Finite Element Analysis of Additional Mini Plates for Enhancing Fixation Stability in Normal and Osteoporotic Fractures

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Summary

This study investigates the biomechanical effects of additional mini-plates in osteoporotic fracture fixation using finite element analysis. The impact of mini-plates on fixation stiffness was evaluated across various screw configurations and bone densities. The results demonstrated that mini-plates significantly enhanced bending stiffness, particularly in osteoporotic models, indicating their potential to reduce reoperation risks. These findings suggest that incorporating mini-plates can improve surgical outcomes in different fracture scenarios.

Introduction

Advancements in fracture fixation, such as locking screws, have contributed to reducing failure rates. However, achieving sufficient fixation stiffness remains a challenge, especially in osteoporotic bones, where screw loosening can compromise stability. This study aims to assess the biomechanical benefits of additional mini-plates in enhancing fixation stiffness in osteoporotic fractures. We hypothesize that mini-plates can compensate for screw loosening and improve overall stability, thereby reducing complications associated with fixation failure.

Methods

Finite element (FE) simulations were performed to analyze the mechanical performance of fixation constructs under four-point bending conditions. Synthetic bone models replicating human bone geometry and material properties were developed and analyzed using COMSOL Multiphysics 6.2. Fracture models included scenarios in which screws near the fracture line were removed, simulating clinical challenges. Mini-plates were applied orthogonally to the primary fixation plate with two additional locking screws, and their effects on stiffness were quantified. Furthermore, the influence of mini-plates on osteoporotic bone models was examined. The accuracy of the FE models was validated against experimental data to ensure reliable simulation outcomes[1,2].

Results and Discussion

The use of locking screws improved mean stiffness by 57.49% (SD 14.17), with a maximum increase of 76.76% in the 3,4 screw-out scenario. Although osteoporotic bone exhibited lower stiffness improvements due to its reduced material properties, mini-plates still provided notable reinforcement. Locking screws combined with mini-plates restored stiffness to levels comparable to normal bone, highlighting their potential to mitigate reoperation risks in osteoporotic fractures.

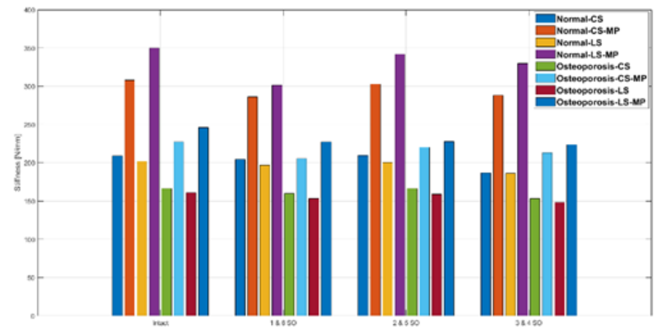

Figure 1: Stiffness comparison for all screw configurations.

From an engineering perspective, mini-plates function as structural reinforcements, resisting displacement caused by external forces. Theoretically, placing the mini-plate opposite the primary fixation plate (aligned with external forces) would yield the greatest stiffness enhancement. However, for surgical feasibility, orthogonal placement was deemed optimal. This study quantified the number of screws that mini-plates could effectively compensate for. Even in cases where two screws were removed (e.g., 2,5 or 3,4 screw-out scenarios), the mini-plate restored stiffness to intact levels or higher. Locking screws further amplified this effect, demonstrating a synergistic relationship between mini-plates and locking screws in enhancing fixation stability.

Conclusions

Additional mini-plates significantly enhance stiffness in osteoporotic fracture fixation, even when screw loosening occurs. The combination of locking screws and mini-plates provides the greatest improvement, potentially reducing the risk of reoperation. These findings support the clinical application of mini-plates as a simple yet effective method for enhancing fracture fixation stability.

Acknowledgments

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References

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