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Original Article

How well do we reduce ankle fractures intra-operatively: A retrospective 1 year review using Pettrone's criteria

James Shelton[a,*], Sara Dorman[a], Ashtin Doorgakant[a], Edward Wood[b]

[a] Health Education North West (Mersey Sector), Summers Road, Liverpool, L3 4BL, UK
[b] Department of Trauma & Orthopaedics, Countess of Chester Hospital, Chester, CH2 1UL, UK

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ABSTRACT

Introduction: Ankle ORIF is a common orthopaedic procedure. Assessment of the reduction is often performed by 'eyeballing' the intra-operative images.
Aims: This study aimed to assess the radiographic reduction of all ankle fracture ORIFs at COCH over a 1-year period using Pettrone's criteria
Method: Using the trauma database at the COCH all patients admitted for ankle ORIF over a 1 year period (n = 284) were identified. Each patient was retrospectively reviewed, duplicates or non-ankle fractures excluded and data collected on: patient demographics, Lauge-Hansen classification, time from injury to theatre, level of primary surgeon, type of fixation, reduction of medial, lateral or posterior malleolar reduction, syndesmosis reduction, date and satisfaction at last clinic appointment and complications.
Results: After exclusions 187 patients were included in the study. The average age of patients was 49 years old (14–93). The most common Lauge-Hansen fracture classifications were SER (51.6% (98)) and PER (29.9% (57)). Registrars were first surgeon in 49.7% (93) of cases. 80% (111 of 139) of medial malleoli were reduced, 90% of lateral malleoli were reduced 11% (21) had residual talar shift. The syndesmosis was reduced in 76.4% (143) of cases. 19% (36) had further operations. There were 35 major complications in 25 (13.4%) patients. Not all malposition of fracture fixation were in the same ankles, 34.2% (64) ankle ORIFs had residual deformity after being fixed.
Conclusion: The implications of this study are very important. The authors aim to raise awareness of Pettrone's radiographic criteria of a successful ORIF of the ankle and subsequently improve the mal-reduction rate of post-fixation ankle ORIF.

1. Introduction

Ankle fractures are a common injury and considered to be part of the 'bread & butter' of orthopaedic trauma surgery. The management of these injuries forms part of the Arbeitsgemeinschaft Für Osteosynthesefragen (AO) Principles course, which is desirable for application to a specialty training programme in trauma & orthopaedics, in England & Scotland. It has also been used for the technical skills assessment for the national selection process. The implication is that ankle fracture fixation is an easy procedure and well within the competencies of all trauma & orthopaedic surgeons.

Previous studies demonstrated that most cases of osteoarthritis of the ankle (78%) are post-traumatic in nature [1]. Further analysis of this group of patients demonstrates that 48% of patients with post-traumatic ankle arthritis had malleolar fractures. This equates to 37.4% of all patients presenting with ankle arthritis having had a 'simple' ankle fracture in the past which, as previously mentioned, is assumed to be well within the competencies of orthopaedic surgeons to fix [1].

The present study was inspired by an abstract from the British Orthopaedic Foot & Ankle Society (BOFAS) annual meeting proceedings from University Hospital Aintree (UHA) [2]. Using Pettrone's criteria, the authors found a 32.5% mal-reduction rate in their study group of ankle fractures, which required open reduction internal fixation [2,3].

2. Aims

As a busy district general hospital the surgeons in the present study aimed to assess whether their rates of mal-reduction were comparable to those from UHA and if there were any common themes from these cases that would be learning points for surgeons in training.

* Corresponding author.
E-mail address: James.shelton@nhs.net (J. Shelton).

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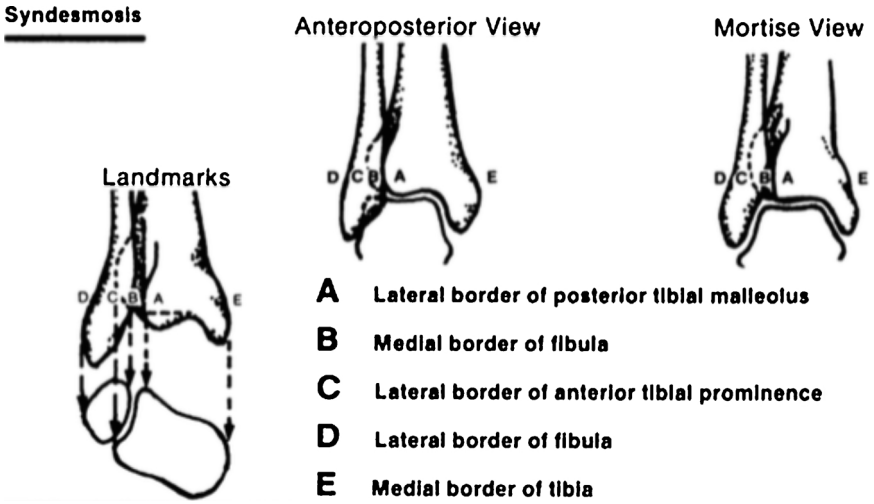


Fig. 1. Diagrammatic illustration from Pettrone's paper detailing the criteria.

3. Methods & materials

A Google form based data collection tool was designed in order to be able to collect anonymized data on a mobile device, whilst using a hospital PC to assess the radiographs. In order to maintain patient confidentiality a master Microsoft Excel (Version 14.6.7) spreadsheet was developed and kept on a hospital computer and each patient assigned a number for use in online data collection. The Hospital's trauma database was used to identify all ankle fractures admitted within a 1-year period. Data was collected on: patient demographics, Lauge-Hansen classification [3,4], level of primary surgeon, type of fixation, satisfaction at last clinic appointment, Pettrone's criteria (detailed below) [5]. The only exclusion was paediatric ankle fractures, defined as those who had not reached skeletal maturity at the time of injury.

Pettrone's criteria is based upon the anatomical landmarks shown in the figure below (Fig. 1).

Medial Malleolus: Satisfactory reduction classed as < 1 mm step in the articular surface on an AP radiograph (Fig. 2).

Lateral Malleolus (AP): Satisfactory reduction classed as < 2 mm step in the articular surface on an AP radiograph (Fig. 3).

Lateral Malleolus (lateral): Satisfactory reduction classed as < 2 mm step in the articular surface on a lateral radiograph (Fig. 4).

Deltoid ligament competence was assessed in Pettrone's criteria using < 3 mm clear space on the mortise view – those with > 3 mm medial clear space are deemed to have an incompetent deltoid ligament with subsequent talar shift. Because the magnification of the radiographs was unknown, this measurement was corroborated using Bemuer's criteria to assess if the medial clear space was greater than the superior clear space [7,8] (Fig. 5).

The tibio-fibula overlap should be > 1 mm on mortise view, if there is syndesmotic injury as the tibia and fibula splay apart the overlap becomes smaller and in severe injuries there is no overlap at all (Fig. 6).

4. Results

After applying the exclusions criteria, 187 patients were included in the study. The average age of patients undergoing ankle ORIF was 49 (14–93). The most common fracture patterns were Supination External Rotation (SER) 51.6% and Pronation External Rotation (PER) 30.8%. The remaining 18.2% was split between Supination Adduction (SA) 7.6%, Pronation Abduction (PA) 9.2% and Pronation Dorsiflextion (PD) 1.2%.

There was consultant supervision on 73.4% of cases however 51% of sub-consultant performed cases were unsupervised. Types of fixation used are demonstrated in the table below and were appropriate to the fracture pattern (Charts 1–3).

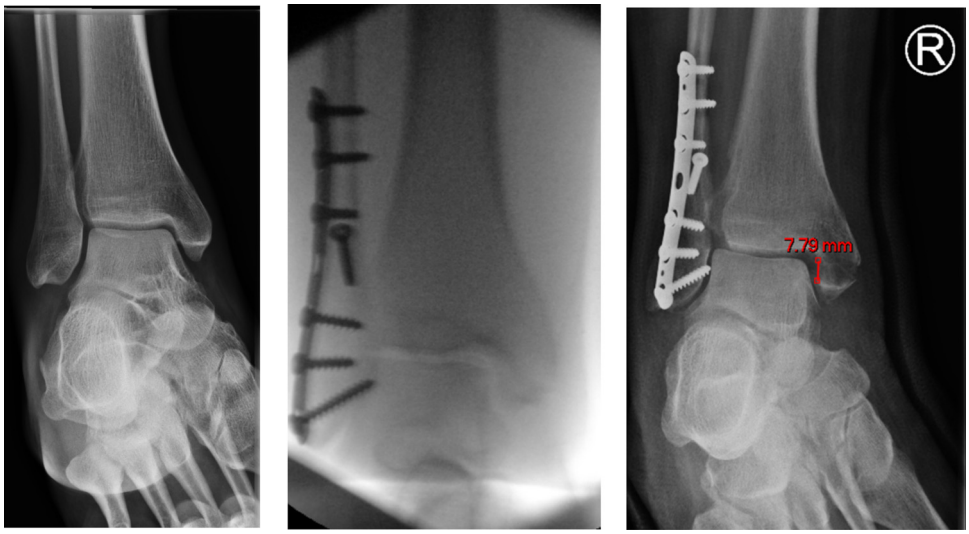


Fig. 2. Radiographs of the AP ankle joint demonstrating normal anatomy, normal fixation and incongruent reduction of the medial malleolus [6].

Fig. 3. Radiographs of the AP ankle joint demonstrating normal anatomy and incongruent reduction of the lateral malleolus [6].

Satisfactory reduction was achieved according to Pettrone's criteria in 123 ankles (65.8%). This is however a composite number and unfortunately there were many ankles that had malreduction in a number of criteria. The lateral malleolus was reduced in 90% of cases (145/165), the medial malleolus was reduced in 80% of cases (111/139) and the syndesmosis was reduced in 76% of cases. The Venn diagram below quantifies the distribution of malreductions (Fig. 7).

36 patients (19%) required further surgery, 5 had revision of fixation, 2 debridement for infection and 29 had removal of metalwork for hardware irritation. Fourteen percent of patients had complications: revision (1.8%), non-union (3.5%), infection (3.5%), Deep Vein Thrombosis (DVT) (0.6%), wound dehiscence (11%), nerve injury (1.8%) and Chronic Regional Pain Syndrome (CRPS) (0.6%), some patients had multiple complications.

Patient satisfaction was assessed using the last clinic letter prior to discharge. 27 (19.9%) of patients were noted to be completely satisfied, 74 (54.4%) satisfied, 15 (11%) indifferent, 17 (12.5%) unhappy and 3 (2.2%) very unhappy. Mean follow up 131 days (27–457 days) (Table 1).

The chart below, Chart 4, demonstrates patient post-operative satisfaction by location of the fracture and subdivided into reduced or mal-reduced categories. These categories have then been cross referenced against the patients' satisfaction at last clinic appointment. The results for medial malleolar fractures are similar but both syndesmotic and lateral malleolus fractures show a positive correlation towards well reduced fractures. Satisfaction at last clinic attendance failed to reach statistical significance with the exception of syndesmosis injury which demonstrated a $p = 0.02$ (single tail student *t*-test with unequal variance) (Chart 4).

With regard to the implants used to fix the malreduced fractures, the table below shows the results. It is apparent that by far the most common reason for malreduction in medial malleolar and syndesmotic fractures was a failure to appreciate the extent of the injury and subsequent insufficient fixation (Table 2).

Fig. 4. Radiographs of the lateral ankle joint demonstrating normal anatomy and incongruent reduction of the lateral malleolus [6].

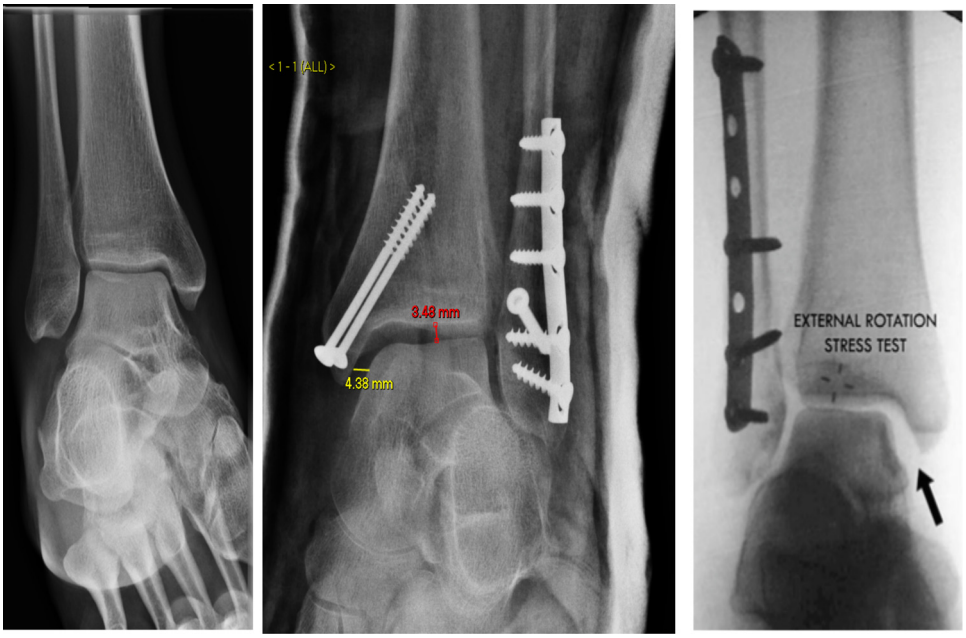


Fig. 5. Radiographs of the AP ankle joint demonstrating normal anatomy and incongruent reduction of the syndesmosis – Medial and superior clearspace [6].

5. Discussion

Ankle fractures are a common injury with an incidence as high as 8.3 per 1000 population [9] and are frequently placed on general trauma lists. It is also known that up to 78% of all ankle arthritis is attributable to post traumatic osteoarthritis [1] and that even minor changes in the ankle's biomechanics such as 1 mm of talar shift causes a significant change in the tibio-talar contact area, reducing the congruency by 44% [10]. Valderrabano's etiological study further defines the pathology of post-traumatic ankle arthritis into injury groups, showing that 37% of all ankle arthritis is caused by malleolar fractures (151/406). This data reinforces the need for anatomical reduction of ankle fractures to give the patient the best chance of a good outcome [11].

This study shows that the majority of malreductions are found in the syndesmosis and there is evidence to suggest that it is difficult to accurately assess syndesmotic congruency on plain films, with studies showing surgeons had a sensitivity of 17–33% [12]. This supports the requirement for dynamic testing of all ankle fractures intra-operatively, including a saved image of said testing. Stark who showed that there is often residual syndesmotic incongruence in up to 39% of SE4 type fractures post fixation further supports this manoeuver [13].

The present study found no skew towards unsupervised non-consultant grade doctors performing the operation and a poor post operative reduction. In this hospital there are 2 foot & ankle consultants in a cohort of 9 consultants, covering upper limb, arthroplasty and soft tissue knee. This may indicate that certain fractures, particularly those with syndesmotic injury may have an improved radiological outcome when treated by a specialist, as opposed to a general trauma surgeon.

Fixation of the syndesmosis was achieved with screws, suture buttons or a combination of both. There is some evidence to suggest that initial fixation with a suture button reduces the syndesmotic malreduction rate [14], this can be further reinforced with a second fixation device of the surgeons choice. Due to the anatomy of the distal

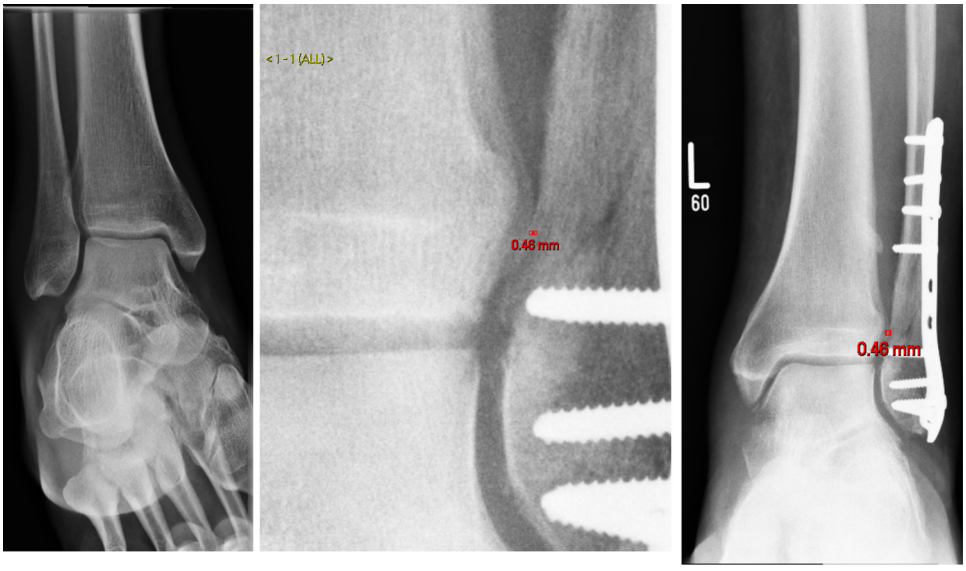


Fig. 6. Radiographs of the AP ankle joint demonstrating normal anatomy and incongruant reduction of the syndesmosis – Tibiofibula overlap [6].

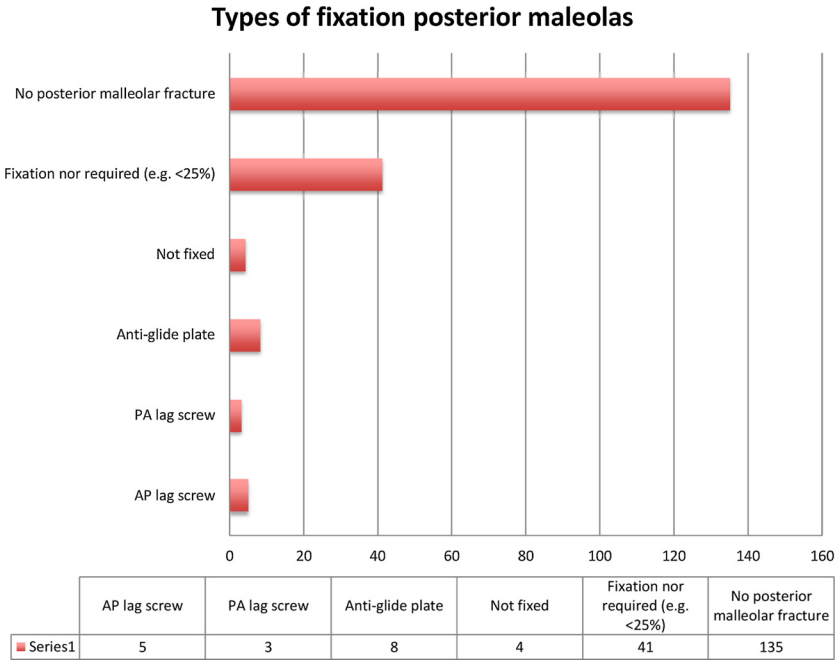


Chart 1. Demonstrating fixation modalities by location.

tibio-fibula joint it is possible, when using a screw as the primary fixation, to perform an in-situ fixation of a malreduced distal tibio-fibula joint. Whilst this still occurs in fixation with a suture button the present authors believe that due to the increased play in the system, it will still snug the fibula down into the notch, aiding in the reduction.

Pettrone's criteria are not particularly well-known amongst trainees. Whilst the senior author was aware of them, none of the investigating authors were previously aware that such strict radiographic criteria existed for ankle fracture fixation. This is a view further reinforced through discussions throughout the region with other trainees, yet it has changed the practice of all of the investigating authors when performing open reduction internal fixation of the ankle. Publicising these criteria is essential in order for trainees to know what is acceptable and hence improve the management of ankle fractures nationwide.

The revision rate is relatively low considering the number of malreductions and hence mal-unions. This hospital has a robust radiographic review meeting where a minimum of 2 consultants review every post-operative X-ray to ensure quality of trauma surgery and prompt revision surgery where necessary. This raises the question of the clinical impact of malreductions according, to Pettrone's criteria, on patients' functional status.

Patient satisfaction was subjectively gained from the patient's last clinic letters. Completely satisfied was selected if the patient reported no problems and full function. The other parameters were interpreted by each assessor and documented accordingly. 74.5% of patients were satisfied at the end of treatment, however, only 65.8% of fractures were adequately reduced. This suggests that there are confounding factors related to satisfaction after ankle fixation. Statistical analysis of patient satisfaction compared with fracture location and reduction found positive significance only with regard to the syndesmosis. This may be due to the relatively small numbers. Once the patients are subdivided into seven possible fracture configurations, however, with the syndesmosis

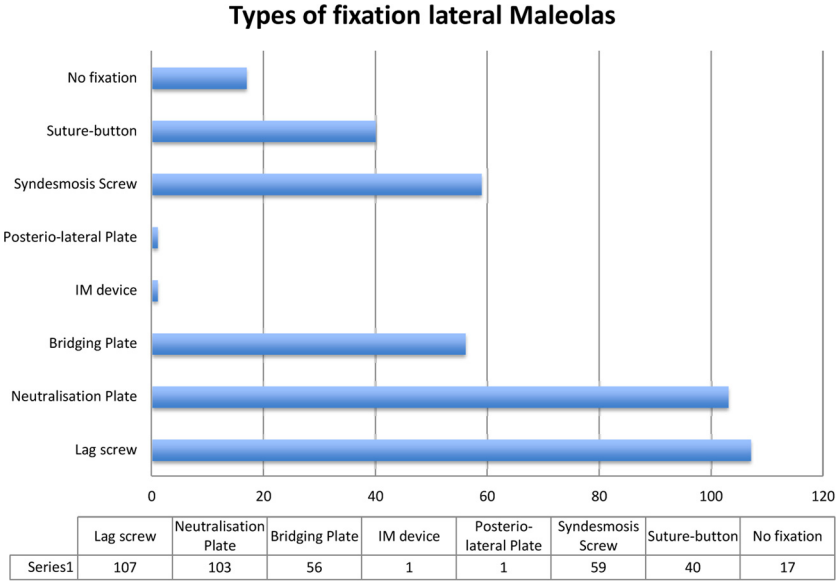


Chart 2. Demonstrating fixation modalities by location.

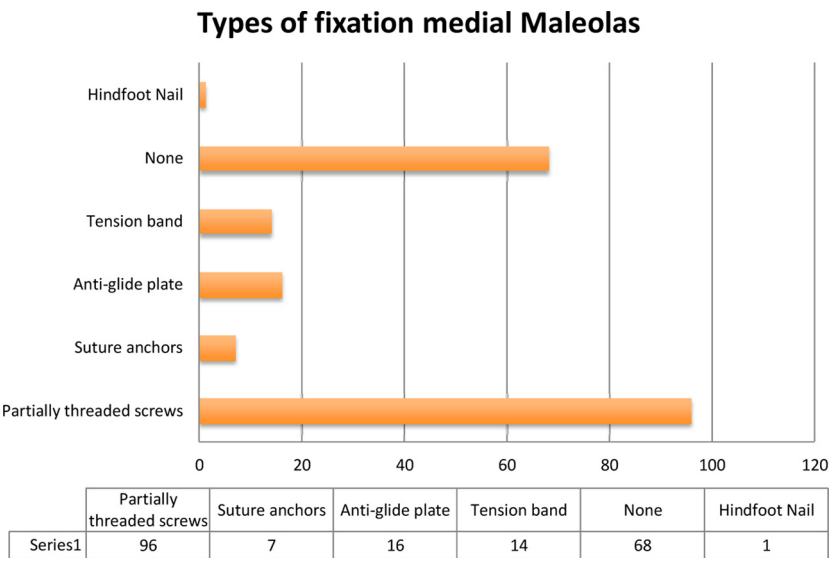


Chart 3. Demonstrating fixation modalities by location.

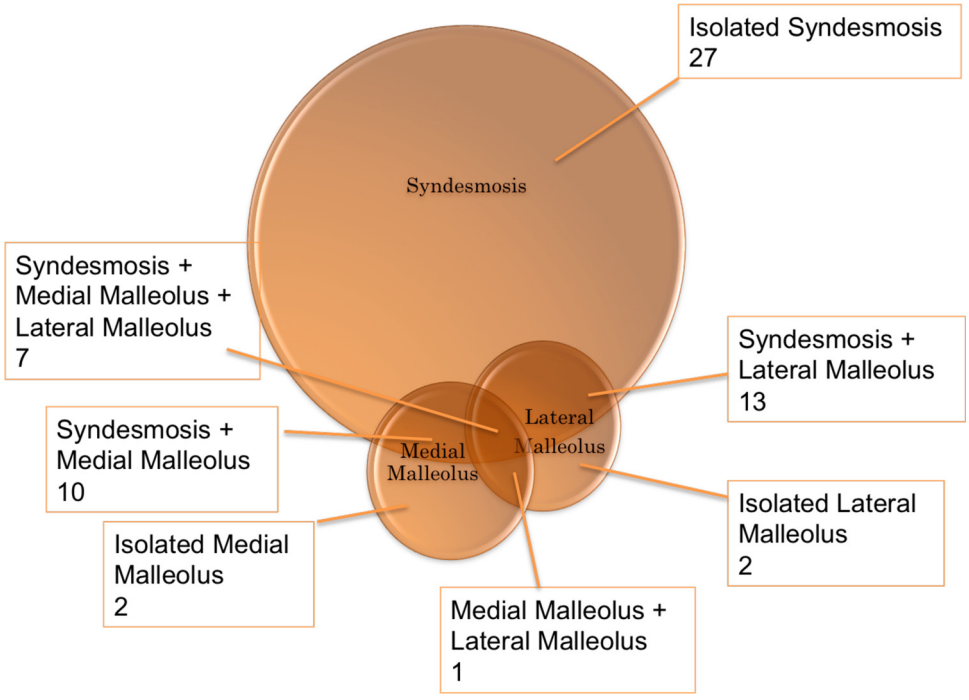


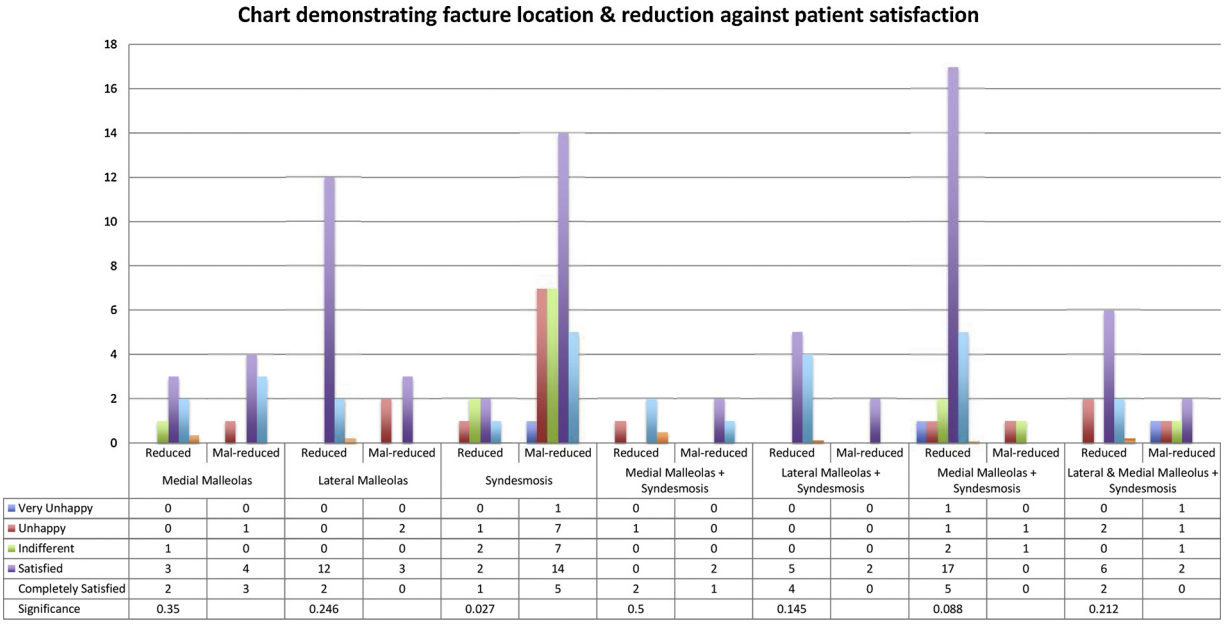
Fig. 7. Venn diagram demonstrating the distribution of malreductions in malreduced ankles.

Table 1
Patient satisfaction by reduction and location.

	Completely satisfied	Satisfied	Indifferent	Unhappy	Very unhappy
Syndesmosis mal reduced	21%	41%	18%	18%	2%
Syndesmosis reduced	20%	60%	8%	10%	10%
Medial malleolus mal reduced	25%	55%	10%	10%	0%
Medial malleolus reduced	19%	52%	12%	14%	3%
Lateral malleolus mal reduced	6%	50%	6%	32%	6%
Lateral malleolus reduced	24%	56%	10%	8%	2%

being the most frequently malreduced area of the ankle. This sample size was large enough to be significant. The breakdown of results and correlation with patient satisfaction will also aid in informed consent within our department.

This study does have a number of limitations: firstly it is a retrospective cohort study with cross sectional analysis at the time of surgery after the common exposure of the cohort to an ankle fracture that required fixation. It was arbitrarily decided at study design to use a 1 year



	Reduced	Mal-reduced	Reduced	Mal-reduced	Reduced	Mal-reduced	Reduced	Mal-reduced	Reduced	Mal-reduced	Reduced	Mal-reduced	Reduced	Mal-reduced
	Medial Malleolas		Lateral Malleolas		Syndesmosis		Medial Malleolas + Syndesmosis		Lateral Malleolas + Syndesmosis		Medial Malleolas + Syndesmosis		Lateral & Medial Malleolus + Syndesmosis	
Very Unhappy	0	0	0	0	0	1	0	0	0	0	1	0	0	1
Unhappy	0	1	0	2	1	7	1	0	0	0	1	1	2	1
Indifferent	1	0	0	0	2	7	0	0	0	0	2	1	0	1
Satisfied	3	4	12	3	2	14	0	2	5	2	17	0	6	2
Completely Satisfied	2	3	2	0	1	5	2	1	4	0	5	0	2	0
Significance	0.35		0.246		0.027		0.5		0.145		0.088		0.212	

Chart 4. Chart demonstrating facture location & reduction against patient satisfaction.

Table 2
Modes of fixation by malreduction.

Modes of fixation associated with mal-reduction				
Medial Malleolus	No fixation	Suture anchor	Anti-glide plate	Partially threaded screws
	21	5	1	1
Lateral Malleolus	No fixation	Lag screw & neutralisation plate	Bridging plate	
	4	9	7	
Syndesmosis	No fixation	Syndesmosis screw	Tightrope	Screw & tightrope
	18	8	3	5

snapshot. Whilst this is a descriptive rather than interventional study in retrospect involvement of a statistician during the design process would have been beneficial in order to provide a more robust study. The radiographs were divided between the authors and reviewed independently, ideally they should have been reviewed by multiple assessors to assess and account for inter-observer reliability. Unfortunately, it was not possible for the radiographs to be reviewed by multiple assessors. Lastly the lack of Patient Reported Outcome Measures (PROMs) limits our ability to draw functional outcomes from this study. The clinic letters suggest that in the short term patients do better than expected based upon the reduction of the ankle fractures. In future studies a prospective cohort study with multiple assessors reviewing the radiographs on a weekly basis is recommended; this way the workload of the study would be manageable in day to day NHS practice. Involvement of a statistician would allow calculation of inter-observer reliability between assessors which could assess the ease of use of Pettrone's criteria. The use of both foot & ankle specific and lifestyle Patient Reported Outcome Measures (PROMS) questionnaires and plan to follow up the cohort for a significant duration after they would have been discharged from fracture clinic to assess the true effect of mal-reduction on patient's ankles and lifestyles are recommended.

6. Conclusion

The present study demonstrates findings consistent with those of Studnicka et al. presented at BOFAS in 2013 [2]. This suggests that it is not an isolated problem but it is likely to be widespread in practice. The authors that recognition of syndesmotic injury and subsequently adequate reduction and fixation of that injury are the most problematic areas. By publicizing Pettrone's criteria more widely, better practice could be achieved. Weber C ankle (PER & PAD) fractures should be considered for additional CT imaging and referral to a foot & ankle specialist for assessment and management. The authors would like to advocate the use of CT scans if there is any doubt of reduction post operatively. CT scans are far more accurate at assessing syndesmosis reduction due to the axial reformats available. Post-operative CT scans should be considered in all Weber C ankle fractures and any Weber B ankle fractures where there is any doubt over the reduction of the syndesmosis.

Conflict of interest

The authors confirm that this project has received no funding (internal or external) and none of the authors have any commercial interest in the conclusions of this paper.

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