Investigating Tibia Stress Fracture Using FEM Analysis

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INTRODUCTION

Tibia is the most common lower extremity stress fracture site comprising about half of the cases.[1] Current approaches typically employ finite element methods (FEM) and statistical shape models (SSMs) to quantify tibial stress/strain distributions but lack explicit fracture modeling. This study addresses this limitation by developing an SSM-based FEM that explicitly models fracture formation, enabling analysis of how tibial geometry variations influence susceptibility to stress fracture.

METHODS

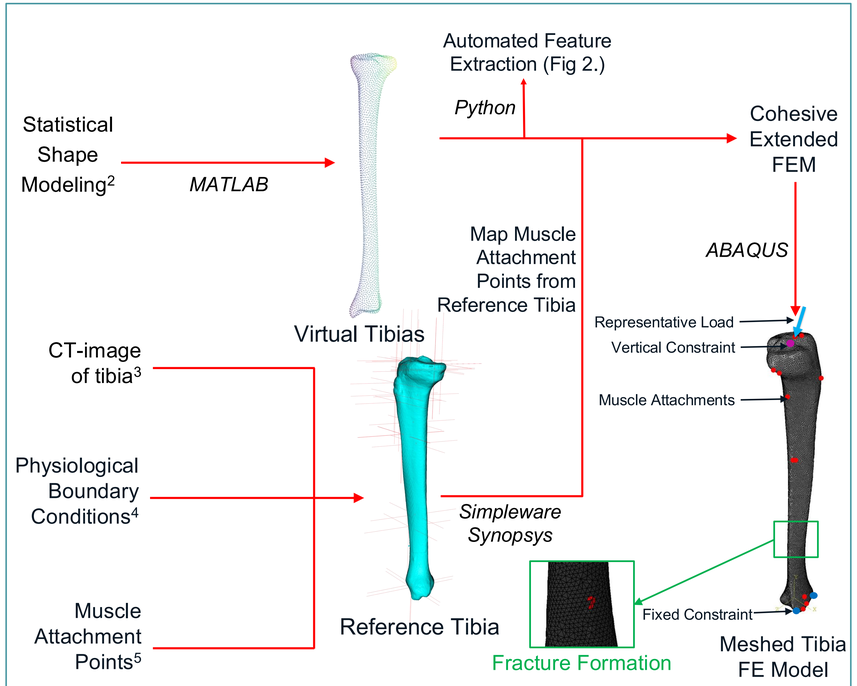

Fig 1. Workflow showing virtual tibia generation, then application of physiological loads and boundary conditions, followed by FE modeling, and finally fracture formation on anterior-distal end of tibia.

RESULTS

- Fractures initiated on the distal third and anterior side of the tibia, as shown in the green highlighted section of Fig 1.
- Tibia length and tibia widths were extracted for each tibia using a Python script (Fig. 2).
- Fracture initiation load (FIL) and tibia length demonstrated a positive correlation (R=0.89, p<0.001) (Fig. 3a).
- FIL showed positive correlation with tibia widths at 50% width (R=0.88, p<0.001), 35% width (R=0.89, p<0.001), 20% width (R=0.89, p<0.001); Fig 3b-d, respectively.
- Several samples showed lower FIL than samples of similar lengths and widths (Fig. 3)
- This may indicate that length and width may not fully capture stress fracture susceptibility.

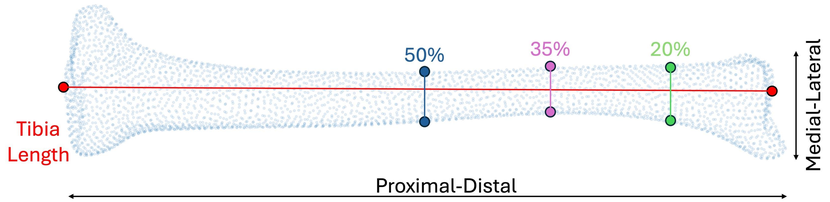

Fig 2. Schematic of tibia geometric measurements (widths measured from distal end).

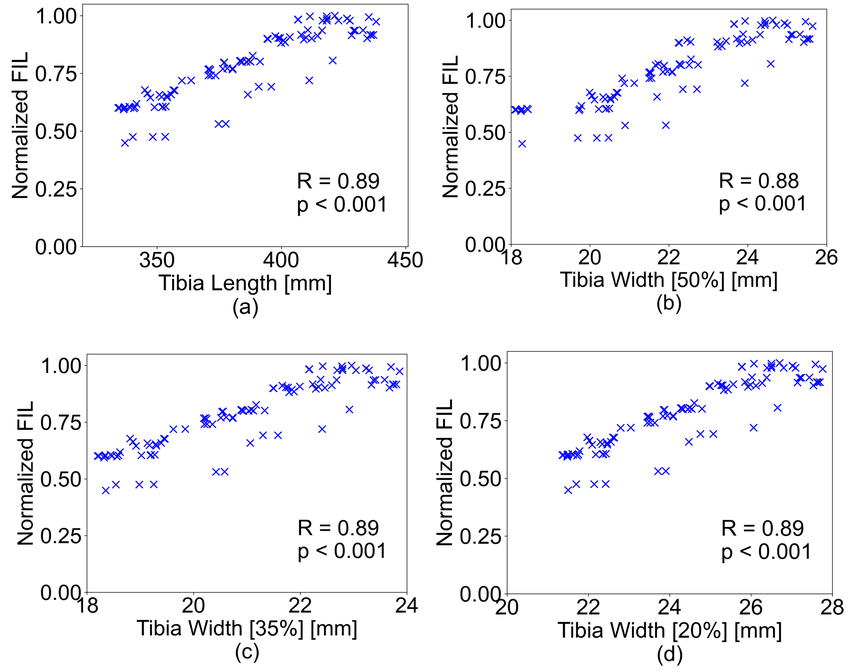

Fig 3. Plot of normalized fracture initiation load (FIL) (relative to the maximum) versus tibia (a) length (b) width at 50% (c) width at 35% (d) width at 20% length.

DISCUSSION

- This study developed a modeling approach integrating SSM- and fracture mechanics-based FEM to assess how tibia geometry influences stress fracture initiation.
- The results underscore the importance of tibia geometry in determining FIL for stress fractures.
- Future work will explore the influence of additional geometric characteristics to develop a more comprehensive understanding of stress fracture initiation.

ACKNOWLEDGEMENTS

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