes within the elderly population [25]. This increased incidence in elderly women has also been observed for closed ankle fractures. Kannus et al. [5] demonstrated the incidence of ankle fractures in patients over the age of 60 changed from 66/year/10⁵ in 1970 to 174/year/10⁵ in 2000.

The major limitation of this study is the small number of fractures included over a prolonged period of study. Although this does limit the strength of the conclusions that can be made, this is due to the rarity of these injuries and may help to explain why no previous studies have been undertaken.

In conclusion, open ankle fractures are becoming a low-energy open fracture that occurs predominantly in elderly females after a simple fall. We may therefore expect to see an increase in the number of open ankle fractures over the coming years as the elderly population continues to increase.

Conflict of interest None.

References

- Court-Brown C, McBurnie J (1998) Adult ankle fractures—an increasing problem? *Acta Orthop Scand* 69:43–47
- Hasselman CT, Vogt MT, Stone KL et al (2003) Foot and ankle fractures in elderly white women. Incidence and risk factors. *J Bone Joint Surg Am* 85-A:820–824
- Bauer M, Bengtner U, Johnell O, Redlund-Johnell I (1987) Supination-eversion fractures of the ankle joint: changes in incidence over 30 years. *Foot Ankle* 8:26–28
- Daly PJ, Fitzgerald RH, Melton LJ, Ilstrup DM (1987) Epidemiology of ankle fractures in Rochester, Minnesota. *Acta Orthop Scand* 58:539–544
- Kannus P, Palvanen M, Niemi S et al (2002) Increasing number and incidence of low-trauma ankle fractures in elderly people: Finnish statistics during 1970–2000 and projections for the future. *Bone* 31:430–433
- Jensen SL, Andresen BK, Mencke S, Nielsen PT (1998) Epidemiology of ankle fractures. A prospective population-based study of 212 cases in Aalborg, Denmark. *Acta Orthop Scand* 69:48–50
- Bray TJ, Endicott M, Capra SE (1989) Treatment of open ankle fractures. Immediate internal fixation versus closed immobilization and delayed fixation. *Clin Orthop Relat Res* 240:47–52
- Ngcelwane MV (1990) Management of open fractures of the ankle joint. *Injury* 21:93–96
- Ye T, Chen A, Yuan W, Gou S (2011) Management of grade III open dislocated ankle fractures: combined internal fixation with bioabsorbable screws/rods and external fixation. *J Am Podiatr Med Assoc* 101:307–315
- Hong-Chuan W, Shi-Lian K, Heng-Sheng S et al (2010) Immediate internal fixation of open ankle fractures. *Foot Ankle Int* 31:959–964. doi:10.3113/FAI.2010.0959
- Gustilo RB, Anderson JT (1976) Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. *J Bone Joint Surg Am* 58:453–458
- Gustilo RB, Mendoza RM, Williams DN (1984) Problems in the management of type III (severe) open fractures: a new classification of type III open fractures. *J Trauma* 24:742–746
- <http://www.scrol.gov.uk/scrol/common/home.jsp>
- Baker SP, O'Neill B, Haddon W, Long WB (1974) The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma* 14:187–196
- Rating the severity of tissue damage. I. The abbreviated scale. (1971) *JAMA* 215:277–280
- Carstairs VV, Morris RR (1990) Deprivation and health in Scotland. *Health Bull (Edinb)* 48:162–175
- Court-Brown CM, Caesar B (2006) Epidemiology of adult fractures: a review. *Injury* 37:691–697. doi:10.1016/j.injury.2006.04.130
- Olerud S, Karlstrom G, Danckwardt-Lilliestrom G (1978) Treatment of open fractures of the tibia and ankle. *Clin Orthop Relat Res* 136:212–224
- Koval KJ, Lurie J, Zhou W et al (2005) Ankle fractures in the elderly: what you get depends on where you live and who you see. *J Orthop Trauma* 19:635–639
- Bologna JL (1995) Aging skin. *Am J Med* 98:99S–103S
- Court-Brown CM, Rimmer S, Prakash U, McQueen MM (1998) The epidemiology of open long bone fractures. *Injury* 29:529–534
- Bengtner U, Johnell O, Redlund-Johnell I (1986) Epidemiology of ankle fracture 1950 and 1980. Increasing incidence in elderly women. *Acta Orthop Scand* 57:35–37. doi:10.3109/17453678608993211
- Reported road casualties Scotland 2010 (2011) A National Statistics Publication for Scotland
- Chisholm D, Naci H, Hyder AA et al (2012) Cost effectiveness of strategies to combat road traffic injuries in sub-Saharan Africa and South East Asia: mathematical modelling study. *BMJ* 344:e612
- Statistics OFN (2012) Population Ageing in the United Kingdom its constituent countries and the European Union

Appendix 2



■ TRAUMA

The treatment of unstable fractures of the ankle using the Acumed fibular nail

DEVELOPMENT OF A TECHNIQUE

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Techniques for fixation of fractures of the lateral malleolus have remained essentially unchanged since the 1960s, but are associated with complication rates of up to 30%. The fibular nail is an alternative method of fixation requiring a minimal incision and tissue dissection, and has the potential to reduce the incidence of complications.

We reviewed the results of 105 patients with unstable fractures of the ankle that were fixed between 2002 and 2010 using the Acumed fibular nail. The mean age of the patients was 64.8 years (22 to 95), and 80 (76%) had significant systemic medical comorbidities. Various different configurations of locking screw were assessed over the study period as experience was gained with the device. Nailing without the use of locking screws gave satisfactory stability in only 66% of cases (4 of 6). Initial locking screw constructs rendered between 91% (10 of 11) and 96% (23 of 24) of ankles stable. Overall, seven patients had loss of fixation of the fracture and there were five post-operative wound infections related to the distal fibula. This led to the development of the current technique with a screw across the syndesmosis in addition to a distal locking screw. In 21 patients treated with this technique there have been no significant complications and only one superficial wound infection. Good fracture reduction was achieved in all of these patients. The mean physical component Short-Form 12, Olerud and Molander score, and American Academy of Orthopaedic Surgeons Foot and Ankle outcome scores at a mean of six years post-injury were 46 (28 to 61), 65 (35 to 100) and 83 (52 to 99), respectively. There have been no cases of fibular nonunion.

Nailing of the fibula using our current technique gives good radiological and functional outcomes with minimal complications, and should be considered in the management of patients with an unstable ankle fracture.

Fractures of the ankle comprise 9% of all fractures¹ and their incidence is increasing, particularly among elderly women.^{2,3} The technique of plating the lateral malleolus has changed little since the 1960s and has a complication rate of up to 30%.⁴ Wound infection has been seen in up to 26%,⁵ symptoms related to the metalwork in up to 50%⁶ and mechanical failure in 14%.⁷ Even higher rates of complications are seen in the elderly⁸ and in those with diabetes or neuropathy.⁹

The fibular nail is an alternative method of fixing the lateral malleolus. It requires a smaller incision (1 cm¹⁰ compared with 8 cm¹¹ for lateral plating) and less soft-tissue dissection. It affords better mechanical stability in osteoporotic bone¹² with less prominent metalwork, and has the potential to reduce the incidence of complications. Favourable short-term outcomes of fibular nailing have been reported in small numbers of patients.^{10,13,14} A study of 37 patients had encouraging results

with a mean Olerud and Molander Score (OMS) of 87, a good radiological outcome in 97% and a low complication rate, with only one case of loss of fixation and two of infection.¹⁰

The purpose of this study was to evaluate our experience of treating unstable ankle fractures with a fibular nail and to assess the outcome of this method of treatment.

Patients and Methods

Between May 2002 and August 2010 we used the Acumed (Hillsboro, Oregon) fibular nail in 105 patients with an unstable fracture of the ankle. These were identified retrospectively from the electronic patient database. Their demographics and medical comorbidities are shown in Table I. Most had significant comorbidities, often multiple, and were treated with a fibular nail because of previously described good outcomes in this sometimes challenging group of patients.¹⁰ There were only 11 young patients (< 60 years) without comorbidity or

Table I. Demographics and comorbidities of the 105 patients with an unstable fracture of the ankle

Demographics	
Mean age (range) (yrs)	64.8 (22 to 95)
Number of female patients (n, %)	86 (82)
Domicile at time of injury (n, %)	
Own home	92 (88)
Own home with help	11 (10)
Residential home	1 (1)
Nursing home/Institution	1 (1)
Deprivation quintile (n, %)	
One (most deprived)	13 (12)
Two	22 (21)
Three	14 (13)
Four	19 (18)
Five (least deprived)	32 (31)
Postcode data missing	5 (5)
Comorbidities (n, %)	
Hypertension	28 (27)
Ischaemic heart disease	16 (15)
Diabetes mellitus	12 (11)
Psychiatric disorders	11 (10)
COPD/Asthma	10 (10)
Cerebrovascular accident	9 (9)
Cardiac failure	7 (7)
Hypothyroidism	6 (6)
Neuropathy	6 (6)
Renal failure	5 (5)
Rheumatoid arthritis	5 (5)
Number of comorbidities (n, %)	
≥ 5	6 (6)
4	6 (6)
3	10 (10)
2	21 (20)
1	37 (35)
0	25 (24)
Smoking (n, %)	
Yes	21 (20)
No	53 (50)
Ex	11 (10)
Unknown	20 (20)
Alcohol use (n, %)	
None	32 (30)
0 to 21 units/week	36 (34)
> 21 units/week	12 (12)
Unknown	25 (24)

Table II. Mechanism of injury

Mechanism of injury (n, %)	
Simple fall	81 (77)
Fall from low height	11 (10)
Fall from height	6 (6)
Motor vehicle collision	3 (3)
Direct blow	2 (2)
Unrecorded	2 (2)

Table III. Fracture type

Fracture type (n, %)	
Bimalleolar	60 (57)
Trimalleolar	29 (28)
Isolated lateral malleolus	14 (13)
Pilon	2 (2)

The Acumed fibular nail is a solid titanium nail available in two diameters (3 mm and 3.6 mm) and three lengths (110 mm, 145 mm and 180 mm). Surgery is performed under general or spinal anaesthesia with the patient supine. A tourniquet is required only if open reduction of the medial side is anticipated. A closed reduction is performed, after which a 1 cm longitudinal incision is made over the tip of the lateral malleolus; the distal metaphysis is prepared with a cannulated 6.1 mm drill over a 1.6 mm guide wire. The diaphysis is reamed by hand using a 3.1 mm or 3.7 mm reamer as appropriate. The nail is then implanted.

Initially we used a variety of techniques to fix the nail to bone. These included distal locking screws to secure the distal fragment, placed either anterior-to-posterior or medial-to-lateral, with a proximal blocking screw to prevent proximal migration; distal locking screws alone; a 'syndesmosis' screw alone; or no fixation. Early evaluation of our results with these techniques revealed complications in a few patients, and consequently the technique was progressively modified. We currently use an anterior-to-posterior distal locking screw that stabilises the distal fragment and reaches the dorsal fibular cortex but does not penetrate it, so as to avoid peroneal tendon irritation. The construct can then be distracted or rotated, under fluoroscopic guidance, to achieve an anatomical reduction of the mortise before the nail is locked with a transverse 'syndesmosis' screw, which prevents proximal migration, lateralisation and rotation (Fig. 1).

Any fracture of the medial or posterior malleolus is then addressed as the surgeon prefers. Post-operatively, a walking cast is applied after 24 hours; patients are allowed to bear weight immediately provided there has been no diastasis.

The notes of all patients were reviewed. Radiographs were available for 80 patients. The adequacy of reduction was assessed by an independent blinded observer (KEB) using the method described by McLennan and Ungersma.¹⁵ If the criteria were not clearly met, the radiographs were

associated soft tissue injury. These were treated with a fibular nail on the basis of surgeon preference.

The mechanism of injury is shown in Table II and the type of ankle fracture in Table III. Bimalleolar fixation was needed in 78 cases and trimalleolar fixation in three. Three patients needed fixation of the lateral and posterior malleoli and 21 a fibular nail on the lateral side only. Patients who needed fixation of the medial malleoli were treated with screws (n = 50), a tension-band wire (n = 15), Kirschner (K)-wires (n = 12) or a plate and screws (n = 4). Surgery was carried out by one of ten consultant surgeons in 56 cases, by a fellow in 19 cases and by a registrar in 30 cases. Most operations (32%) were carried out on the first day after injury (interquartile range one to three days); only five were performed more than a week after injury.



Fig. 1

Radiograph showing the current technique of fixation of fibular nail to bone. The percutaneously inserted nail is fixed to the fibula with a distal anterior to posterior locking screw and a transverse screw across the syndesmosis.

further reviewed by the senior author (TOW). Good reduction was defined as the fibula being out to length; < 2 mm posterior displacement; and < 1 mm increase in medial clear space. A fair reduction was described as fibular shortening of < 2 mm; 2 mm to 4 mm posterior displacement; 2 mm lateral displacement; and 1 mm to 3 mm increase in medial clear space. A poor reduction was defined as fibular shortening > 2 mm; > 4 mm posterior displacement; > 2 mm lateral displacement; and > 3 mm increase in medial clear space. Routine radiological parameters were also measured, including the medial and tibiotalar clear space and the talocrural angle.

After a mean of six years (1 to 9), 52 of the original 105 patients completed functional questionnaires, including the Short-Form 12 (SF-12),¹⁶ the abbreviated Olerud and Molander Score (OMS)¹⁷ and the American Academy of Orthopaedic Surgeons (AAOS) Foot and Ankle Outcomes¹⁸ questionnaire. Of the 53 patients who did not complete the questionnaires, 25 had died, eight were unable to do so because of dementia, three had emigrated and 17 declined.

The SF-12 provides normalised physical and mental component scores in relation to the general British population. The mean score for the population is 50.0 (SD 10.0). The OMS is an ankle-specific outcome measure that includes questions on pain, stiffness, swelling, stair climbing, supports, activities of daily living, squatting, running and jumping. As most patients in this cohort were not able to run, jump or squat before their injury these questions were omitted, and a score was calculated out of 100. Scores < 30 are deemed poor, 30 to 60 fair, 60 to 90 good and

> 90 excellent. The AAOS questionnaire is a validated assessment of foot and ankle pathology and its treatment.

Statistical analysis. This was performed using SPSS v19 (SPSS Inc., Chicago, Illinois). Chi-squared tests were used for categorical data and unpaired *t*-tests for continuous data. A *p*-value < 0.05 was considered significant; 95% confidence intervals (CI) were calculated, and Kaplan-Meier survival curves were produced to assess the survival of the nail.¹⁹

Results

Mortality. Overall, 25 patients (24%) died during the follow-up period, 11 in the first year. This gives a standardised mortality ratio (SMR) of 3.29 (95% CI 1.93 to 6.37, *p* < 0.001), which means that this cohort was more than three times as likely to die within one year than an age- and gender-matched population. As no deaths were due either directly or indirectly to the ankle fixation, it is clear that the observed cohort was significantly less well than the age-matched general population. Moreover, the SMR for all patients with ankle fractures treated in our hospital in 2008 was 1.89 (95% CI 1.14 to 2.96, *p* = 0.008) and the odds ratio (OR) for death of our cohort compared with all patients with ankle fractures was 4.9 (95% CI 2.22 to 10.77). This indicates that the observed cohort was also significantly less well than our other patients with the same injury (*p* < 0.0001).

Overall results. A total of 82 patients (78%) did not experience any complications from the fixation of the lateral malleolus. However, the construct failed in seven patients, five of whom (5%) underwent revision surgery. There were five patients with a lateral wound infection, of whom four also had an infection of the medial wound. The metalwork was removed from 16 patients (15%); the fibular nail in seven and locking screws only in nine (Table IV). The Kaplan-Meier survival curve for the fibular nail is shown in Figure 2.

Results of initial locking screw constructs. In six patients the fibular nail was implanted without either proximal or distal locking screws, somewhat in the manner of a Rush nail. Significant failure of fixation occurred in two, with shortening of the fibula and lateral subluxation of the talus. One patient died from a myocardial infarction shortly afterwards; the other needed an ankle fusion.

In order to improve the fixation, 24 patients had a fibular nail implanted with distal locking screws but with no syndesmosis or blocking screw: 23 (96%) went on to satisfactory union. One construct failed in a similar manner to that described above, with lateral talar subluxation, and the patient required a fusion.

A total of 43 nails were implanted with a distal locking screw and an additional proximal blocking screw, in an attempt to maintain length. Of these, 40 fractures (93%) united without complication. The other three constructs, all in elderly patients, failed. One required revision surgery and ultimately an amputation. It became apparent that the

Table IV. Technique of fixation of the fibular nail to bone and complications experienced with each technique

	Locking screw constructs				Current technique
	None	Distal locking screw alone	Proximal blocking screw + distal locking screw	Syndesmosis screw alone	Syndesmosis screw + distal locking screw
Number of patients	6	24	43	11	21
Failure of fixation	2	1	3	1	0
Removal of fibular nail	0	2	4	1	0
Removal of medial metalwork	3	3	9	2	1
Removal of locking screws	0	1	7	n/a	1
Medial wound infection	1	1	4	0	1
Lateral wound infection	0	0	1	0	0
Both sides wound infection	0	2	1	1	0
Patients with complications related to lateral fixation (n, %)	2 (33)	5 (21)	14 (32.5)	1 (9)	1 (5)

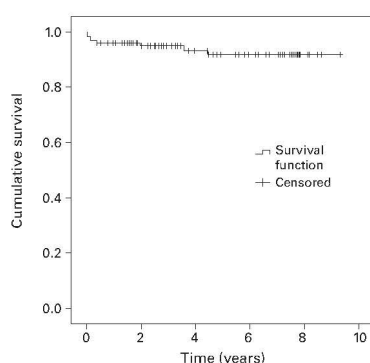


Fig. 2

Kaplan-Meier curve showing survival of the fibular nail.

talus still had the potential to subluxate laterally with this technique, as it was possible for the fibular nail to bypass the blocking screw (Fig. 3). In addition, the distal locking screws irritated the soft tissues in seven patients and were removed electively after the fracture had united.

There were also 11 patients who underwent fixation with a fibular nail that incorporated a 'syndesmosis' screw but no distal locking screw. Most experienced no further problems, but the fixation failed in one, who ignored medical advice to avoid weight-bearing, and required a revision operation. Another patient developed osteoarthritis after anatomical union and underwent ankle replacement seven years later. As a result of this experience we developed our current technique, which incorporates both proximal and distal locking.

This uses a 'syndesmosis' screw and a distal locking screw that reaches the dorsal cortex of the fibular. We have treated 21 patients in this manner and all their fractures have gone on to heal anatomically and uneventfully. In one case, however, a morbidly obese patient with a body mass

index of 40.1 kg/m² and a complete diastasis did bear full weight through the affected ankle immediately, and although the fracture united uneventfully, the diastasis recurred after ten weeks; it was treated successfully by further reduction and the placement of a second diastasis screw. We have not removed any syndesmosis screw electively, and with the exception of the patient described above, none have displaced or broken to date.

Radiological results. An anatomical reduction was achieved in 77 patients (96%) with radiographs according to the criteria previously described. There was no increase in medial clear space and no fibular shortening. The other three patients (4%) had a fair reduction. In one case the length of the fibula was not completely restored, although the talocrural angle was > 0° and the fibular shortening < 2 mm. In the other two cases the medial clear space was > 1 mm greater than the tibiotalar space. The OMS in those patients with only a fair reduction was 40 in one, 30 in another, and unobtainable in the third as the result of a cerebrovascular accident. No patients had a poor reduction.

Outcome. The outcome scores are shown in Table V. There was a trend to a higher score for patients treated with the current technique, but this was not significant ($p = 0.26$). The mean SF-12 scores were within 1 SD of the mean for the normal population, the mean of the mental component being slightly higher than the mean for the population. Of the 52 patients who completed the OMS, 24 (46%) had a good outcome, 21 (40%) had a fair outcome and the remaining seven (14%) had a poor outcome. The mean AAOS score was 79.0 (26.3 to 100) for all patients and 82.5 (51.8 to 98.7) for those treated with the current technique.

Discussion

Unstable ankle fractures are most commonly treated by open reduction and internal fixation (ORIF) using techniques that have not changed significantly for many years and have a high rate of complications, particularly in osteoporotic bone. Metalwork and scarring can be troublesome and require secondary surgery. The complication rate following ORIF in the elderly is up to 40%.⁸ It is also considerably higher in patients with systemic disease, particularly diabetes and neuropathy,⁹ and in those with compromised



Fig. 3a



Fig. 3b



Fig. 3c

Radiographs of a bimalleolar ankle fracture in a 71-year-old female patient with multiple comorbidities, a) at presentation, b) immediately post-operatively showing the lateral malleolar fracture managed with a fibular nail fixed to bone with a distal locking screw and proximal blocking screw, and c) at six weeks post-operatively showing failure of fixation, with the fibular nail moving proximally past the blocking screw, resulting in lateral talar shift due to inadequate lateral buttressing.

Table V. Patient-reported outcome scores

Mean outcome score (range)	All techniques	Current technique
Olerud and Molander score	62.2 (0 to 100)	65.2 (35 to 100)
Short-Form 12		
Physical component	41.5 (17.7 to 60.6)	45.7 (27.9 to 60.6)
Mental component	53.1 (26.7 to 66.3)	55.2 (45.3 to 63.1)
AAOS ^a score	79.0 (26.3 to 100)	82.5 (51.8 to 98.7)

^a AAOS, American Association of Orthopaedic Surgeons

local soft tissues and those who smoke.²⁰ A proportion of those patients who avoid initial complications will later require removal of metalwork.^{6,11,21}

Suggested alternatives to traditional lateral plating techniques include the use of locking plates and minimally invasive plating techniques. Although locking plates have been shown to be biomechanically advantageous in osteoporotic bone,²² this benefit may be negated by a higher rate of wound complications.²³ Minimally invasive plating techniques allow surgery to be carried out through marginally smaller wounds (3 cm to 4 cm in a recent report²⁴) but are more technically challenging than traditional techniques.²⁴

Intramedullary fixation of the fibula minimises dissection. Successful results have been reported for a variety of implants, including the Rush nail and other types of fibular nail.^{13,14,25} Two groups have reported their results using the Biomet SST fibular nail (Biomet Inc., Warsaw, Indiana), an intramedullary nail that is fixed to bone with a distal anteroposterior locking screw only.^{13,14} In total, they report 35 patients with good functional and radiological results.

However, this nail does not allow for placement of a screw across the syndesmosis, and Ramasamy et al¹³ reported failure of fixation with lateral talar subluxation in one patient (9%). Rajeev et al¹⁴ do not report any cases of failure of fixation but the post-operative radiograph included does show evidence of talar shift.

The Acumed fibular nail is unique in allowing secure cross-locking of the fracture fragments, thereby maintaining tibiotalar congruence as well as fibular length and rotation. The technique is conceptually straightforward and involves the skills used to nail other long bones. Almost half of the fractures presented here were fixed by fellows or registrars, with good results.

We have presented our results with this device in 105 patients over eight years. Our surgical technique has evolved as our experience has grown: we have found that whereas an unlocked (or partially locked) construct remains potentially unstable, our preferred technique, using a syndesmosis screw and a distal locking screw, has so far proved entirely stable. Overall, anatomical reduction was possible in 97% of patients, and satisfactory fracture healing occurred in 93%. Lateral wound problems occurred in five patients, four of whom also had a medial infection. This wound complication rate of 3.8% compares favourably with that of lateral plating techniques.^{11,23}

Patient reported outcome measures also suggest a satisfactory subjective outcome: the psychological domain score of the normalised SF-12 was slightly better than the population mean (53.1 (26.7 to 66.3) *vs* 50.0), and the mean physical function score was only slightly less than that of the healthy population (41.5 (17.7 to 60.6) *vs* 50.0). These are comparable with the results reported by Shah et al²⁶ of 85 ankle fractures in patients with a much younger mean

age of 50 years treated with lateral plating augmented with lag screw fixation, who had a mean psychological domain score of 49.9 and a physical score of 45.6. The mean abbreviated Olerud and Molander joint-specific scores (62.2 for the entire cohort) were also comparable to those reported for similar patient groups. Yang et al²⁷ reported a mean score of 61 in patients aged > 50 years within their cohort of supination external rotation Lauge-Hansen grade IV²³ ankle fractures. The mean AAOs score for patients treated by the current technique was 82.5. This is within 1 SD of the mean score for a healthy population²⁹ (mean 93.2 (SD 12.3)) and comparable to results found in other cohorts of patients sustaining ankle fractures. Bois et al,³⁰ in their cohort of 17 patients with posterior malleolar fractures, found a mean score of 87, and Gardner et al³¹ found a mean score of 79 at a follow-up of eight months in another cohort of patients with posterior malleolar fractures and a mean age of 45 years.

Like most retrospective cohort studies, ours can be criticised for incomplete follow-up. Several sets of radiographs could not be located. We have only been able to obtain outcome scores for half of our original cohort. However, 62% of those cases without outcome scores had either died or had dementia, reflecting the age and comorbidities of these patients. This series comes from a single hospital with an academic interest in trauma management, but experience with the technique suggests that it can be generalised.

In conclusion, we have found the fibular nail to be an attractive alternative for the fixation of unstable ankle fractures. The technique allows for accurate reduction of the ankle mortise, early weight-bearing and predictable bone healing, with a low rate of wound complications.

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References

- Court-Brown CM, McBurnie J, Wilson G. Adult ankle fractures: an increasing problem? *Acta Orthop* 1998;69:43–47.
- Koval KJ, Lurie J, Zhou W, et al. Ankle fractures in the elderly: what you get depends on where you live and who you see. *J Orthop Trauma* 2005;19:635–639.
- Kannus P, Peltanen M, Niemi S, Parkkari J, Järvinen M. Increasing number and incidence of low-trauma ankle fractures in elderly people: Finnish statistics during 1970–2000 and projections for the future. *Bone* 2002;31:430–433.
- Lamontagne J, Blechut PA, Broekhuysen HM, O'Brien PJ, Meek RN. Surgical treatment of a displaced lateral malleolus fracture: the antilide technique versus lateral plate fixation. *J Orthop Trauma* 2002;16:498–502.
- 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;22:642–648.
- McKenna PB, O'Shea K, Burke T. Less is more: lag screw only fixation of lateral malleolar fractures. *Int Orthop* 2007;31:497–502.
- Beauchamp CG, Clay NR, Thexton PW. Displaced ankle fractures in patients over 50 years of age. *J Bone Joint Surg [Br]* 1983;65-B:329–332.
- Anderson SA, Li X, Franklin P, Wixted JJ. Ankle fractures in the elderly: initial and long-term outcomes. *Foot Ankle Int* 2006;29:1184–1188.
- Wukich DK, Joseph A, Ryan M, Ramirez C, Irrgang JJ. Outcomes of ankle fractures in patients with uncomplicated versus complicated diabetes. *Foot Ankle Int* 2011;32:120–130.
- Appleton P, McQueen M, Court-Brown C. The fibula nail for treatment of ankle fractures in elderly and high risk patients. *Tech Foot Ankle* 2006;5:204–208.
- Lee YS, Huang HL, Lo TY, Huang CR. Lateral fixation of AO type-B2 ankle fractures in the elderly: the Knowles pin versus the plate. *Int Orthop* 2007;31:817–821.
- Smith G, Wallace R, Findlater G, White T. The fibular nail: a biomechanical study [abstract]. *Proc Seventh SICOT/SIROT Annual International Conference*, Gothenburg, 2010.
- Ramasamy PR, Sherry P. The role of a fibular nail in the management of Weber type B ankle fractures in elderly patients with osteoporotic bone: a preliminary report. *Injury* 2001;32:477–485.
- Rajeev A, Seneviratna S, Radhe S, Kashayap NS. Functional outcomes after fibula locking nail for fragility fractures of the ankle. *J Foot Ankle Surg* 2011;50:547–550.
- McLennan JG, Ungersma JA. A new approach to the treatment of ankle fractures: the Inyo nail. *Clin Orthop Relat Res* 1986;213:125–136.
- Ware J Jr, Kosinski M, Keller SD. A 12-item short-form health survey: construction of scales and preliminary tests of reliability and validity. *Med Care* 1996;34:220–233.
- Olerud C, Molander H. A scoring scale for symptom evaluation after ankle fracture. *Arch Orthop Trauma Surg* 1984;103:190–194.
- Johanson NA, Liang MH, Daltroy L, Rudicel S, Richmond J. American Academy of Orthopaedic Surgeons lower limb outcomes assessment instruments: reliability, validity, and sensitivity to change. *J Bone Joint Surg [Am]* 2004;86-A:902–909.
- Kaplan EL, Meier P. Nonparametric estimation from incomplete observations. *J Am Stat Assoc* 1958;53:457–481.
- Näsell H, Ottosson C, Törnqvist H, Lindé J, Ponzer S. The impact of smoking on complications after operatively treated ankle fractures: a follow-up study of 906 patients. *J Orthop Trauma* 2011;25:748–755.
- Tornetta P 3rd, Creevy W. Lag screw only fixation of the lateral malleolus. *J Orthop Trauma* 2001;15:119–121.
- Zahn RK, Frey S, Jakubietz RG, et al. A contoured locking plate for distal fibular fractures in osteoporotic bone: a biomechanical cadaver study. *Injury* 2011;Epub.
- Schepers T, Van Lieshout EM, De Vries MR, Van der Elst M. Increased rates of wound complications with locking plates in distal fibular fractures. *Injury* 2011;42:1125–1129.
- Hess F, Sommer C. Minimally invasive plate osteosynthesis of the distal fibula with the locking compression plate: first experience of 20 cases. *J Orthop Trauma* 2011;25:110–115.
- Pritchett JW. Rush rods versus plate osteosyntheses for unstable ankle fractures in the elderly. *Orthop Rev* 1993;22:691–696.
- Shah NH, Sundaram RQ, Velusamy A, Braithwaite IJ. Five-year functional outcome analysis of ankle fracture fixation. *Injury* 2007;38:1308–1312.
- Yang E, Wu Y, Dorcil J. Surgical versus nonsurgical treatment of the SE4-equivalent ankle fracture: a retrospective functional outcome study. *Orthopedics* 2011;34...
- Lauge-Hansen N. Fractures of the ankle. II: combined experimental-surgical and experimental-roentgenologic investigations. *Arch Surg* 1950;60:957–965.
- Hunsaker FG, Cioffi DA, Amadio PC, Wright JG, Caughlin B. The American academy of orthopaedic surgeons outcomes instruments: normative values from the general population. *J Bone Joint Surg [Am]* 2002;84-A:208–215.
- Bois AJ, Dust W. Posterior fracture dislocation of the ankle: technique and clinical experience using a posteromedial surgical approach. *J Orthop Trauma* 2008;22:629–636.
- Gardner MJ, Streubel PN, McCormick JJ, et al. Surgeon practices regarding operative treatment of posterior malleolus fractures. *Foot Ankle Int* 2011;32:385–393.

Bibliography

1. Bucholz, R. W., Court-Brown, C. & Heckman, J. D. Rockwood and Green fractures in adults. 2296 (2009).
2. Court-Brown, C. M., McBirnie, J. & Wilson, G. Adult ankle fractures--an increasing problem? *Acta Orthop Scand* **69**, 43–47 (1998).
3. Court-Brown, C. M. & Caesar, B. Epidemiology of adult fractures: A review. *Injury* **37**, 691–697 (2006).
4. BUHR, A. J. & COOKE, A. M. *Fracture patterns. Lancet* **1**, 531–536 (1959).
5. Randsborg, P. H. *et al.* Fractures in children: epidemiology and activity-specific fracture rates. *J Bone Jt. Surg Am* **95**, e42 (2013).
6. 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).
7. Stein, E. M. *et al.* Abnormal microarchitecture and stiffness in postmenopausal women with ankle fractures. *J. Clin. Endocrinol. Metab.* **96**, 2041–2048 (2011).
8. Hasselman, C. T., Vogt, M. T., Stone, K. L., Cauley, J. A. & Conti, S. F. Foot and ankle fractures in elderly white women. Incidence and risk factors. *J. Bone Joint Surg. Am.* **85–A**, 820–824 (2003).

9. Kannus, P., Palvanen, M., Niemi, S., Parkkari, J. & Järvinen, M. Increasing number and incidence of low-trauma ankle fractures in elderly people: Finnish statistics during 1970-2000 and projections for the future. *Bone* **31**, 430–433 (2002).
10. Kannus, P., Niemi, S., Parkkari, J. & Sievänen, H. Declining incidence of fall-induced ankle fractures in elderly adults: Finnish statistics between 1970 and 2014. *Arch. Orthop. Trauma Surg.* **136**, 1243–1246 (2016).
11. Bengner, U. *et al.* Epidemiology of ankle fracture 1950 and 1980. Increasing incidence in elderly women. *Acta Orthop. Scand.* **57**, 35–37 (1986).
12. Oxford English Dictionary. Available at: <https://www.oed.com/>.
13. Takebe, K., Nakagawa, A., Minami, H., Kanazawa, H. & Hirohata, K. Role of the fibula in weight-bearing. *Clin. Orthop. Relat. Res.* 289–292 (1984).
14. Michelson, J. D., Hamel, A. J., Buczek, F. L. & Sharkey, N. A. Kinematic behavior of the ankle following malleolar fracture repair in a high-fidelity cadaver model. *J. Bone Joint Surg. Am.* **84–A**, 2029–2038 (2002).
15. Pankovich, A. M. & Shivaram, M. S. Anatomical basis of variability in injuries of the medial malleolus and the deltoid ligament. II. Clinical studies. *Acta Orthop. Scand.* **50**, 217–223 (1979).
16. Mcphail, S. M., Dunstan, J., Canning, J. & Haines, T. P. *Life impact of ankle fractures: Qualitative analysis of patient and clinician experiences.* (2012).
doi:10.1186/1471-2474-13-224

17. Larsson, D., Ekstrand, J. & Karlsson, M. K. Fracture epidemiology in male elite football players from 2001 to 2013: ‘How long will this fracture keep me out?’ *Br J Sport. Med* (2016). doi:10.1136/bjsports-2015-095838
18. Earle, H. Simple, succeeded by compound dislocation forwards, of the inferior extremity of the tibia, with fracture of its posterior edge, comminuted fracture of the fibula, amputation of the leg, and death. *Lancet* **12**, 346–350 (1828).
19. Court-Brown, C. M., Bugler, K. E., Clement, N. D., Duckworth, A. D. & McQueen, M. M. The epidemiology of open fractures in adults. A 15-year review. *Injury* **43**, 891–897 (2012).
20. Müller, M. E. *et al. The Comprehensive Classification of Fractures of Long Bones. The Comprehensive Classification of Fractures of Long Bones* (Springer Berlin Heidelberg, 1990). doi:10.1007/978-3-642-61261-9_1
21. Pott, P. *Some Few General Remarks on Fractures and Dislocations*. (1758).
22. Broos, P. L. & Bisschop, A. P. Operative treatment of ankle fractures in adults: correlation between types of fracture and final results. *Injury* **22**, 403–406 (1991).
23. Weber, B. G. *Die Verletzungen des oberen Sprunggelenkes*. (Bern: Hans Huber, 1966).
24. Danis. Les fractures malleolaires theorie et pratique de l’osteosynthese. . in *Theorie et Pratique de l’Osteosynthese* (1949).

25. Malek, I. A., Machani, B., Mevcha, A. M. & Hyder, N. H. Inter-observer reliability and intra-observer reproducibility of the Weber classification of ankle fractures. *J. Bone Joint Surg. Br.* **88**, 1204–1206 (2006).
26. Lindsjö, U. Classification of ankle fractures: the Lauge-Hansen or AO system? *Clin. Orthop. Relat. Res.* 12–16 (1985).
27. Nielson, J. H., Sallis, J. G., Potter, H. G., Helfet, D. L. & Lorich, D. G. Correlation of interosseous membrane tears to the level of the fibular fracture. *J. Orthop. Trauma* **18**, 68–74 (2004).
28. Kennedy, J. G. *et al.* An evaluation of the Weber classification of ankle fractures. *Injury* **29**, 577–580 (1998).
29. Lauge-Hansen, N. Fractures of the ankle. II. Combined experimental-surgical and experimental-roentgenologic investigations. *Arch. Surg.* **60**, 957–985 (1950).
30. 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. *Arch. Surg.* **4**, 51 (1922).
31. Yde, J. The Lauge Hansen classification of malleolar fractures. *Acta Orthop. Scand.* **51**, 181–192 (1980).
32. Kwon, J. Y., Chacko, A. T., Kadzielski, J. J., Appleton, P. T. & Rodriguez, E. K. A novel methodology for the study of injury mechanism: ankle fracture

- analysis using injury videos posted on YouTube.com. *J. Orthop. Trauma* **24**, 477–482 (2010).
33. Aitken, S. A., Hutchison, J. D., McQueen, M. M. & Court-Brown, C. M. The importance of epidemiological fracture data: injury epidemiology for the non-epidemiologist. *Bone Jt. J* **96–B**, 863–867 (2014).
34. Court-Brown, C. M., Biant, L., Bugler, K. E. & McQueen, M. M. Changing epidemiology of adult fractures in Scotland. *Scott Med J* **59**, 30–34 (2014).
35. Court-Brown, C. M., Aitken, S. A., Duckworth, A. D., Clement, N. D. & McQueen, M. M. The relationship between social deprivation and the incidence of adult fractures. *J Bone Jt. Surg Am* **95**, e321-7 (2013).
36. Bauer, M., Johnell, O., Redlund-Johnell, I. & Johnsson, K. Ankle fractures. *Foot Ankle* **8**, 23–25 (1987).
37. Daly, P. J., Fitzgerald, R. H., Melton, L. J. & Ilstrup, D. M. Epidemiology of ankle fractures in Rochester, Minnesota. *Acta Orthop. Scand.* **58**, 539–544 (1987).
38. Bray, T. J., Endicott, M. & Capra, S. E. Treatment of open ankle fractures. Immediate internal fixation versus closed immobilization and delayed fixation. *Clin. Orthop. Relat. Res.* 47–52 (1989).
39. Ngcelwane, M. V. Management of open fractures of the ankle joint. *Injury* **21**, 93–96 (1990).

40. Ye, T., Chen, A., Yuan, W. & Gou, S. *Management of grade III open dislocated ankle fractures: combined internal fixation with bioabsorbable screws/rods and external fixation. J Am Podiatr Med Assoc* **101**, 307–315 (2011).
41. Hong-Chuan, W., Shi-Lian, K., Heng-Sheng, S., Gui-Gen, P. & Ya-Fei, Z. Immediate internal fixation of open ankle fractures. *Foot ankle Int. / Am. Orthop. Foot Ankle Soc. [and] Swiss Foot Ankle Soc.* **31**, 959–964 (2010).
42. Court-Brown, C. M. *et al.* The spectrum of fractures in the elderly. *Bone Jt. J* **96–B**, 366–372 (2014).
43. Greek Medicine - Hippocrates. Available at: https://www.nlm.nih.gov/hmd/greek/popup/16_hippo_oath.html. (Accessed: 9th April 2019)
44. Duties of a doctor - GMC. Available at: <https://www.gmc-uk.org/ethical-guidance/ethical-guidance-for-doctors/good-medical-practice/duties-of-a-doctor>. (Accessed: 9th April 2019)
45. ICHOM | Healthcare Improvement | Patient-Reported Outcomes. Available at: <https://www.ichom.org/>. (Accessed: 9th April 2019)
46. Clement, N. D. & Burnett, R. Patient satisfaction after total knee arthroplasty is affected by their general physical well-being. *Knee Surg Sport. Traumatol Arthrosc* **21**, 2638–2646 (2013).
47. Olerud, C. & Molander, H. A scoring scale for symptom evaluation after ankle

- fracture. *Arch. Orthop. Trauma Surg.* **103**, 190–194 (1984).
48. Johanson, N. A., Liang, M. H., Daltroy, L., Rudicel, S. & Richmond, J. American Academy of Orthopaedic Surgeons lower limb outcomes assessment instruments. Reliability, validity, and sensitivity to change. *J. Bone Joint Surg. Am.* **86–A**, 902–909 (2004).
49. Dawson, J. *et al.* A patient-based questionnaire to assess outcomes of foot surgery: Validation in the context of surgery for hallux valgus. *Qual. Life Res.* **15**, 1211–1222 (2006).
50. Dawson, J. *et al.* Responsiveness of the Manchester–Oxford foot questionnaire (MOXFQ) compared with AOFAS, SF-36 and EQ-5D assessments following foot or ankle surgery. *J. Bone Joint Surg. Br.* **94–B**, 215–221 (2012).
51. Ware, J., Kosinski, M. & Keller, S. D. A 12-Item Short-Form Health Survey: construction of scales and preliminary tests of reliability and validity. *Med. Care* **34**, 220–233 (1996).
52. EuroQol Group. EuroQol--a new facility for the measurement of health-related quality of life. *Health Policy* **16**, 199–208 (1990).
53. Zahiri, C. A., Schmalzried, T. P., Szuszczewicz, E. S. & Amstutz, H. C. Assessing activity in joint replacement patients. *J. Arthroplasty* **13**, 890–895 (1998).
54. Muller, M., Boitzy, A., Bandi, W. & Willenegger, H. *Manuel d'osteosynthese*

technique AO. (1970).

55. Close, J. R. Some applications of the functional anatomy of the ankle joint. *J. Bone Joint Surg. Am.* **38–A**, 761–781 (1956).
56. Park, S. S., Kubiak, E. N., Egol, K. A., Kummer, F. & Koval, K. J. Stress radiographs after ankle fracture: the effect of ankle position and deltoid ligament status on medial clear space measurements. *J. Orthop. Trauma* **20**, 11–18 (2006).
57. Michelson, J. D., Varner, K. E. & Checcone, M. Diagnosing deltoid injury in ankle fractures: the gravity stress view. *Clin. Orthop. Relat. Res.* 178–182 (2001).
58. Port, A. M., McVie, J. L., Naylor, G. & Kreibich, D. N. Comparison of two conservative methods of treating an isolated fracture of the lateral malleolus. *J. Bone Joint Surg. Br.* **78**, 568–572 (1996).
59. 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).
60. Donken, C. C. M. A., Verhofstad, M. H. J., Edwards, M. J. & van Laarhoven, C. J. H. M. Twenty-two-Year Follow-up of Pronation External Rotation Type III-IV (OTA type C) Ankle Fractures; A Retrospective Cohort Study. *J. Orthop. Trauma* (2011).
61. Yde, J. & Kristensen, K. D. Ankle fractures. Supination-eversion fractures

stage II. Primary and late results of operative and non-operative treatment.

Acta Orthop. Scand. **51**, 695–702 (1980).

62. Brink, O., Staunstrup, H. & Sommer, J. Stable lateral malleolar fractures treated with aircast ankle brace and DonJoy R.O.M.-Walker brace: a prospective randomized study. *Foot ankle Int. / Am. Orthop. Foot Ankle Soc. [and] Swiss Foot Ankle Soc.* **17**, 679–684 (1996).
63. Kristensen, K. D. & Hansen, T. Closed treatment of ankle fractures. Stage II supination-eversion fractures followed for 20 years. *Acta Orthop. Scand.* **56**, 107–109 (1985).
64. Ryd, L. & Bengtsson, S. Isolated fracture of the lateral malleolus requires no treatment. 49 prospective cases of supination-eversion type II ankle fractures. *Acta Orthop. Scand.* **63**, 443–446 (1992).
65. DeAngelis, N. A., Eskander, M. S. & French, B. G. Does medial tenderness predict deep deltoid ligament incompetence in supination-external rotation type ankle fractures? *J. Orthop. Trauma* **21**, 244–247 (2007).
66. Egol, K. A. *et al.* Ankle stress test for predicting the need for surgical fixation of isolated fibular fractures. *J. Bone Joint Surg. Am.* **86–A**, 2393–2398 (2004).
67. Park, J. S., Jeong, B. O., Song, S. H., Baek, J. H. & Kim, T. Y. Assessment of Ankle Mortise Instability After Isolated Supination-External Rotation Lateral Malleolar Fractures. *J. Bone Jt. Surg.* **100**, 1557–1562 (2018).
68. Gill, J. B., Risko, T., Raducan, V., Grimes, J. S. & Schutt, R. C. Comparison

- of manual and gravity stress radiographs for the evaluation of supination-external rotation fibular fractures. *J. Bone Joint Surg. Am.* **89**, 994–999 (2007).
69. Schock, H. J., Pinzur, M., Manion, L. & Stover, M. The use of gravity or manual-stress radiographs in the assessment of supination-external rotation fractures of the ankle. *J. Bone Joint Surg. Br.* **89**, 1055–1059 (2007).
70. Nortunen, S. *et al.* Diagnostic accuracy of the gravity stress test and clinical signs in cases of isolated supination–external rotation-type lateral malleolar fractures. *Bone Jt. J* 97–1126 (2015). doi:10.1302/0301-620X.97B8
71. Koval, K. J., Egol, K. A., Cheung, Y., Goodwin, D. W. & Spratt, K. F. Does a positive ankle stress test indicate the need for operative treatment after lateral malleolus fracture? A preliminary report. *J. Orthop. Trauma* **21**, 449–455 (2007).
72. Harper, M. C. Talar shift. The stabilizing role of the medial, lateral, and posterior ankle structures. *Clin. Orthop. Relat. Res.* 177–183 (1990).
73. McConnell, T., Creevy, W. & Tornetta, P. Stress examination of supination external rotation-type fibular fractures. *J. Bone Joint Surg. Am.* **86–A**, 2171–2178 (2004).
74. Lamontagne, J., Blachut, P. A., Broekhuysen, H. M., O’Brien, P. J. & Meek, R. N. Surgical treatment of a displaced lateral malleolus fracture: the antiglide technique versus lateral plate fixation. *J. Orthop. Trauma* **16**, 498–502 (2002).

75. Høiness, P., Engebretsen, L. & Strømsøe, K. The influence of perioperative soft tissue complications on the clinical outcome in surgically treated ankle fractures. *Foot ankle Int. / Am. Orthop. Foot Ankle Soc. [and] Swiss Foot Ankle Soc.* **22**, 642–648 (2001).
76. McKenna, P. B., O'Shea, K. & Burke, T. Less is more: lag screw only fixation of lateral malleolar fractures. *Int. Orthop.* **31**, 497–502 (2007).
77. Beauchamp, C. G., Clay, N. R. & Thexton, P. W. Displaced ankle fractures in patients over 50 years of age. *J. Bone Joint Surg. Br.* **65**, 329–332 (1983).
78. Anderson, S. A., Li, X., Franklin, P. & Wixted, J. J. Ankle fractures in the elderly: initial and long-term outcomes. *Foot ankle Int. / Am. Orthop. Foot Ankle Soc. [and] Swiss Foot Ankle Soc.* **29**, 1184–1188 (2008).
79. Wukich, D. K., Joseph, A., Ryan, M., Ramirez, C. & Irrgang, J. J. Outcomes of ankle fractures in patients with uncomplicated versus complicated diabetes. *Foot ankle Int. / Am. Orthop. Foot Ankle Soc. [and] Swiss Foot Ankle Soc.* **32**, 120–130 (2011).
80. Appleton, P. & McQueen, M. The Fibula Nail for Treatment of Ankle Fractures in Elderly and High Risk Patients. *Tech. Foot Ankle Surg.* (2006).
81. Lee, Y.-S., Huang, H.-L., Lo, T.-Y. & Huang, C.-R. *Lateral fixation of AO type-B2 ankle fractures in the elderly: the Knowles pin versus the plate. International Orthopaedics* **31**, 817–821 (2007).
82. Smith, G., Mackenzie, S. P., Wallace, R. J., Carter, T. & White, T. O.

Biomechanical Comparison of Intramedullary Fibular Nail Versus Plate and Screw Fixation. *Foot Ankle Int.* (2017). doi:10.1177/1071100717731757

83. Ramasamy, P. R. & Sherry, P. The role of a fibular nail in the management of Weber type B ankle fractures in elderly patients with osteoporotic bone--a preliminary report. *Injury* **32**, 477–485 (2001).
84. Rajeev, A., Senevirathna, S., Radha, S. & Kashayap, N. S. Functional outcomes after fibula locking nail for fragility fractures of the ankle. *J. Foot Ankle Surg.* **50**, 547–550 (2011).
85. Zeegers, A. V, Van Raay, J. J. & van der Werken, C. Ankle fractures treated with a stabilizing shoe. *Acta Orthop. Scand.* **60**, 597–599 (1989).
86. Ahl, T., Dalén, N. & Selvik, G. Mobilization after operation of ankle fractures. Good results of early motion and weight bearing. *Acta Orthop. Scand.* **59**, 302–306 (1988).
87. Ahl, T., Dalén, N., Holmberg, S. & Selvik, G. Early weight bearing of displaced ankle fractures. *Acta Orthop. Scand.* **58**, 535–538 (1987).
88. Finsen, V. *et al.* Early postoperative weight-bearing and muscle activity in patients who have a fracture of the ankle. *J. Bone Joint Surg. Am.* **71**, 23–27 (1989).
89. van Laarhoven, C. J., Meeuwis, J. D. & WerkenC, van der. Postoperative treatment of internally fixed ankle fractures: a prospective randomised study. *J. Bone Joint Surg. Br.* **78**, 395–399 (1996).

90. Harager, K., Hviid, K., Jensen, C. M. & Schantz, K. Successful immediate weight-bearing of internal fixated ankle fractures in a general population. *J. Orthop. Sci.* **5**, 552–554 (2000).
91. Tropp, H. & Norlin, R. Ankle performance after ankle fracture: a randomized study of early mobilization. *Foot ankle Int. / Am. Orthop. Foot Ankle Soc. [and] Swiss Foot Ankle Soc.* **16**, 79–83 (1995).
92. Simanski, C. J. P. *et al.* Functional treatment and early weightbearing after an ankle fracture: a prospective study. *J. Orthop. Trauma* **20**, 108–114 (2006).
93. Hedström, M., Ahl, T. & Dalén, N. Early postoperative ankle exercise. A study of postoperative lateral malleolar fractures. *Clin. Orthop. Relat. Res.* 193–196 (1994).
94. Cimino, W., Ichtertz, D. & Slabaugh, P. Early mobilization of ankle fractures after open reduction and internal fixation. *Clin. Orthop. Relat. Res.* 152–156 (1991).
95. Ahl, T., Dalén, N., Lundberg, A. & Bylund, C. Early mobilization of operated on ankle fractures. Prospective, controlled study of 40 bimalleolar cases. *Acta Orthop. Scand.* **64**, 95–99 (1993).
96. Ahl, T., Dalén, N., Holmberg, S. & Selvik, G. Early weight bearing of malleolar fractures. *Acta Orthop. Scand.* **57**, 526–529 (1986).
97. Swart, E., Bezhani, H., Greisberg, J. & Vosseller, J. T. How long should patients be kept non-weight bearing after ankle fracture fixation? A survey of

- OTA and AOFAS members. *Injury* **46**, 1127–1130 (2015).
98. Collaborative, B. Weight-bearing in ankle fractures: An audit of UK practice. *Foot* **39**, 28–36 (2019).
99. Hak, D. J. Prevention of venous thromboembolism in trauma and long bone fractures. *Curr. Opin. Pulm. Med.* **7**, 338–343 (2001).
100. Chen, L. & Soares, D. Fatal pulmonary embolism following ankle fracture in a 17-year-old girl. *J Bone Jt. Surg Br* **88**, 400–401 (2006).
101. Shrader, M. W., Ho, A. K., Notrica, D. M. & Segal, L. S. Pulmonary embolism following an ankle fracture in a 9-year-old boy: a case report. *Acta Orthop Belg* **78**, 564–567 (2012).
102. Mukhtar, M., Hamid, M., Khan, M. A. A. & Ullah, W. Sudden death due to pulmonary embolism after minor ankle surgery. *BMJ Case Rep.* **12**, e227649 (2019).
103. Patil, S., Gandhi, J., Curzon, I. & Hui, A. C. W. Incidence of deep-vein thrombosis in patients with fractures of the ankle treated in a plaster cast. *J Bone Jt. Surg Br* **89**, 1340–1343 (2007).
104. Callaghan, J. J. *et al.* Prophylaxis for thromboembolic disease: recommendations from the American College of Chest Physicians--are they appropriate for orthopaedic surgery? *J. Arthroplasty* **20**, 273–4 (2005).
105. Sobieraj, D. M. *et al.* Comparative Effectiveness of Low-Molecular-Weight

- Heparins versus Other Anticoagulants in Major Orthopedic Surgery: A Systematic Review and Meta-analysis. *Pharmacother. J. Hum. Pharmacol. Drug Ther.* **32**, 799–808 (2012).
106. Overview | Venous thromboembolism in over 16s: reducing the risk of hospital-acquired deep vein thrombosis or pulmonary embolism | Guidance | NICE.
 107. Iqbal, H. J., Dahab, R. & Barnes, S. UK national survey of venous thromboembolism prophylaxis in ankle fracture patients treated with plaster casts. *Foot Ankle Surg* **18**, 157–159 (2012).
 108. www.scotlandscensus.gov.uk.
 109. Carstairs, V. V & Morris, R. R. *Deprivation and health in Scotland. Health Bull (Edinb)* **48**, 162–175 (1990).
 110. No Title. <http://www.isdscotland.org/Products-and-Services/G>
 111. Gustilo, R. B. & Anderson, J. T. *Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. J Bone Joint Surg Am* **58**, 453–458 (1976).
 112. Gustilo, R. B., Mendoza, R. M. & Williams, D. N. *Problems in the management of type III (severe) open fractures: a new classification of type III open fractures. J Trauma* **24**, 742–746 (1984).
 113. Baker, S. P., O'Neill, B., Haddon, W. & Long, W. B. *The injury severity*

- score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma* **14**, 187–196 (1974).
114. *Rating the severity of tissue damage. I. The abbreviated scale. JAMA* **215**, 277–280 (1971).
 115. McLennan, J. G. & Ungersma, J. Evaluation of the treatment of ankle fractures with the Inyo nail. *J. Orthop. Trauma* **2**, 272–276 (1988).
 116. Stein, G. *et al.* Tibiofibular screw fixation for syndesmotic ruptures: a biomechanical analysis. *Surg Radiol Anat* **34**, 593–597 (2012).
 117. Information Services Division Scotland. **2016**, (2016).
 118. Haque, S., Bishnoi, A., Khairandish, H. & Menon, D. Thromboprophylaxis in Ambulatory Trauma Patients With Foot and Ankle Fractures: Prospective Study Using a Risk Scoring System. *Foot Ankle Spec* (2016).
doi:10.1177/1938640016640892
 119. Wells, P. S. *et al.* Value of assessment of pretest probability of deep-vein thrombosis in clinical management. *Lancet* **350**, 1795–1798 (1997).
 120. KAPLAN, E. L. & MEIER, P. *Nonparametric-Estimation From Incomplete Observations. J Am Stat Assoc* **53**, 457–481 (1958).
 121. Elsoe, R., Ostgaard, S. E. & Larsen, P. Population-based epidemiology of 9767 ankle fractures. *Foot Ankle Surg.* **24**, 34–39 (2018).
 122. Thur, C. K., Edgren, G., Jansson, K. Å. & Wretenberg, P. Epidemiology of

adult ankle fractures in Sweden between 1987 and 2004. *Acta Orthopaedica* **83**, 276–281 (2012).

123. Census Results | Scotland Census 2011. Available at:
<https://www.scotlandscensus.gov.uk/census-results>. (Accessed: 19th December 2018)
124. Office for National Statistics. *Changing trends in mortality: an international comparison - Office for National Statistics*. (2018).
125. WHO | Finland leads the way in taking health into all policies. *WHO* (2014).
126. Koval, K. J. *et al.* Complications after ankle fracture in elderly patients. *Foot ankle Int. / Am. Orthop. Foot Ankle Soc. [and] Swiss Foot Ankle Soc.* **28**, 1249–1255 (2007).
127. Kemler, E., van de Port, I., Valkenberg, H., Hoes, A. W. & Backx, F. J. G. Ankle injuries in the Netherlands: Trends over 10-25 years. *Scand. J. Med. Sci. Sport.* **25**, 331–337 (2015).
128. Ramaesh, R., Clement, N. D., Rennie, L., Court-Brown, C. & Gaston, M. S. Social deprivation as a risk factor for fractures in childhood. *Bone Jt. J* **97–B**, 240–245 (2015).
129. Bugler, K. E. *et al.* Open ankle fractures: who gets them and why? *Arch Orthop Trauma Surg* **135**, 297–303 (2015).
130. Olerud, S., Karlstrom, G. & Danckwardt-Lillieström, G. Treatment of open

- fractures of the tibia and ankle. *Clin. Orthop. Relat. Res.* 212–224 (1978).
131. Koval, K. J. *et al.* Ankle fractures in the elderly: what you get depends on where you live and who you see. *J. Orthop. Trauma* **19**, 635–639 (2005).
132. Bologna, J. L. *Aging skin. Am. J. Med.* **98**, 99S–103S (1995).
133. Court-Brown, C. M., Rimmer, S., Prakash, U. & McQueen, M. M. *The epidemiology of open long bone fractures. Injury* **29**, 529–534 (1998).
134. Statistics, N. Reported road casualties Scotland 2010. (2011).
135. Chisholm, D., Naci, H., Hyder, A. A., Tran, N. T. & Peden, M. Cost effectiveness of strategies to combat road traffic injuries in sub-Saharan Africa and South East Asia: mathematical modelling study. *BMJ* **344**, e612 (2012).
136. Statistics, O. for N. Population Ageing in the United Kingdom its constituent countries and the European Union. (2012).
137. van Leeuwen, C. *et al.* The additional value of gravity stress radiographs in predicting deep deltoid ligament integrity in supination external rotation ankle fractures. *European Journal of Trauma and Emergency Surgery* **0**, 1–9 (2018).
138. Seidel, A., Krause, F. & Weber, M. Weightbearing vs Gravity Stress Radiographs for Stability Evaluation of Supination-External Rotation Fractures of the Ankle. *Foot Ankle Int.* **38**, 736–744 (2017).
139. Sanders, D. W., Tieszer, C., Corbett, B., Canadian Orthopedic Trauma, S. & Canadian Orthopedic Trauma Society. Operative versus nonoperative

- treatment of unstable lateral malleolar fractures: a randomized multicenter trial. *J Orthop Trauma* **26**, 129–134 (2012).
140. Holmes, J. R. *et al.* A Novel Algorithm for Isolated Weber B Ankle Fractures: A Retrospective Review of 51 Nonsurgically Treated Patients. *Journal of the American Academy of Orthopaedic Surgeons* **24**, 645–652 (2016).
 141. van Leeuwen, C. A. T. *et al.* The diagnosis and treatment of isolated type B fibular fractures: Results of a nationwide survey. *Injury* **50**, 579–589 (2019).
 142. Weber, M., Burmeister, H., Flueckiger, G. & Krause, F. G. The use of weightbearing radiographs to assess the stability of supination-external rotation fractures of the ankle. *Arch. Orthop. Trauma Surg.* **130**, 693–698 (2010).
 143. Stewart, C. *et al.* Axial Load Weightbearing Radiography in Determining Lateral Malleolus Fracture Stability: A Cadaveric Study. (2012).
doi:10.3113/FAI.2012.0548
 144. Horisberger, M., Valderrabano, V. & Hintermann, B. Posttraumatic ankle osteoarthritis after ankle-related fractures. *J. Orthop. Trauma* **23**, 60–67 (2009).
 145. Pitakveerakul, A., Kungwan, S., Arunakul, P. & Arunakul, M. Radiographic Parameters in Gravity Stress View of the Ankle: Normative Data. *Foot Ankle Surg.* (2018). doi:10.1016/j.fas.2018.10.011
 146. Zelle, B. A., Buttacavoli, F. A., Shroff, J. B. & Stirton, J. B. Loss of Follow-

- up in Orthopaedic Trauma. *J. Orthop. Trauma* **29**, 510–515 (2015).
147. Bugler, K. E. *et al.* The treatment of unstable fractures of the ankle using the Acumed fibular nail: development of a technique. *J Bone Jt. Surg Br* **94**, 1107–1112 (2012).
148. Nåsell, H., Ottosson, C., Törnqvist, H., Lindé, J. & Ponzer, S. The Impact of Smoking on Complications After Operatively Treated Ankle Fractures-A Follow-Up Study of 906 Patients. *J. Orthop. Trauma* (2011).
149. Tornetta, P., Creevy, W. & Lindsjö, U. Lag screw only fixation of the lateral malleolus. *J. Orthop. Trauma* **15**, 119–121 (2001).
150. Zahn, R. K. *et al.* A contoured locking plate for distal fibular fractures in osteoporotic bone: a biomechanical cadaver study. *Injury* **43**, 718–725 (2011).
151. Schepers, T., Lieshout, E. M. M. Van, Vries, M. R. De & Van der Elst, M. Increased rates of wound complications with locking plates in distal fibular fractures. *Injury* (2011).
152. Hess, F. & Sommer, C. Minimally invasive plate osteosynthesis of the distal fibula with the locking compression plate: first experience of 20 cases. *J. Orthop. Trauma* **25**, 110–115 (2011).
153. Pritchett, J. W. Rush rods versus plate osteosyntheses for unstable ankle fractures in the elderly. *Orthop. Rev.* **22**, 691–696 (1993).
154. Shah, N. H., Sundaram, R. O., Velusamy, A. & Braithwaite, I. J. Five-year

- functional outcome analysis of ankle fracture fixation. *Injury* **38**, 1308–1312 (2007).
155. Yang, E., Wu, Y. & Dorcil, J. *Surgical versus nonsurgical treatment of the SE4-equivalent ankle fracture: a retrospective functional outcome study. Orthopedics* **34**, (2011).
156. Hunsaker, F. G., Cioffi, D. A., Amadio, P. C., Wright, J. G. & Caughlin, B. The American academy of orthopaedic surgeons outcomes instruments: normative values from the general population. *J. Bone Joint Surg. Am.* **84–A**, 208–215 (2002).
157. Bois, A. J. & Dust, W. Posterior fracture dislocation of the ankle: technique and clinical experience using a posteromedial surgical approach. *J. Orthop. Trauma* **22**, 629–636 (2008).
158. Gardner, M. J. *et al.* Surgeon practices regarding operative treatment of posterior malleolus fractures. *Foot Ankle Int* **32**, 385–393 (2011).
159. Dehghan, N. *et al.* Early Weightbearing and Range of Motion Versus Non-Weightbearing and Immobilization After Open Reduction and Internal Fixation of Unstable Ankle Fractures: A Randomized Controlled Trial. *J. Orthop. Trauma* **30**, 345–52 (2016).
160. Smeeing, D. P. J. *et al.* Weight-bearing or non-weight-bearing after surgical treatment of ankle fractures: a multicenter randomized controlled trial. *Eur. J. Trauma Emerg. Surg.* (2018). doi:10.1007/s00068-018-1016-6

161. Al-Hourani, K., Stoddart, M. & Chesser, T. J. S. Syndesmotic fixation in unstable ankle fractures: Does early post-operative weight bearing affect radiographic outcomes? *Injury* **50**, 790–795 (2019).
162. Egol, K. A., Dolan, R. & Koval, K. J. Functional outcome of surgery for fractures of the ankle. A prospective, randomised comparison of management in a cast or a functional brace. *J. Bone Joint Surg. Br.* **82**, 246–249 (2000).
163. Thomas, G., Whalley, H. & Modi, C. Early mobilization of operatively fixed ankle fractures: a systematic review. *Foot ankle Int. / Am. Orthop. Foot Ankle Soc. [and] Swiss Foot Ankle Soc.* **30**, 666–674 (2009).
164. Braun, B. J. *et al.* Weight-bearing recommendations after operative fracture treatment—fact or fiction? Gait results with and feasibility of a dynamic, continuous pedobarography insole. doi:10.1007/s00264-017-3481-7
165. Jameson, S. S. *et al.* Pulmonary embolism following ankle fractures treated without an operation - an analysis using National Health Service data. *Injury* **45**, 1256–1261 (2014).
166. NICE. *Venous thromboembolism: reducing the risk of venous thromboembolism (deep vein thrombosis and pulmonary embolism) in patients admitted to hospital.* (2010).
167. Howie, C., Hughes, H. & Watts, A. C. Venous thromboembolism associated with hip and knee replacement over a ten-year period: a population-based study. *J Bone Jt. Surg Br* **87**, 1675–1680 (2005).

168. Falck-Ytter, Y. *et al.* Prevention of VTE in orthopedic surgery patients: Antithrombotic Therapy and Prevention of Thrombosis, 9th ed: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines. *Chest* **141**, e278S–325S (2012).
169. DAHL, O. E., QUINLAN, D. J., BERGQVIST, D. & EIKELBOOM, J. W. A critical appraisal of bleeding events reported in venous thromboembolism prevention trials of patients undergoing hip and knee arthroplasty. *J. Thromb. Haemost.* **8**, 1966–1975 (2010).
170. Selby, R. *et al.* Symptomatic venous thromboembolism uncommon without thromboprophylaxis after isolated lower-limb fracture: the knee-to-ankle fracture (KAF) cohort study. *J Bone Jt. Surg Am* **96**, e83 (2014).
171. Thomas, S. & Van Kampen, M. Should orthopedic outpatients with lower limb casts be given deep vein thrombosis prophylaxis? *Clin Appl Thromb Hemost* **17**, 405–407 (2011).
172. Jameson, S. S. *et al.* Venous thromboembolic events following foot and ankle surgery in the English National Health Service. *J Bone Jt. Surg Br* **93**, 490–497 (2011).
173. SooHoo, N. F., Eagan, M., Krenek, L. & Zingmond, D. S. Incidence and factors predicting pulmonary embolism and deep venous thrombosis following surgical treatment of ankle fractures. *Foot Ankle Surg* **17**, 259–262 (2011).
174. Sweetland, S. *et al.* Duration and magnitude of the postoperative risk of

- venous thromboembolism in middle aged women: prospective cohort study. *BMJ* **339**, b4583–b4583 (2009).
175. Barrack, R. L. Thromboprophylaxis for patients undergoing joint replacement. *Bone Jt. J* **96–B**, 3–4 (2014).
 176. Selby, R. *et al.* A double-blind, randomized controlled trial of the prevention of clinically important venous thromboembolism after isolated lower leg fractures. *J Orthop Trauma* **29**, 224–230 (2015).
 177. Bruntink, M. M. *et al.* Nadroparin or fondaparinux versus no thromboprophylaxis in patients immobilised in a below-knee plaster cast (PROTECT): A randomised controlled trial. *Injury* **48**, 936–940 (2017).
 178. Westaby, S. *et al.* Comparison of hospital episode statistics and central cardiac audit database in public reporting of congenital heart surgery mortality. *BMJ* **335**, 759 (2007).
 179. Thorn, J. C. *et al.* Validation of the Hospital Episode Statistics Outpatient Dataset in England. *Pharmacoeconomics* **34**, 161–168 (2016).
 180. Ovaska, M. T., Madanat, R., Honkamaa, M. & Mäkinen, T. J. Contemporary demographics and complications of patients treated for open ankle fractures. *Injury* **46**, 1650–1655 (2015).
 181. Wijendra, A., Alwe, R., Lamyman, M., Grammatopoulos, G. A. & Kambouroglou, G. Low energy open ankle fractures in the elderly: Outcome and treatment algorithm. *Injury* **48**, 763–769 (2017).

182. Toth, M. J., Yoon, R. S., Liporace, F. A. & Koval, K. J. What's new in ankle fractures. *Injury* **48**, 2035–2041 (2017).
183. Asloun, Y. *et al.* Internal fixation of the fibula in ankle fractures. A prospective, randomized and comparative study: plating versus nailing. *Orthop Traumatol Surg Res* **100**, S255-9 (2014).
184. White, T. O. *et al.* A prospective randomised controlled trial of the fibular nail versus standard open reduction and internal fixation for fixation of ankle fractures in elderly patients. *Bone Jt. J* **98–B**, 1248–1252 (2016).
185. Ashman, B. D. *et al.* Fluoroscopy-guided reduction and fibular nail fixation to manage unstable ankle fractures in patients with diabetes: a retrospective cohort study. *Bone Jt. J* **98–B**, 1197–1201 (2016).
186. Thevendran, G. & Younger, A. Arthroscopic Reduction and Fibula Nailing in High-Risk Diabetic Ankle Fractures: Case Reviews and Technical Tip. *Foot Ankle Spec.* **5**, 124–127 (2012).
187. Goss, D. A., Reb, C. W. & Philbin, T. M. Anatomic Structures at Risk When Utilizing an Intramedullary Nail for Distal Fibular Fractures: A Cadaveric Study. *Foot Ankle Int.* **38**, 916–920 (2017).
188. Switaj, P. J. *et al.* A biomechanical comparison study of a modern fibular nail and distal fibular locking plate in AO/OTA 44C2 ankle fractures. *J. Orthop. Surg. Res.* **11**, 100 (2016).

