The Role of Contact Area in Regulating Interfragmentary Movement Following Proximal Femoral Osteotomy

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Summary

This study investigated how interfragmentary (IF) contact area, determined by the selection of neck-shaft angle (NSA) and anteversion angle (AVA), impacts IF movement following proximal femoral osteotomy (PFO). The results demonstrated that a reduced contact area increases IF movement, highlighting the critical role of optimizing surgical geometry to promote bone healing and union.

Introduction

PFO is a surgical intervention correcting femoral deformities in paediatric/adolescent patients. Despite the efficacy of PFO in treatment of femoral deformities, the surgery carries risks such as delayed healing in the femur. Interfragmentary movement following PFO, can affect the callus formation rate [1]. Likewise, post-op NSA and AVA may also influence IF contact area. This study examined how surgical variations in IF contact area affects IF movements during walking gait. sequentially linked and personalized neuromusculoskeletal (NMSK)-informed finite element analysis (FEA) probed how contact area, NSA, and AVA affect IF movement after PFO.

Methods

Three paediatric patients with femoral deformities underwent a thorough pre-operative biomechanical analysis involving acquisition of detailed motion capture data and computed tomography (CT) images of the lower limbs. Virtual corrective surgeries systematically incorporated three femoral NSAs (128°, 135°, and 143°) for each patient custom computer assisted design (CAD) scripts, thereby ensuring precision, and reducing human error (Fig 1).

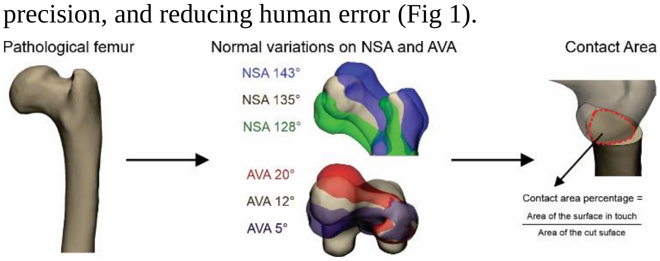

Figure 1: Resulted contact area as a function of selected surgery setup (postoperative NSA and AVA)

For each patient, walking gait data were used to determine external biomechanics (e.g., joint kinematics and kinetics) and muscle tendon unit kinematics in OpenSim [2]. Then, an electromyogram-informed NMSK model was calibrated and then used to estimate lower limb muscle and joint contact forces. These muscle and joint contact forces were then used as loading conditions within FEA of the isolated femur.

The CT imaging was used to map the material properties of the femoral bone for each patient. The femur FE models were subjected to a benchmarked 'biomechanical constraint' [3] to ensure physiological constraint during simulation. For each femur, the prescribed NSA and AVA set were applied systematically [4], implanted with the OrthoPediatrics blade plate, and the simulation conducted across the walking gait cycle. The IF movement was extracted and compared across models with different contact areas.

Results and Discussion

There was a significant negative correlation between maximum interfragmentary movement and the contact area ($r = -0.90$, $p < 0.0001$) (Fig 2).

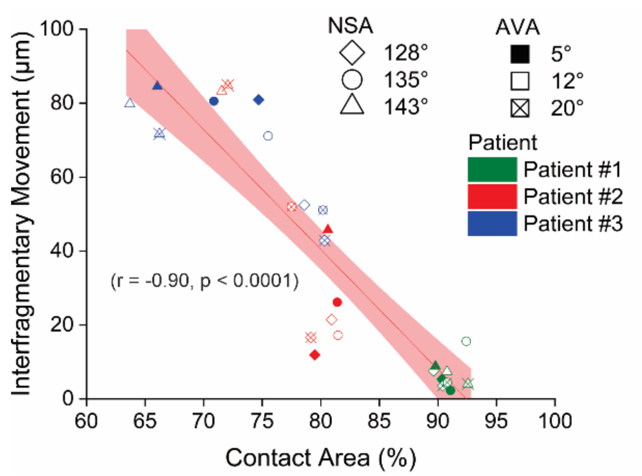

Figure 1: Peak IF movements in models with altered contact areas

Results of this analysis indicated that the resulted contact area and peak IF movements were highly patient-specific (range 5-90 μm). Additionally, the wide range of IF contact area highlights its dependence on the initial femoral geometry more so than the selected NSA and AVA.

Conclusions

The inverse relationship between contact area and IF movement suggests that maximizing contact area during PFO may help to reduce excessive postoperative IF movement, thereby creating a more favorable environment for callus formation and bone healing.

References

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