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WORKSHOPS OF THE SOO (2011, LA BAULE). ORIGINAL ARTICLE

Total talar fracture — Inter- and intra-observer reproducibility of two classification systems (Hawkins and AO) for central talar fractures

T. Williams[a], N. Barba[b], T. Noailles[c], V. Steiger[d], V. Pineau[e], G. Carvalhana[f], B. Le Jacques[a], A. Clave[a], D. Huten[b,*]

[a] *Service de chirurgie orthopédique, hôpital de la Cavale-Blanche, CHU, boulevard Tanguy-Prigent, 29200 Brest cedex, France*
[b] *Service de chirurgie orthopédique, hôpital Sud, CHU, boulevard de Bulgarie, 35200 Rennes cedex 2, France*
[c] *Service de chirurgie orthopédique, CHU Hôtel-Dieu, place Alexis-Ricordeau, 44093 Nantes cedex, France*
[d] *Département chirurgie orthopédique, CHU, 4, rue Larrey, 49933 Angers cedex, France*
[e] *Département d'orthopédie, CHU Côte-de-Nacre, avenue de la Côte-de-Nacre, 14033 Caen cedex, France*
[f] *Service de chirurgie orthopédique, hôpital Charles-Nicolle, CHU, Pavillon Dève, l, rue de Germont, 76031 Rouen cedex, France*

KEYWORDS
Talus;
Fracture;
Classification;
CT scan;
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Inter- and intra-observer reproducibility

Summary
Introduction: We evaluated the inter- and intra-observer reproducibility of two classification systems for central talar fractures (Hawkins, as modified by Canal and Kelly and then by us; AO/AOT).
Hypothesis: The analysis and classification of these fractures will be better with CT scans than with X-rays.
Material and Methods: Four observers evaluated 39 X-ray and CT scan files twice in the span of six weeks; each evaluation entailed classifying the fractures and describing their main features. Cohen's Kappa coefficient for inter-rater agreement was calculated and analysed.
Results: The inter- and intra-observer reproducibility with CT scans was better with X-rays for most of the parameters evaluated. The modified Hawkins classification provided better reproducibility than the AO/AOT one. However, this classification system was not perfect, even after modifications and use of CT scans.
Discussion: CT scans are an essential tool for the analysis of all talar fractures. We modified the Hawkins classification (as modified by Canal and Kelly) to include a Type 0 (no displacement or less than 2 mm), include frontal body fractures that are displaced like neck fractures and take into account comminuted fractures and other trauma in the area.
Level of proof: IV — retrospective clinical study.

* Corresponding author. Tel.: +33 02 99 26 71 67.
E-mail address: denis.huten@orange.fr (D. Huten).

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MESH TERMS
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Fractures/classification ;
Fractures/radiography

Introduction

Talar neck and body fractures are rare and have a poor prognosis [1—8]. Their progression is compromised by the presence of avascular necrosis and peritalar osteoarthritis, which are enhanced by technical errors during surgery.

These problems can in part be attributed to inadequate analysis of the fracture pattern. The complex shape of the talus and the challenge of obtaining good radiographic views of the injured hind-foot make this bone difficult to evaluate with plain X-rays [9]. As a consequence, computed tomography scans (CT scan) are being increasingly recommended [3,4,8,10—13] to better characterise the fracture and to help determine the best treatment.

Furthermore, there is no consensus on the classification system to use. The first proposed classification system by Coltart [14], was followed by systems from Butel and Witvoet [15], Hawkins [5], Marti [16], Sneppen [17], Canal and Kelly [2], Inokuchi [18] and the AO/AOT [19]. The Hawkins system as modified by Canale and Kelly, and the AO/AOT system are used most often.

A symposium at the French Société Orthopédique de l'Ouest (SOO) in 2011, focussed on central talar fractures, with a retrospective, multicentre study of 287 fractures treated between 1985 and 2009. Partial (or peripheral) fractures were excluded from this study. We used the Hawkins classification as modified by Canale and Kelly and then our group (Hawkins classification modified by SOO, discussed later on).

We wanted to compare the inter- and intra-observer reproducibility of the analysis of the talus fracture imaging, in cases where the assessment only included X-rays or when it also included a CT scan. Our goal was to show that the inter- and intra-observer reproducibility of the CT scan analysis was better than the X-ray analysis. Our modified classification and the AO/AOT system were evaluated.

Material and methods

SOO symposium series 2011

This series included 287 fractures treated between 1985 and 2009. The patient records came from nine study centres (Fig. 1).

Of these fractures, only 85 (29.6%) had a CT scan performed on them at the initial visit. From 2007 to 2009, a CT scan was performed in only 42.1% of cases.

To be included in this evaluation, the imaging file had to have at least A/P and lateral X-rays and a CT scan with sagittal and frontal reconstructions. The slice thickness, which was not always known, was not a study parameter. If they existed, three-dimensional reconstructions were not included in the files. Of the 72 files with X-rays and CT scans, 39 met the criteria for inclusion.

Classification systems used for this study

Hawkins classification as modified by the SOO in 2011

We chose to use the Hawkins classification system for this study since it is the most commonly used system, and more importantly, because it has a known prognostic value relative to the risk of avascular necrosis [1—8].

Hawkins described three types of neck fractures and drew attention to the risk of necrosis, which increases from Type I to Type III fractures:

- Type I: non-displaced vertical fracture;
- Type II: displaced vertical fracture with subluxation or dislocation of the subtalar joint (ST);
- Type III: displaced fracture with dislocation of the ST and tibiotalar (TT) joints.

According to Hawkins, the fracture line often goes through the anterior part of the talar body.

Canale and Kelly revised this classification (Table 1). They made minor changes and added a fourth type:

- Type I: non-displaced or slightly displaced fracture;
- Type II and Type III: no changes;
- Type IV: fracture with ST or TT dislocation and talonavicular (TN) joint subluxation or dislocation.

Although not specified in these two classification systems, the posterior ST joint is subluxed or dislocated in Type II, III and IV fractures. The Hawkins classification mainly addresses talar neck fractures; fractures were also included that involved the anterior part of the talar body, thus the ST and/or TT joint surfaces. The risk of osteoarthritis may be different in fractures involving the subtalar joint.

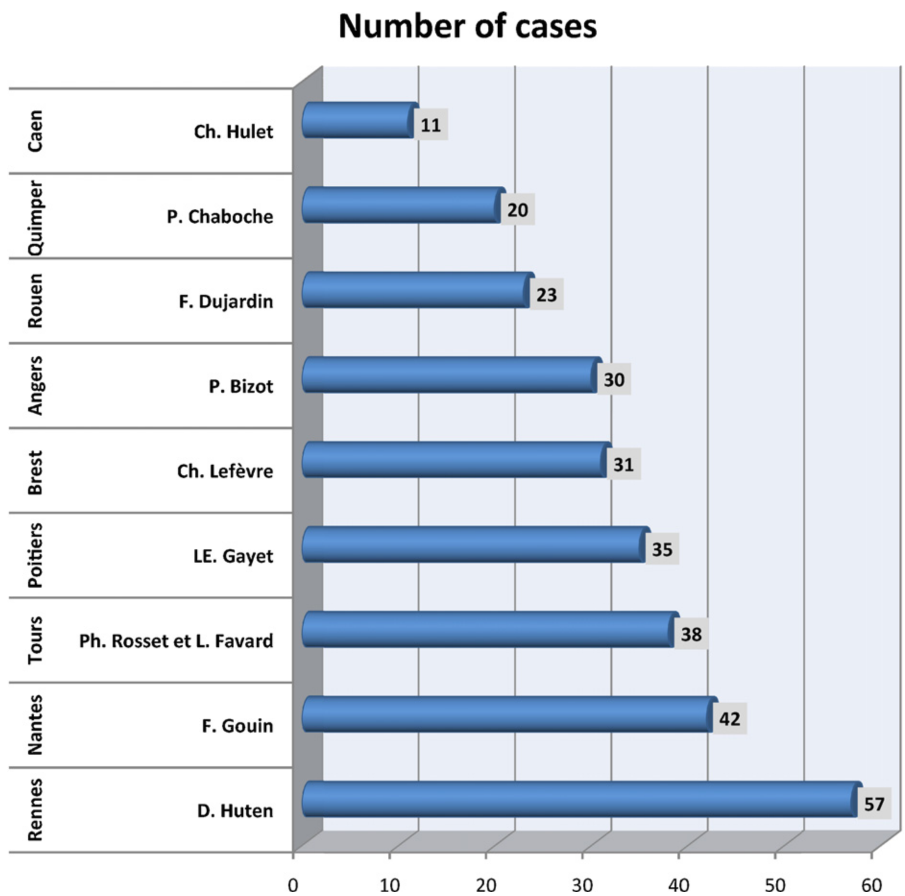

Figure 1 Source of cases included in the SOO 2011 series (287 cases).

To distinguish between neck and body fractures, Inokuchi [18] suggested using the location of the lower part of the fracture line relative to the lateral process (thus relative to the anterior border of the posterior ST cartilage); talar body fractures pass into or behind this structure, while talar neck fractures pass in front of it.

However, this approach does not take into account the location of the upper part of the fracture line. There are

Table 1 Hawkins classification for talar neck fractures and relevant modifications.

Hawkins classification		Modified by Canale and Kelly		Modified by SOO in 2011	
				Hawkins 0	Non-displaced neck or frontal body (or displacement < 2 mm)
Hawkins 1	Non-displaced neck	Hawkins 1	Slightly or non-displaced neck	Hawkins 1 A and B	Displaced neck or frontal talar body (> 2 mm)
Hawkins 2	Neck with ST subluxation or dislocation	Hawkins 2	Neck with ST subluxation or dislocation	Hawkins 2 A and B	Neck or frontal body with posterior ST subluxation or dislocation
Hawkins 3	Neck with ST and TT dislocation	Hawkins 3	Neck with ST and TT dislocation	Hawkins 3 A and B	Neck or frontal talar body with posterior ST and TT dislocation
		Hawkins 4	With ST or TT dislocation and TN subluxation or dislocation	Hawkins 4 A and B	Neck or frontal body with ST or TT dislocation and TN subluxation or dislocation

ST: subtalar; TT: tibiotalar; TN: talonavicular.

Boxed text 1: 2011 SOO Classification for talar fractures.

*Partial** (Head, lateral process, posterior process, dome)

*Central**

- Neck and frontal talar body fractures:
  - Type 0: displacement < 2 mm
  - Type I: displacement of 2 mm or more**
  - Type II: with posterior ST subluxation or dislocation**
  - Type III: with posterior ST and TT dislocation (enucleation)**
  - Type IV: with ST or TT dislocation and TN subluxation or dislocation**
  - ''True'' body fractures (sagittal, horizontal, comminuted).

*Add **C** (complex) if nearby structure also fractured (tibial plafond, malleoli, calcaneus, cuboid, navicular, etc.).

Add **A (simple fracture) or **B** (comminuted)

cases where the fracture line passes in the upper part of the neck (in front of the articular surface of the talar dome) and in the lower part of the neck (in the posterior ST cartilage); the inverse is also possible. In these cases, we classified these as being combined neck-body fractures. Thus it would be logical to say that body fractures are those that involve the TT joint in the upper part and the ST joint in the lower part, while neck fractures do not involve these two joints.

We then applied the Hawkins classification system to frontal fractures of the talus body (Fig. 2). Frontal fractures of the talus body stem from the same mechanism as neck fractures (which are also frontal) and displace in the same direction – the posterior fragment (either all or part of the body) is displaced backwards. Sagittal, horizontal and comminuted fractures of the body are the only ''true'' fractures of the body, as described by Sneppen and the AO/AOT.

Furthermore, since we observed that some frontal fractures were barely displaced while others were only slightly displaced, we added a Type 0 level (Fig. 3) to describe fractures with no displacement or a displacement less than 2 mm (Table 1). These types of fracture may benefit from conservative treatment, which we wanted to demonstrate. The Type I fracture described by Canal and Kelly corresponds to our Types 0 and I.

A few more details were added to our classification system (Box 1):

- for neck and frontal body fractures, a distinction was made between simple fractures (letter A) and comminuted fractures (letter B), as the latter can lead to poor reduction (shortening, rotation errors). The AO/AOT classification also emphasizes this aspect;
- associated foot and ankle fractures (letter C) were included.

AO/AOT Classification

The AO/AOT classification assigns the number 81 to the talus. In addition to partial Type A fractures, it describes:

- type B neck fractures:
  - non-displaced 81-B1,
  - displaced with subluxation of the ST joint 81-B2:
    - non-comminuted 81-B2.1,
    - comminuted 81-B2.2,
    - with fracture of the talar head 81-B2.3,
  - displaced with subluxation of the ST and TT joints 81-B3:
    - non-comminuted 81-B3.1,
    - comminuted 81-B3.2,
    - with fracture of the talar head 81-B3.3;
- type C body fractures:
  - fractures involving the TT joint (talar dome) 81-C1:
    - non-comminuted 81-C2.1,
    - comminuted 81-C2.2,
  - fractures involving the ST joint 81-C2:
    - non-comminuted 81-C2.1,
    - comminuted 81-C2.2,
  - fractures involving both the ST and TT joints 81-C3:
    - non-comminuted 81-C3.1,
    - comminuted 81-C3.2.

The AO/AOT classification was described in an article that included all traumatic injuries to the foot, including fractures, dislocations and sprains [20]; although this system is comprehensive, we do not use it currently because it is very complex.

Methods for reading the images

X-rays of each fracture were digitized, then numbered and placed in a random order. The same was done with the CT scans, but they were placed in a different order.

These imaging files were then analysed by four observers who were orthopaedic surgeons with general trauma experience:

- two senior lower limb specialists (A and B);
- one senior upper limb specialist (C);
- one resident surgeon at the end of studies (D).

None of these observers had been involved in the care of the fractures under study. Each classified the fractures according to the Hawkins (with SOO modifications) and AO/AOT classification systems, and answered the following six questions;

- location of fracture: body, neck or combined neck-body?
- orientation of main fracture line: frontal, sagittal or mixed?
- does the fracture line involve the following joint surfaces:
  - posterior subtalar: yes or no?
  - tibiotalar: yes or no?
  - talonavicular: yes or no?
  - is the fracture comminuted: yes or no?

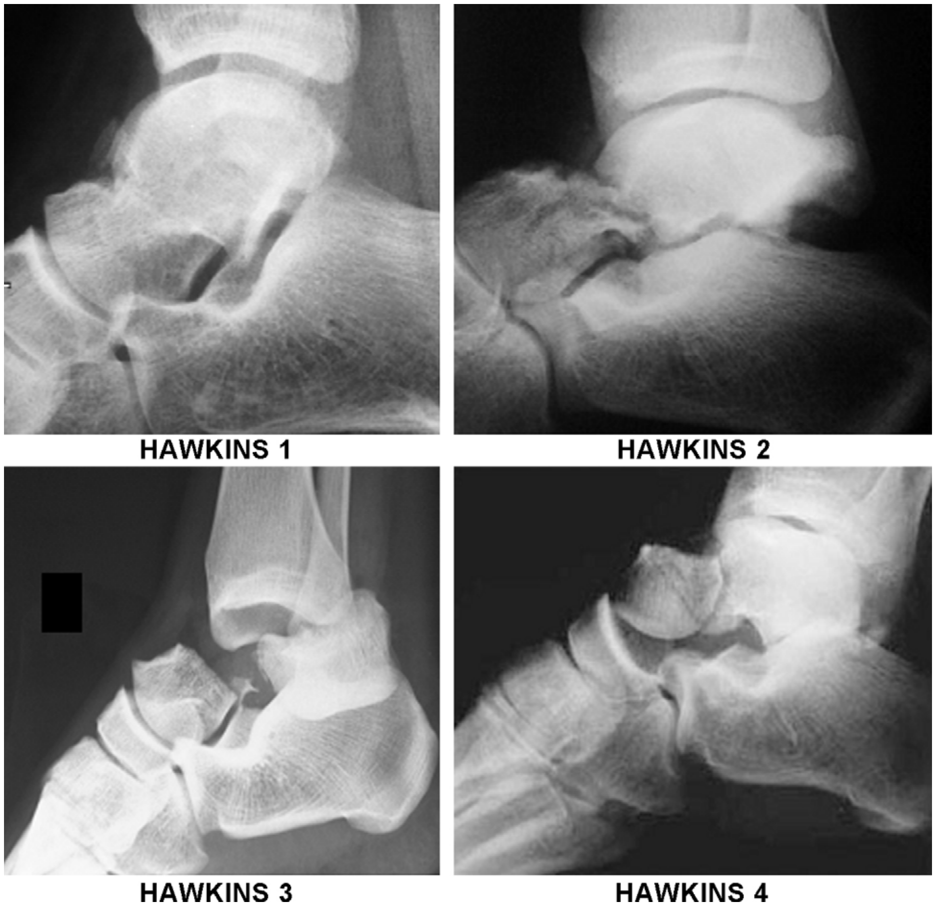

Figure 2 Hawkins classification.

The published articles and diagrams that corresponded to the two classification systems were provided to the four observers. Six weeks after the images were first read, the same files were analysed again after changing the order in which they were presented.

The kappa (κ) coefficient for inter-rater agreement was calculated for each study parameter. This correlation coefficient is most commonly used in this type of study [21—24] since it was introduced by Cohen in 1960 [25]. The calculations were performed with MedCalc© software (version 12.1.4.0).

Based on its value, the κ coefficient is summarized according to Landis and Koch [26]:

- above 0.8: excellent correlation;
- between 0.6 and 0.8: good correlation;
- between 0.4 and 0.6: moderate correlation;
- below 0.4: poor correlation.

For the inter-observer analysis, only the first reading of the X-rays and CT scans was used, to avoid any recall bias.

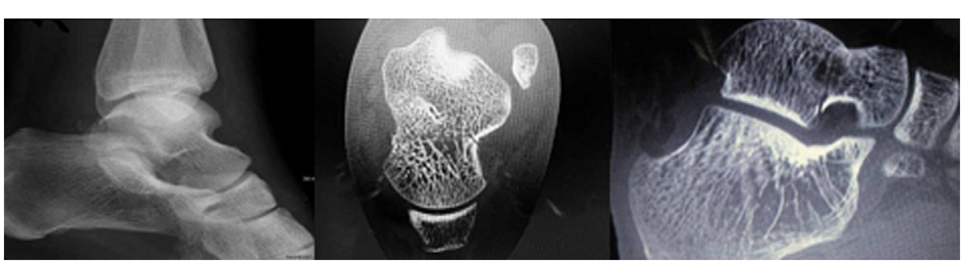

Figure 3 A Type 0 fracture in the 2011 SOO-modified Hawkins classification: X-rays and CT scan from the same patient in the 2011 SOO series.

Table 2 Inter-observer correlation for the 2011 SOO-modified Hawkins fracture classification and AO/AOT fracture classification.

	Hawkins modified SOO 2011	Hawkins modified SOO 2011	AO/AOT	AO/AOT
Observers	Kappa X-ray	Kappa CT scan	Kappa X-ray	Kappa CT scan
A/B	0.303	0.795	0.386	0.435
A/C	0.160	0.446	0.188	0.353
A/D	0.446	0.501	0.200	0.251
B/C	0.369	0.611	0.087	0.358
B/D	0.487	0.592	0.216	0.240
C/D	0.370	0.595	0.126	0.300
Average κ	0.356	0.590	0.201	0.322
Paired t-test	0.234 ($p<0.02$)	0.122 ($p<0.03$)		

For the intra-observer analysis, differences between the X-rays and CT scans were considered as being statistically significant when the 95% confidence intervals (CI) for the κ coefficient did not overlap ($p < 0.05$) [22,23]. Since there were few options for some of the questions asked (2 or 3 for the fracture characteristics), the 95% CI were large and often overlapped.

A paired Student's *t*-test was used to compare the average kappa scores; the differences were significant if the *p* value was less than 0.01 [21].

Results

SOO-modified Hawkins classification and AO/AOT classification systems

Inter-observer (six comparisons of the four observers 2 by 2)

For the X-ray portion, the inter-observer correlation was poor, both for the modified Hawkins classification (poor correlation four times, moderate correlation two times; average kappa value = 0.356, poor correlation) and the AO/AOT classification (poor correlation 6 times; average kappa value = 0.021, poor correlation) (Table 2).

For the CT scan portion, the inter-observer correlation was better, especially for the modified Hawkins classification (good correlation two times, moderate correlation three times, poor correlation one time; average kappa value = 0.590, moderate correlation) but not so much for the AO/AOT classification (moderate correlation one time, poor correlation five times; average kappa value = 0.322, poor correlation).

The differences between the κ coefficients for the X-ray and CT scan portions were not significant for each of the two classification systems (X-ray: $p < 0.02$ and CT scan: $p < 0.03$).

Intra-observer (four comparisons)

For the X-ray portion, the correlation was moderate 3 times and poor 1 time for the modified Hawkins classification; the correlation was poor 4 times for the AO/AOT classification (Table 3).

For the CT scan portion, the correlation was better, with no occurrences of a poor correlation between the two readings for the same observer. For the modified Hawkins classification, the correlation was good 3 times and excellent 1 time. For the AO/AOT classification, the correlation was moderate 3 times and good 1 time.

However, this difference between the X-ray and CT scan portions was only statistically significant ($p < 0.05$) for

Observer A (Hawkins classification) and Observer B (both classifications).

If the κ coefficient averages for the four observers are taken into consideration, this difference was statistically significant ($p < 0.01$) only for the AO/AOT classification.

Fracture characteristics (6 parameters)

Inter-observer (six comparisons of the four observers 2 by 2)

For the X-ray portion, the correlation was moderate (eight times) or poor (28 times) (Table 3).

For the CT scan portion, the correlation was better: good (six times), moderate (23 times) or poor (seven times).

Nevertheless, the differences between the averages for the six pairs of observers were statistically significant for only three of the six parameters ($p < 0.01$).

Intra-observer (four comparisons)

For the X-ray portion, the correlation was good (one time), moderate (15 times) or poor (8 times) (Table 4).

For the CT scan portion, the results were better: excellent (seven times), good (11 times) or moderate (six times) correlation.

However, this difference between the X-ray and CT scan portions was only statistically significant ($p < 0.05$) twice.

If the κ coefficient averages for the four observers are taken into consideration, this difference was statistically significant ($p < 0.01$) for five of the six parameters. Only the fracture line involvement of the TT joint did not follow this pattern, but the *p*-value did suggest the same trend ($p = 0.037$).

Discussion

Proper analysis of talar fractures is required to choose the appropriate surgical approach and fixation method, and as a consequence, improve the outcome.

Table 3 Comparison of the intra-observer correlations.

Observer	X-ray kappa	Category	CT scan kappa	Category	*p*
A					
Hawkins	0.395	Poor	0.812	Excellent	< 0.05[a]
AO	0.220	Poor	0.498	Moderate	
Fracture location	0.415	Moderate	0.625	Good	
Orientation of fracture line	0.318	Poor	0.588	Moderate	
Subtalar	0.402	Moderate	0.726	Good	
Tibiotalar	0.519	Moderate	0.827	Excellent	
Talonavicular	0.264	Poor	0.539	Moderate	
Comminuted	0.426	Moderate	0.683	Good	
B					
Hawkins	0.462	Moderate	0.772	Good	<0.05[a]
AO	0.376	Poor	0.691	Good	<0.05[a]
Fracture location	0.38	Poor	0.657	Good	
Orientation of fracture line	0.403	Moderate	0.637	Good	<0.05[a]
Subtalar	0.539	Moderate	0.719	Good	
Tibiotalar	0.545	Moderate	0.885	Excellent	
Talonavicular	0.361	Poor	0.541	Moderate	
Comminuted	0.568	Moderate	0.875	Excellent	
C					
Hawkins	0.598	Moderate	0.695	Good	
AO	0.328	Poor	0.463	Moderate	
Fracture location	0.367	Poor	0.72	Good	
Orientation of fracture line	0.426	Moderate	0.79	Good	
Subtalar	0.602	Good	0.866	Excellent	
Tibiotalar	0.444	Moderate	0.941	Excellent	
Talonavicular	0.480	Moderate	0.723	Good	
Comminuted	0.449	Moderate	0.806	Excellent	
D					
Hawkins	0.453	Moderate	0.746	Good	
AO	0.278	Poor	0.493	Moderate	
Fracture location	0.458	Moderate	0.724	Good	
Orientation of fracture line	0.326	Poor	0.624	Good	
Subtalar	0.492	Moderate	0.880	Excellent	<0.05[a]
Tibiotalar	0.507	Moderate	0.588	Moderate	
Talonavicular	0.278	Poor	0.480	Moderate	
Comminuted	0.268	Poor	0.585	Moderate	
Averages[b]					
Hawkins	0.477	Moderate	0.756	Good	0.025
AO	0.300	Poor	0.536	Moderate	< 0.01
Fracture location	0.405	Moderate	0.681	Good	< 0.003
Orientation of fracture line	0.368	Poor	0.660	Good	< 0.002
Subtalar	0.508	Moderate	0.798	Good	<0.008
Tibiotalar	0.504	Moderate	0.810	Excellent	0.037
Talonavicular	0.301	Poor	0.520	Moderate	< 0.01
Comminuted	0.428	Moderate	0.737	Good	< 0.001

[a] No overlap in the 95% CI ($p<0.05$).
[b] Paired Student-s *t*-test ($p<0.01$).

In this study, we evaluated X-rays and CT scans separately. The logical approach would be to assess and classify the fractures with X-rays, and then use the CT scan to confirm or deny the X-ray analysis results. However, such an approach would increase the risk that the X-ray readings would be corrected after reading the CT scan, which we wanted to avoid. The X-rays and CT scans were read separately, so they could not be linked to each other. Also, during the second read that took place six weeks later, we changed the order in which the files were presented, so that the raters did not remember any patterns from their first round of readings.

The fracture patterns analysed here (location, orientation of main fracture line, joint surfaces involved in fracture, comminution) are common to all articular fractures so they will not be discussed

Table 4 Inter-observer correlation for the fractures characteristics.

	Fracture location		Orientation of fracture line		ST involvement		TT involvement		TN involvement		Comminution	
	RX	TDM	RX	TDM	RX	TDM	RX	TDM	RX	TDM	RX	TDM
A/B	0.132	0.494	0.107	0.442	0.287	0.547	0.548	0.517	0.538	0.412	0.355	0.541
A/C	0.16	0.533	0.188	0.337	0.11	0.588	0.491	0.625	0.316	0.355	0.253	0.524
A/D	0.341	0.474	0.124	0.478	0.448	0.524	0.382	0.327	0.17	0.355	0.153	0.441
B/C	0.44	0.613	0.364	0.487	0.394	0.544	0.4	0.759	0.229	0.472	0.122	0.389
B/D	0.365	0.492	0.083	0.374	0.538	0.759	0.371	0.54	0.361	0.472	0.206	0.478
C/D	0.289	0.334	0.206	0.573	0.264	0.748	0.437	0.4	0.17	0.409	0.278	0.637
Average κ	0.288	0.49	0.179	0.448	0.34	0.619	0.438	0.528	0.297	0.412	0.228	0.5
Paired t-test	0.202		0.27		0.278		0.09		0.115		0.274	
	($p < 0.02$)		($p < 0.002$)		($p < 0.01$)		($p = 0.23$)		($p = 0.103$)		($p < 0.002$)	

here. Conversely, there is no consensus on classification.

Many of the classification systems include the concept of subluxation or dislocation of peritalar joints. They will not be discussed in detail here, as they are consistent with each other. The Hawkins classification that was modified by Canale and Kelly is indispensable as it is the most heavily used, and its ability to predict post-traumatic avascular necrosis is well established [2,5,8,18]. We made minor modifications to include frontal talar body fractures, as Witvoet and Butel [15] and Marti [16] had also done. As both they and we believe, if the main fracture line is in the frontal body, it must be addressed as a neck fracture since they both have identical mechanisms and displacements. However, if the fracture line is within the body, the risk of necrosis for the posterior fragment is higher than in neck fractures because the detached fragment is no longer being vascularized by the tarsal sinus. The risk of osteoarthritis is also probably higher when the TT and ST joint surfaces are involved.

We added a Type 0 fracture, which could be an indication for conservative treatment. We also added the concept of comminuted fractures, as reduction is more difficult, and added the combination of ankle and hind-foot injuries (e.g. fracture of the thalamic part of the calcaneus), because these would be detrimental to the functional outcomes and increase the risk of osteoarthritis.

As with our modified classification, the AO/AOT classification also includes the concept of comminuted fractures, but it does not provide a mechanism to identify frontal body fractures with dislocation of one or more peritalar joints, similarly to the Sneppen classification [17]. It should be pointed out that even in ''true'' talar body fractures, a fragment from the body can sublux or dislocate; none of the classification systems takes this into account.

Our results showed that CT scans were better than X-rays, although not all the parameters evaluated were statistically significant. Thus it is absolutely necessary that a CT scan be performed when a patient presents with a talar fracture, even if the fracture appears simple and not displaced. The CT scan can often show secondary fractures lines that involve the peritalar joints and even a posterior ST joint subluxation that does not appear on X-rays; this would change the Hawkins classification from a Type I to a Type II fracture.

But why were the CT scan inter- and intra-observer correlations so poor in our study?

Since there was no mechanism to classify frontal talar body fractures with dislocation of the posterior fragment, this could have led to the observers making different choices among the different types of AO/AOT classification. We were surprised by the weak correlation with the SOO modified Hawkins classification. However the correlation (0.795) was good and nearly excellent between the two senior raters who were lower limb specialists. Even with a CT scan, it is hard to discern between a Type II fracture with moderate subluxation of the posterior ST joint from certain Type I fractures. It is plausible that a displacement greater than 2 mm in the frontal fracture line can only occur if there is the same amount of subluxation in the posterior ST joint.

It is relatively easy to explain the differences between observers and between two readings from the same observer when it comes to fracture characteristics:

- location of the fracture line (body, neck or neck-body?): for example, if the line that passes through the body in its upper section detaches a tiny part of the posterior ST surface in its lower section, one rater might have responded ''neck-body fracture'' while the other may not have considered it and answered ''neck fracture'';
- orientation of main fracture line (frontal, sagittal or mixed?): the CT scan often showed multiple fractures lines instead of only one; these were located in multiple planes and sometimes had horizontal fracture lines that were not included in the study protocol; this may have led the observers to answer very differently for the same fracture;
- does the fracture line involve the posterior ST, TT and TN joints (yes or no?): as for the fracture location, the multiple slices and reconstructions may have led some observers to take into account fractures that detached a tiny part of a certain joint surface or secondary fractures that end in one of these joints, which would have resulted in a poor or moderate correlation between these evaluations;
- comminuted fracture (yes or no?): The CT scans very often showed a certain amount of comminution. We know that evaluating this comminution is subjective and can be confusing.

Conclusion

Although this study has its limitations, it showed that CT scans were clearly better than X-rays. Thus a CT scan is mandatory when treating a talar fracture, even if it appears simple or not displaced on X-rays.

The inter- and intra-observer correlations were mediocre for the fracture classification and the analysis of main features.

Of the two classification systems evaluated, the AO/AOT classification seemed less useful to use, as it does not provide a way to classify frontal talar body fractures associated with dislocation of one or two peritalar joints. Furthermore, two published studies have shown that this classification system did not have a prognostic value in both neck and body fractures [27,28]. The Hawkins classification is easy to remember, has the advantage of evaluating the risk of post-traumatic necrosis, and can also be used with frontal talar body fractures; however the prognosis of the latter could be different than with neck fractures of the same type (greater risk of posterior fragment necrosis?). This classification was introduced in 1970, when CT scans were not yet available to precisely determine fracture lines and displacements. These findings led us to propose modifications that do not compromise the Hawkins classification as modified by Canal and Kelly. These should be validated in other studies that could establish a correlation between the new individualized fracture sub-groups and the relevant outcomes.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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