Quantifying Tibial Plafond Fracture Severity: Absorbed Energy and Fragment Displacement Agree with Clinical Rank Ordering

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Introduction: Intra-articular fractures often portend secondary osteoarthritis (OA), chronic pain, and decreased joint function. The success of peri-articular fracture management depends not only on how the fracture is treated, but also on the fracture type and severity. There is currently no practical means to objectively measure fracture comminution and injury severity. This is a problem because comparing results from disparate fracture series hinders compilation of a body of literature and collective experience to guide patient care, aimed at restoring joint function and forestalling OA.

We have developed CT-based methods to objectively quantify injury severity in complex fractures.¹ The methods exploit the principle that mechanical energy is required to create new free surface area in a brittle solid, and that the amount of energy required is directly related to the amount of de novo surface area. Fragment displacement and soft tissue injury are other factors of clinical significance in these cases amenable to quantification from CT.

The utility of these fracture severity assessment methods will depend first upon their ability to replicate injury severity assessments made by highly trained clinicians. In this study, CT-based measures were used to quantify injury severity in a series of tibial plafond fracture cases, and the results were compared to the clinical judgment of experienced orthopaedic surgeons.

Materials and Methods: Injury severity was quantified in a series of 20 tibial plafond fracture cases, selected from a larger group treated at our institution. The patients (13 male, 7 female) ranged in age from 20 to 64 years. Communion severity ranged from minimal to extensive.

CT studies obtained during standard clinical care were analyzed. Contralateral limb scans provided intact bone surface areas, for taring purposes. Bone free surface areas were extracted from CT datasets using validated digital image analyses.² The difference between free surface areas measured on fractured and intact tibias for each patient yields the de novo surface area liberated during fracture. Patient age and local bone densities, extrapolated from CT Hounsfield units,³ were incorporated into a formal fracture energy measure. The bone surfaces identified in fracture energy analysis were also used to quantify fragment displacement and soft tissue swelling (Figure 1).

Results: Fracture energies ranged from 11 to 53 J, and fragment displacement volumes ranged from 3.4 to 47.4 cm³, reflecting a wide variation in severity, fairly evenly distributed across the fracture series.

The concordance between the three raters ranged from 87 to 91% (Figure 2).

Discussion: The concordance rates confirm strong agreement between the subjective expert opinion of fracture severity and the objective CT-based measures. The differences in concordance between the two CT based bony metrics and the clinical rank orderings suggest that clinicians consider fragment displacement a more important indicator of severity than fracture comminution.

This constitutes the first objective, CT image-analysis-based measure of fracture severity. With further refinement, these conceptually novel methods have the potential to serve as a valuable tool, allowing one to control for this previously confounding variable in large multi-center studies.


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Figure 1: Assessment of fragment displacement and soft tissue injury began with (a) alignment of the proximal base of the fractured tibia with a mirrored image of its healthy contralateral limb. (b) Fragment displacement was indexed by calculating the volume of tissues through which fracture fragments were dispersed. (c) The volume of non-osseous regions in the fractured limb, minus the analogous intact volume, was used to quantify the degree of soft tissue swelling.

Figure 2: Agreement between injury severity rankings and CT-based metrics. The graphs compare the rank ordering of rater 1 versus that of raters 2 and 3, and of the individual CT-based metrics. Concordance values are enclosed in parentheses following the rater/metric.

The rank ordering of the fracture energy metric agreed well with the raters’ judgment, with concordance rates from 73 to 76%. The concordance rates between raters’ assessment of fracture severity and fragment displacement were higher, from 82 to 89%. The CT-based soft tissue swelling metric had agreement rates with the clinical fracture rankings of 61 to 65%.