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Quantifying the Biomechanical Improvement from Mini-Plate Augmentation in Unstable Osteoporotic Fractures

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Introduction and Background

Achieving stable fixation in osteoporotic long bone fractures presents a significant clinical challenge. Surgeons often employ extended plating strategies by increasing the screw count to address poor screw purchase, yet construct failure remains common. The quantitative magnitude of biomechanical improvement using a mini-plate(MP) compared to extended plating is not fully understood. Furthermore, there is no established biomechanical standard regarding the optimal angular placement of the MP. This study utilizes finite element analysis to quantify the stability improvement provided by MP augmentation in osteoporotic bone and determine the critical angular threshold required for healing.

Material and Method

We developed 3D models of a comminuted long bone fracture using COMSOL Multiphysics. We compared two fixation strategies: (1) a conventional extended plating construct with 8 screws and (2) a construct with 6 screws augmented with a MP. We systematically varied the position of the MP from 45° to 180°. Physiological loads including 800 N axial compression and 100 N cantilever bending were applied. The optimal criterion was reducing interfragmentary strain(IFS) below 10%, the accepted threshold for indirect bone healing.

Results

In the osteoporotic model, the conventional extended plating strategy with 8 screws failed and resulted in IFS exceeding the 10% limit. In contrast, MP augmentation increased stiffness by approximately 170% and reduced IFS by 60% compared to the extended plating model. Crucially, angular analysis identified 90° as the critical threshold. MP placement at angles less than 90° failed to reduce strain below 10% reliably, whereas angles of 90° or greater consistently achieved the healing target.

Conclusions

This study demonstrates that simply adding screws via extended plating is biomechanically inadequate for unstable osteoporotic fractures. MP augmentation provides superior multiplanar stability. Clinically, this study establishes a clear guideline: to ensure the mechanical environment necessary for bone healing, the MP must be positioned at a minimum of 90° relative to the primary plate.

