"Bringing Balance to the Force": Structural Optimization and Fracture Fixation

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Hypothesis/ Purpose: Management of distal femoral fractures with extensive comminution or a large gap can be a tremendous challenge. Evaluating fracture fixation systematically could improve patient biomechanics and enhance the potential for a more predictable union. We hypothesised that under clinical conditions, the ratio between the proximal working length (WLp) and length of proximal femoral segment (lp) would have the greatest impact on the mechanical properties of internal fixation constructs for distal femur defects (Cp=WLP/lp). This study aims to determine the stress distribution and the axial stiffness of plates and screws under these conditions, and to find the best possible screw configuration for large femoral shaft defects using finite element (FE) analysis.

Method: A 3D FE model of a 50mm segmental defect of the distal femur with internal fixation was generated using Abaqus/Explicit 6.14-5 (Simula, Providence, RI). Nine different screw configurations were simulated under single leg stance during 10% of a gait cycle condition.

Result: The strength and stiffness of the fracture/plate construct was reduced when the ratio of working length (WLP=93) to the length of proximal bone (lp=315) was (Cp=WLP/lp) 0.47 for an average femur (424mm long). The maximum von Mises stress in screws was 21% less for less than 90 mm compared to more than 150mm proximal working length (146.2MPa, and 184.8MPa, respectively). Mechanical stability was achieved when screws were placed close to the fracture on either side of the gap.

Conclusion: When using internal fixation with a lateral plate for a distal femoral defect or comminution with more than a 5 cm gap, we recommend the proximal working length to be in between 60 – 155mm to minimise the risk of construct failure related to plate failure or screw loosening.