Radiographic Investigation of the Distal Extension of Fractures into the Articular Surface of the Tibia (The RIDE FAST Study)

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Purpose: Distal third tibial shaft fractures are known to have a high rate of associated posterior malleolar fractures, and this phenomenon is well documented in the literature. Occult intra-articular fracture involvement can be difficult to diagnose on plain film radiographs. This may lead to CT evaluation of many tibial shaft fractures, at the cost of additional radiation and financial burden. No studies have previously investigated whether specific plain radiograph fracture characteristics in the tibia are predictive of distal intra-articular involvement (DII). The purpose of this study is to determine whether the geometry of the fracture plane in the tibial shaft is predictive of involvement of the distal tibial articular surface.

Methods: All patients presenting to our academic Level I regional trauma center between January 2010 and December 2015 with a distal tibial shaft fracture were captured using an IRB-approved university database. Patients with fractures proximal to the tibial isthmus were excluded. Plain radiographs and CT scans obtained at the time of clinical evaluation were examined to determine the location of the fracture, intra-articular involvement, and measure predetermined geometric parameters. On both the AP and lateral radiographs the following parameters were measured: (1) angle between the predominant fracture line and the plane of the tibial plafond (α-angle), (2) length of the fracture, (3) distance from the most inferior extent of the fracture to the tibial plafond (DTP), (4) width of the tibial plafond, and (5) width of the tibial isthmus. Finally, the ratio of fracture length to DTP (fracture to plafond ratio [FTP]) was calculated to produce a single, dimensionless number, independent of the effects of radiograph magnification or tibial size (Fig. 2). Measurements for established cohorts of patients with and without DII were compared. Simple logistic regression was utilized to examine the relationship between the above measurements and DII. Receiver operating characteristic (ROC) curves were created for variables significantly associated with DII. Backwards stepwise multivariable logistic regression was performed to identify measurement independently associated with DII with a leave criteria of $P > 0.05$.

Results: 217 patients with distal tibial shaft fractures were identified via retrospective review. There were 56 (25.8%) patients with DII. Advanced statistics ultimately proved that the FTP ratio can be used as an effective screening tool to rule out DII in distal tibia fractures. Simple logistic regression reveals that several radiographic measurements including fracture obliquity, length, distance from the plafond, and the FTP ratio were significantly associated with DII (Table 1). However, many of these measurements are inter-related and, therefore, multivariable logistic regression was performed to reveal that DTP measured in the AP plane (odds ratio [OR] 0.97, 95% CI 0.96, 0.99) and fracture length measured in the AP plane (OR 1.04, 95% CI 1.02, 1.06) were independently associated with DII ($P < 0.0001$ for both). The FTP ratio was the most effective screening measurement for DII with ROC area under the curve of 0.83 (Fig. 1). A threshold FTP ratio of 0.61 produced a sensitivity of

0.88 and, most significantly, a negative predictive value (NPV) of 94% (Table 2). This testing characteristic highlights the utility of the FTP ratio as a rule-out test for DII in distal tibia fractures. Finally, patients with proximal-lateral to distal-medial fracture obliquity were associated with a 138% greater odds of DII (OR 2.38, 95% CI 1.02, 5.30).

Table 1. Simple logistic regression of radiographic measurements associated with DII

Variable	*Odds Ratio	Lower 95%	Upper 95%	P-value
AP DTP	0.96	0.95	0.98	<0.0001
AP α-angle	1.05	1.02	1.07	<0.0001
AP fracture length	1.05	1.04	1.07	<0.0001
AP FTP	8.20	4.26	17.22	<0.0001
AP fracture obliquity	2.33	1.02	5.31	0.04
LAT DTP	0.96	0.95	0.97	<0.0001
LAT fracture length	1.03	1.02	1.05	<0.0001
LAT FTP	10.00	4.78	23.23	<0.0001
LAT α-angle	1.03	1.01	1.05	0.006

*Odds ratio of having distal intra-articular extension of the tibia

Table 2 Evaluation of AP Fracture to Plafond ratio as a diagnostic test measure.

Cutoff	Sensitivity	Specificity	PPV	NPV	TP	TN	FP	FN
< 0.61**	0.88	0.6584	0.47	**0.94**	49	106	55	7
> 1.62*	0.27	0.9752	**0.79**	0.79	15	157	4	41

TP: true positive, TN: true negative, FP: false positive, FN, false negative, PPV: positive predictive value, NPV: negative predictive value

* A cut-off of < 0.61 will rule out DII with a NPV of 94%,

** A cut-off of > 1.62 will rule in DII with a PPV of 79%

Figure 1 Receiver operating characteristic curve of AP Fracture to Plafond ratio

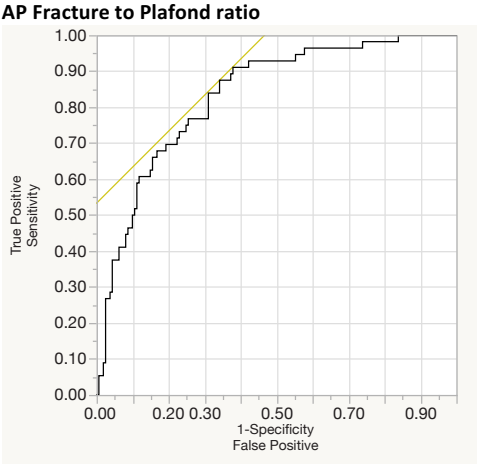
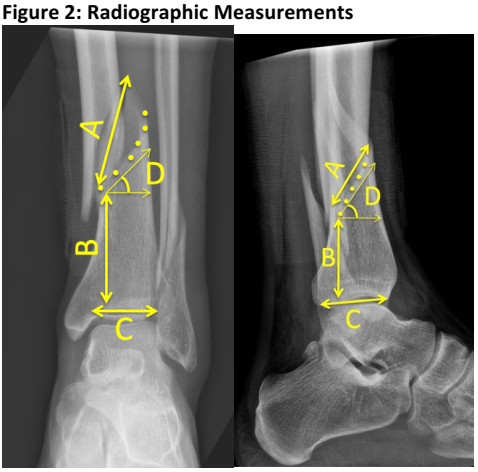


Figure 2: Radiographic Measurements



A: Fracture length
B: Distance to Plafond (DTP)
C: Width of tibial plafond
D: α-angle
●●●Fracture line

See pages 49 - 106 for financial disclosure information.

Conclusion: Involvement of the distal articular surface in patients with distal tibial shaft fractures is significantly associated with fracture geometry. Our results suggest that patients with an FTP ratio (simply the length of the fracture divided by the distance from the fracture to the plafond on an AP radiograph) of less than 0.61 likely do not have distal intra-articular extension of their fracture. With an NPV of 94%, the FTP ratio may be used as an effective screening tool for ruling out intra-articular involvement of distal tibia shaft fractures. Employment of this instrument clinically may significantly reduce radiation and expense due to CT examination in the preoperative workup of patients being evaluated for tibial shaft fractures.