QUANTIFYING FRAGMENT DISPERSION IN HIGHLY COMMINUTED FRACTURES

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INTRODUCTION

The assessment of injury severity in a highly comminuted fracture (one with many fragments) is a crucial prelude to treatment, guiding treatment decisions and signaling potential complications. Complexities such as the degree of comminution, axial malalignment and fragment dispersal preclude a reliable and reproducible human-based assessment of injury. This hinders progress by leaving variable injury severity as a substantial confounder in multi-center studies of treatment and outcome for specific fracture types. New validated CT-based methodologies have yielded an objective fracture severity metric [1], opening the door to studies aimed at improving patient outcomes.

While this metric has been shown to agree well with experienced clinician opinion, its full clinical efficacy is limited since it only accounts for comminution. Though comminution is a principal component of injury severity, other factors have significant implications for treatment and complications. The current study addresses this limitation by developing techniques to quantify fracture characteristics such as fragment displacement and fragment dispersal.

METHODS

CT studies were obtained from 6 tibial pilon fracture cases. The intact and the fractured tibias were segmented using a semi-automated algorithm. The mirror image of the healthy contralateral tibia provided a reference template from which fracture fragment displacement and dispersal were assessed.

Two measurements were developed to quantify the amount of fragment dispersion. One was the change in polar moment of inertia of the fractured bone compared to its intact state. Centroids and polar moments of inertia of the intact tibia and of the constellation of fracture fragments were calculated slice-by-slice, and the polar moments were subsequently summed across all slices spanning the particular limb. The intact cumulative moment of inertia was subtracted from that calculated across the fractured limb. The second measure quantified fragment dispersion directly, in a volumetric sense. In each slice, the convex hull (the smallest convex polygon circumscribing an object) of segmented bone was found (figure 1 inset). The difference in circumscribed volumes between the intact and fractured limbs reflects the amount of fragment dispersion.

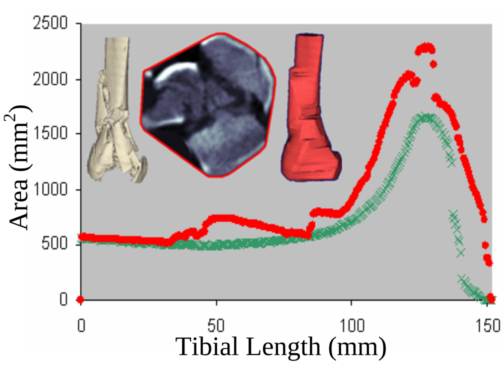

Figure 1: The area circumscribed by the convex hull for healthy (in green) and fractured limb (in red) is plotted along the tibial length. Dispersion is indicated by increases in area.

Some fractures display minor bony comminution but exhibit substantial malalignment, indicating the presence of threatening soft tissue injuries. The omission of this component results in underestimated injury severity assessments. As a surrogate for malalignment, fragment constellation displacements were calculated within each slice. The CT data contain a proximal segment of the tibial shaft that was unaffected by the fracture event (base fragment). Using the commercially available Geomagic Studio software, the fractured bone base fragment was registered in space relative to its intact contralateral template (mirrored about mid-sagittal plane) using an iterative closest point algorithm (Figure 2). Once aligned, the deviation of the fractured centroids from the healthy centroids was calculated.

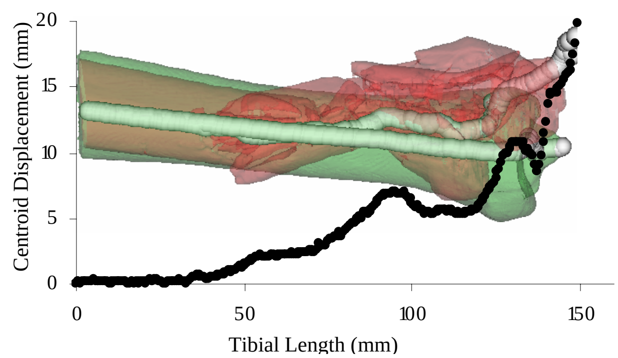

Figure 2: The transverse centroidal displacements relative to their estimated healthy positions are plotted along the tibia. Increased severity of angulation is indicated by large centroidal deviations.

RESULTS AND DISCUSSION

Fragment dispersion was measured in 6 cases with volumetric differences ranging from 14,300 mm^2 to 38,300mm^2 and cumulative inertial changes ranging from 5,800m^4 to 20,400m^4. The amount of transverse displacement ranged from 21mm to 1300mm.

The significant range in dispersion calculations illustrate the broad spectrum of injury severities presented in pilon fractures. The developed measures separate and quantify these complex characteristics, enabling their individual identification and analysis. The clinical need for an objective injury assessment compels progressive development of these measures. Future work will include the application of dispersion measures to additional cases and examination of their influence on fracture treatment and outcome.

REFERENCES

1. Anderson D, et al. Trans 50th ORS Meeting, 29, 488, 2004.

Acknowledgements

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