

# QUANTIFYING FRACTURE ENERGY IN A CLINICAL SERIES OF TIBIAL PILON FRACTURE CASES

Donald D. Anderson, Valerie L. Muehling, J. Lawrence Marsh, and Thomas D. Brown

Department of Orthopaedics and Rehabilitation, The University of Iowa, Iowa City, IA, USA  
e-mail: don-anderson@uiowa.edu      web: poppy.obrl.uiowa.edu/OBL\_Lab\_Website

## INTRODUCTION

One of the first qualitative judgments an orthopaedic surgeon makes in fracture treatment involves looking at the injured limb and its radiographs to assess injury severity. Particularly for severe, highly comminuted fractures, important treatment decisions hinge on this judgment, including the timing and type of treatment. This in turn influences the risk for limb-threatening complications and the patient's prognosis for healing and the potential for post-traumatic osteoarthritis.

Surgeon judgments currently rely primarily upon radiographic fracture classification, identifying (using plain radiographs or CT scans) characteristic features shown to correlate with clinical prognosis. The features can be subtle, making the process highly susceptible to error and very sensitive to the level of experience of the grader. Not surprisingly, classification of comminuted intra-articular fractures has proven very problematic, with no single ordinal scale able to reliably and reproducibly provide agreement among different clinicians as to injury severity (Swiontkowski et al., 1997). This presents a problem because it limits the compilation of a collective body of literature to guide the evolution of clinical care of these patients.

We have developed and piloted a CT-based technique that has the potential to quantify the assessment of injury severity in complex fractures in a way not previously possible (Anderson et al., 2003). The technique

exploits the fundamental principle that mechanical energy is required to create new free surface area in a brittle solid (bone), and that the amount of energy required is directly related to the amount of *de novo* surface area.

In this study, fracture energy measures were used to quantify injury severity in a series of clinical fracture cases, and these measures were compared to the clinical judgment of an experienced orthopaedic surgeon.

## METHODS

Injury severity was quantified in a series of eleven tibial pilon fracture cases seen between 8/2001 and 5/2003. The patients (9 male, 2 female) ranged in age from 20 to 64 years. Comminution severity ranged from minimal to extensive.

CT studies obtained during standard clinical care were analyzed. Contralateral limb scans provided intact endosteal and periosteal bone surface areas over a comparable distal segment of the patient's tibia, for taring purposes. Bone free surface area measurements were extracted from CT datasets using validated digital image analysis routines (Beardsley et al., 2002). The *de novo* surface area liberated during fracture was estimated based on the difference between free surface areas measured on fractured and intact tibias of each patient. Local bone densities, extrapolated from CT Hounsfield units, were incorporated into a formal fracture energy measure. The clinical cases were rank

ordered by an experienced orthopaedic traumatologist in terms of lowest to highest injury severity, based on subjective appearance of A-P and lateral plain radiographs of the cases. A Spearman rank order analysis was performed to compare the fracture energy measures with the clinical rank ordering.

## RESULTS AND DISCUSSION

Bone free surface areas measured in intact tibias ranged from 8577 to 25,059 mm<sup>2</sup>. Among fractured tibias, surface areas ranged from 8722 to 30,826 mm<sup>2</sup>, yielding net liberated surface areas ranging from 2 to 75% of the intact side. (Of note, between matched intact tibias in two publicly available CT datasets, there was a less than 1.2% side-to-side variation in measured surface area.) When plotted alongside scout images of the distal tibia (Figure 1), these differences in measured bone surface areas show variation in the degree of proximal to distal fragmentation, and reflect the proximity of a given fracture to the distal tibia articular surface. The Spearman analysis comparing clinical rank ordering with the fracture-liberated surface area ranking yielded an R value of 0.72, showing good agreement. Incorporating local bone densities into a fracture energy measure increased the correlation to an R = 0.90.

## SUMMARY

We have developed estimates of the liberated bone surface area associated with a series of clinical pilon fractures. Our previous work has shown that this parameter correlates closely with fragmentation energy. Because mechanical fracture toughness is bone density-dependent, we have incorporated local material variability, available in the form of CT Hounsfield densities, into a formal fracture energy measure. The energy measures here calculated agree favorably with the clinical impression of the treating surgeon, in terms of a rank ordering of injury severity.

## REFERENCES

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**Figure 1:** A plot of bone surface areas along two fractured distal tibias shows the unique traits of different fractures.

