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A morphological review of medial malleolar fractures – A large single centre series

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ABSTRACT

Background: Many approaches to management of medial malleolar fractures are described in the literature however, their morphology is under investigated.

The aim of this study was to analyse the morphology of medial malleolar fractures to identify any association with medial malleolar fracture non-union or malunion.

Methods: Patients who had undergone surgical fixation of their MMF were identified from 2012 to 2022, using electronic patient records. Retrospective analysis of their preoperative, intraoperative, and postoperative radiographs was performed to determine their morphology and prevalence of non-union and malunion. Lauge-Hansen classification was used to characterise ankle fracture morphology and Herscovici classification to characterise MMF morphology.

Results: A total of 650 patients were identified across a 10-year period which could be included in the study. The overall non-union rate for our cohort was 18.77% (122/650). The overall malunion rate was 6.92% (45/650). Herscovici type A fractures were significantly more frequently mal-reduced at time of surgery as compared to other fracture types (p = .003). Medial wall blowout combined with Hercovici type B fractures showed a significant increase in malunion rate. There is a higher rate of bone union in patients who had been anatomically reduced.

Conclusion: The morphology of medial malleolar fractures does have an impact of the radiological outcome following surgical management. Medial wall blowout fractures were most prevalent in adduction-type injuries; however, it should not be ruled out in rotational injuries with medial wall blowouts combined with and Herscovici type B fractures showing a significant increase in malunions. Herscovici type A fractures had significantly higher malreductions.

Level of evidence: Level 3 – Retrospective Cohort Study

1. Introduction

Ankle fractures are one of the most common fractures presenting to a trauma surgeon with one study reporting an incidence of 171.37 ankle fractures per 100,000 persons [1]. It is estimated that up to 25% of all ankle fractures require surgical management [2]. Medial malleolus fractures (MMF) can occur in isolation or alongside lateral and/or posterior malleolus fractures. MMF have been regularly described in literature with their multiple modalities of management [2,3]. Isolated MMF specifically can be categorised using Herscovici's classification whereby the level of the fracture is categorised into four groups: avulsion fractures, between medial malleolus tip and plafond, the level of the plafond and proximal to plafond (types A, B, C and D respectively, Fig. 1) [6]. In terms of clinical relevance, studies demonstrate type D fractures have higher rates of plate fixation than type C fractures but overall, indicate Hescovici's classifications are not associated with specific methods of fixation [14].

The Lauge-Hansen classification is another well-known method of categorising ankle injuries including MMF [9–13]. Despite the wealth of evidence regarding fracture management in MMF, there is little literature assessing the morphology of MMF with associated lateral and posterior malleolus injuries and whether there is any association with the various types of both Herscovici and Lauge-Hansen injuries and radiological outcomes such as non-union and malunion. The aim of this study was to analyse the morphology of medial malleolar fractures to identify any association with medial malleolar fracture non-union or malunion. The nul hypothesis being that there is no association between fracture morphology and non-union or malunion.

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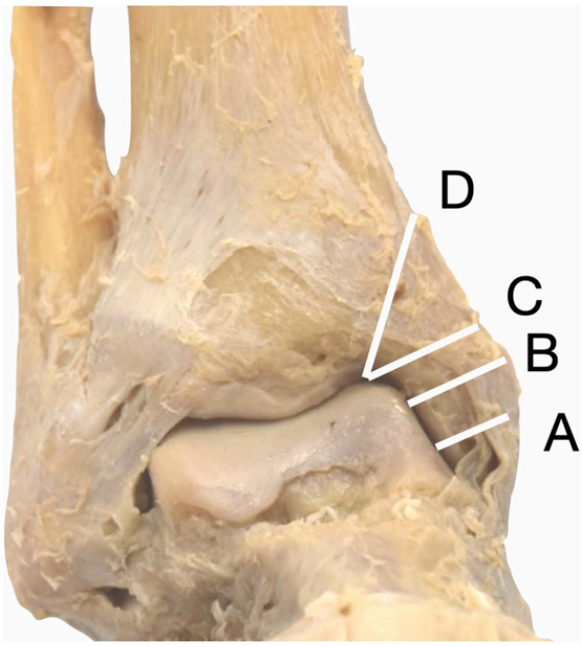

Fig. 1. Herscovici classification as displayed on a cadaveric dissection of an ankle.

2. Methods

This was a retrospective observational study of all patients from who were admitted to Liverpool University Hospitals NHS Foundation Trust between August 2012 to August 2022 who had sustained an ankle fracture and was undergoing surgery. Data was obtained from our institutions prospectively collected electronic patient record system (Bluespier, Droitwich, UK). Inclusion criteria were all adult patients who had sustained an ankle fracture which included a MMF that had undergone open reduction internal fixation. Any patients which did not have follow up radiographs were excluded.

Ankle fracture characteristics were identified using our Picture Archiving and Communication System (Carestream Health Inc, New York, USA). Analysis was performed of all preoperative, intraoperative and postoperative imaging. Data collected included: demographics, soft tissue injury, dislocation, Herscovici classification of MMF and Lauge-Hansen classification [6,9–13]. Postoperative imaging was analysed, and all patients most recent postoperative imaging was utilised to determine whether radiological evidence of non-union or malunion was present. Malunion was defined as displacement on at least 1 radiograph image of greater than 1 mm. Non-union was defined as no trabecular crossing on radiograph at least 6 months postoperatively. All radiographs were reviewed by two separate reviewers and any disagreement was discussed.

3. Statistics

Statistical analysis was performed using SPSS 27 (IBM Corp, USA). Comparisons were made between group characteristics. Chi-squared and Fisher's exact tests were used for categorical variables and independent samples t-tests and Mann-Whitney U test for variable means depending on normality testing. Significance was given to variables that reached $p < 0.05$. Interobserver reliability assessment was performed using Cohen's Kappa for nominal variable sand weighted Cohen's Kappa for ordinal variables and similar results were obtained.

4. Results

A total of 650 patients were identified across a 10-year period which could be included in the study. The average age of patients was 47.7 years (95% CI 46.33, 49.14). Acute ankle dislocation was witnessed on radiographs in 293 cases (45.07%). Thirty-seven patients sustained an open ankle fracture (5.69%). There were 380 right ankles (58.46%) and 270 left ankles (41.53%).

Regarding Lauge-Hansen and Herscovici classifications, crosstabulation is shown in Table 1. Almost 50% (322/650) of cases attended with a type C Herscovici classification medial malleolus fracture. The most common Herscovici classification with supination adduction injury was a type D and with a pronation abduction injury was a type B. Type C Herscovici type fractures were, however, common across all Lauge Hansen classifications accounting for over 25% in all types.

Further analysis of the whole cohort identified further information relating to injury patterns. Medial wall blow out fracture (Fig. 2) was identified in almost 20% of all cases (19.138%, 126/650). Most commonly medial wall blowout fractures were most associated with Hercovici type D and least commonly associated with Hercovici type A. (Table 2) This association was significant (<.001). Regarding Lauge Hansen classification, there was a significant ($p < .001$) association with supination adduction injuries. (Table 3).

All the fractures underwent operative fixation. The overall nonunion rate for our cohort was 18.77% (122/650). The overall malunion rate was 6.92% (45/650). Herscovici type A fractures were significantly more frequently mal-reduced at time of surgery as compared to other fracture types ($p = .003$). Medial wall blowout has no significant effect on bony union ($p = .889$) or malreduction ($p = 846$) in the overall cohort. However, in Hercovici type B fractures there was an association of medial wall blowout with medial malleolar malunion, where 21.05% (4/19) of cases with medial blowout fractures were malreduced compared to 5.77% (9/156) of cases without medial blowout fractures ($p = .038$). There is a higher rate of bone union in patients who have been anatomically reduced with 82.27% (501/609) patients uniting in the anatomically reduced group compared to 64.44% (29/45) of patients in the mal-reduced group ($p = .003$). There were no other factors significantly associated with nonunion. (Table 4) On univariate and multivariate analysis, Herscovici A fractures were the only factor associated with malunions, with an OR of 4.789 (Table 5).

Table 1
Crosstabulation of medial malleolar fracture (Herscovici) and Lauge Hansen classification.

		Herscovici Classification								
		A		B		C		D		Total
		N	%	N	%	N	%	N	%	
Lauge Hansen	SAD	2	5.13%	10	25.64%	10	25.64%	17	43.59%	39
	SER	24	4.89%	127	25.87%	259	52.75%	81	16.50%	491
	PER	6	7.14%	21	25.00%	41	48.81%	16	19.05%	84
	PAB	0	0.00%	15	45.45%	12	36.36%	6	18.18%	33
Total		32	4.95%	173	26.74%	322	49.77%	120	18.55%	647

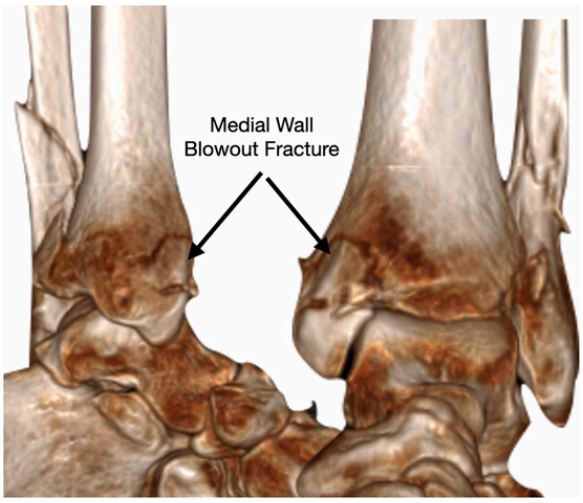

Fig. 2. Medial wall blow out as displayed on a 3D CT surface rendering of an ankle.

Table 2
Crosstabulation of medial malleolar fracture classification (Herscovici) and medial wall blowout.

		Medial Wall Blowout				
		No		Yes		Total
		N	%	N	%	
Herscovici Classification	A	30	93.75%	2	6.25%	32
	B	156	89.14%	19	10.86%	175
	C	286	88.54%	37	11.46%	323
	D	53	44.54%	66	55.46%	119
Total		525	80.89%	124	19.11%	649

Table 3
Crosstabulation of Lauge Hansen fracture classification and medial wall blowout.

		Medial Wall Blowout				Total
		No		Yes		
		N	%	N	%	
Lauge Hansen	SAD	19	48.72%	20	51.28%	39
	SER	404	81.78%	90	18.22%	494
	PER	73	86.90%	11	13.10%	84
	PAB	28	84.85%	5	15.15%	33
Total		524	80.62%	126	19.38%	650

5. Discussion

The primary aim of this study was to analyse the morphology of medial malleolus fractures to identify any fracture patterns that were associated with fracture non-union and malunion. The nul hypothesis being that there is no association between medial malleolar fracture morphology and non-union or malunion. Our study found significant associations with Herscovici type A fractures and malunion, combined medial wall blow out fractures and Herscovici type B fractures with malunion and the significant association between anatomical reduction and bony union. Therefore, the nul hypothesis can be rejected.

We found that most medial malleolus cases were Herscovici type C occurring most commonly in the external rotation injury patterns, both supination and pronation. The most common pattern of ankle injury was supination-external rotation. Pronation abduction injuries were most involved with Herscovici type B fractures, and supination abduction injuries were most associated with Herscovici type D fractures. Herscovici et al. also reported Type C fractures to be the most common, however these were in a conservatively treated fracture study [6]. Medial wall blowout fractures were present in almost 20% of cases in our study.

Currently, there is little evidence documenting the injury patterns and overall morphology of medial malleolus injuries within the literature. There have been few studies proposing various classification systems utilising more in-depth imaging techniques, such as, computerised tomography to further assess fracture patterns. *Hu et al.* designed a classification system utilising three-dimensional reconstruction from CT scans to identify four types of medial malleolus injury, which focused on involvement of the posterior colliculus [7]. Our findings relating to transverse fractures of the medial malleolus correlate with *Ebraheim et al.* who discovered in their review of 112 patients, that, 57% supination-external rotation injuries had sustained a transverse medial malleolus injury (N = 64) [4]. Our findings highlight that an understanding of the common fracture morphologies can provide further information preoperatively for surgical planning.

Our study identified a high percentage of medial wall blowout fractures. Of note, supination adduction types were most identified to have sustained this injury. It is well established within the literature that supination adduction injuries are associated with a vertical medial malleolus fracture and often require plate fixation as opposed to traditional screw fixation [15,18]. Although medial wall blow out fractures occurred most commonly in supination adduction injuries, it was in Herscovici type B fractures that they resulted in a significant increase in fracture malunion. Ma et al. noted an improvement in results when supination adduction injuries were treated as medial pilon injuries and not fixed in a routine ankle fracture method (i.e. compression screw fixation) [3]. Although not examined specifically in our paper, the medial blow out fractures in combination with a smaller medial malleolar fracture fragment is likely to not be treated like a medial pilon, and thus any compression screw fixation would worsen the medial blow out and cause malreduction. There were medial wall blowout fractures both in pronation-external rotation and supination-external rotation injuries. This evidence highlights the need for further assessment, particularly intraoperatively, to ensure that surgeons are aware of the fracture patterns and perform the necessary fixation. Many studies have been performed to assess adduction-type injuries and their fixation however our findings suggest that

Table 4
Crosstabulation of medial malleolar fracture classification (Herscovici) and bone union and anatomical reduction.

		Union					Anatomical Reduction				
		No		Yes		Total	No		Yes		Total
		N	%	N	%		N	%	N	%	
Herscovici Classification	A	6	18.75%	26	81.25%	32	7	21.88%	25	78.13%	32
	B	40	22.86%	135	77.14%	175	13	7.43%	162	92.57%	175
	C	62	19.20%	261	80.80%	323	21	6.50%	302	93.50%	323
	D	14	11.67%	106	88.33%	120	4	3.33%	116	96.67%	120
Total		122	18.77%	528	81.23%	650	45	6.92%	605	93.08%	650

Table 5
Univariate and multivariate regression analysis on the development of malunion.

	Univariate				Multivariate			
	Sig	OR	95% CI		Sig	OR	95% CI	
			Lower	Upper			Lower	Upper
Herscovici A	0.002	9.935	0.033	0.453	0.029	4.789	0.136	0.896
Herscovici B	0.148	2.088	0.137	1.351				
Herscovici C	0.207	1.589	0.167	1.476				
Herscovici D	0.096	2.769	0.854	6.924	0.186	3.574	0.708	5.934
Lauge Hansen SAD	0.257	1.284	0.029	2.577				
Lauge Hansen SER	0.372	0.798	0.053	3.001				
Lauge Hansen PER	0.679	0.171	0.067	5.808				
Lauge Hansen PAB	0.383	0.763	0.327	18.377				
Open Fracture	0.336	0.925	0.198	1.738				
Medial Wall	0.837	0.042	0.562	1.596				
Percutaneous. or Open	0.136	2.222	0.661	20.966				
Syndesmosis Fixation	0.044	4.058	0.29	0.983	0.063	3.462	0.295	1.032
Fibula Length Restored	0.809	0.058	0.34	2.321				

even in the context of external-rotation injures, surgeons should have an awareness that medial wall blowout is still a possibility [1,5,16].

Another key finding from our analysis was that Herscovici A fractures were significantly more frequently mal-reduced at time of surgery compared to other fracture types. Malreduction of the medial malleolus has been known to result is significantly worse postoperative outcomes, particularly with regards to function and residual symptoms, such as, pain or restriction of range of movement [8,17]. Given the smaller fracture fragments associated with Herscovici type A, we could presume that this presents a more technically challenging procedure to attempt and achieve anatomical reduction. There is, however, a limited amount of information available relating to the size of medial malleolus fracture fragment size and anatomical reduction rates. Use of smaller screws and ligamentous repair should be within the surgeon's armamentarium when treating the smaller medial malleolar fracture types.

Malreduction in ankle fractures has been reported to occur following surgery in over 40% [4,5]. Malreduction is also noted to cause worse functional outcomes [6]. However, we are unaware of a link between non-union and malreduction being reported previously in ankle fractures. It is logical that any malreduction that has caused a gap may result in problems in primary bone healing. Additionally, malreductions may alter the contact and compression forces at the fracture site thus altering the strain and leading to non-union. Bai et al. have reported force alterations in biomechanical studies in the syndesmosis when malreduced [7].

5.1. Limitations

This was a retrospective study and is therefore susceptible to bias. However, the large numbers and scoping nature gives us some understanding of the different fracture morphology encountered when treating medial malleolar fractures. The study had gaps within analysis, particularly pertaining to follow up radiographs. Out of area patients who were operated locally were not able to be assessed for long periods, where non-unions may have progressed to union. The definition of union was radiographic and does not indicate the clinical outcome and whether these were symptomatic. A prospective study may wish to use CT to define non-union, although this was not possible in our retrospective analysis.

6. Conclusion

The morphology of medial malleolar fractures does have an impact of the radiological outcome following surgical management. Medial wall blowout fractures were most prevalent in adduction-type injuries; however, it should not be ruled out in rotational injuries with medial wall blowouts combined with and Herscovici type B fractures showing a significant increase in malunions. Herscovici type A fractures were most commonly malreduced and further assessment should be performed to determine other fractures which have contributed to the malreduction of these injuries (fixation method and operative approach).

Ethical statement

Compliance with Ethical Standards: All human studies have been approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. National laws have been adhered to.

Ethical approval

Institutional review board judged the study to be a service provision project and therefore no formal ethics was required.

Informed consent

Patients were retrospectively analysed. No consent required.

Funding

Non applicable.

Declaration of Competing Interest

Prof Lyndon Mason is an implant designer for Orthosolutions, UK.

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