# The Effect of Plate-Bone Contact in Bridge Plating Fixation – A Parametric Finite Element Analysis

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**INTRODUCTION:** Bridge plating is a common type of surgical fracture fixation in which a plate bridges a comminuted fracture or segmental defect site. Bridge plates are inherently subject to large mechanical loads and can be at risk of yield or fatigue failure. Additionally, the interfragmentary displacements at the fracture site have importance for the course of secondary fracture healing. Over the past decade, a number of studies on bridge plating focused primarily on the relative positioning of screws in relation to the fracture, as well as the stresses on plates and interfragmentary displacements resulting from these positions [1-3]. These studies have demonstrated that longer working length generally leads to greater interfragmentary motions. In recent work in our lab, aimed at validating simplified finite element models of bridge plating, we observed plate-bone contact occurring at the near cortex, substantially altering the relationship between working length and interfragmentary motion. The role of plate-bone contact in bridge plate biomechanics has not been explored parametrically[3]. The aim of this parametric study was to generate finite element models of commercially available bridge plate constructs while varying the plate-bone distance, fracture gap size, and the inner and outer working lengths. We hypothesized that constructs with plate-bone contact would exhibit biomechanics with less dependence on screw configuration.

**METHODS:** The modeling framework in this study was based primarily on an experimentally validated model of diaphyseal bone bridge plating (submitted in a separate abstract). Using Abaqus (Dassault Systèmes), the boundary conditions, interactions, meshing, and bone geometry were maintained. A 14-hole commercial plate (4.5 mm Narrow Locking Compression Plate, 4 mm thickness, Depuy Synthes, West Chester, PA) was modeled. The main differences between the validated model's plate and the current plate were the curved profile and the difference in hole distances. After a mesh convergence test (< 5% difference in the number of elements), the commercial plate contained approximately 105,000 quadratic tetrahedral elements, with increased mesh density in the center region for stress analysis. A sensitivity analysis was performed, involving alterations in bone geometry, bone properties, the coefficient of friction between the plate and bone, and plate properties. Subsequently, three cases of fracture gap sizes that avoided bone-bone gap contact (5, 10, and 25 mm), three plate-bone distances (0, 1, and 2 mm), and five different inner working lengths (36, 73, 108, 144, and 180 mm) were modeled, resulting in a total of 45 cases. Locking screws were modeled as cylinders and were tie-constrained to the plate's holes at the head and the bone's holes at the shaft. Axial compressive loads were applied in three steps—50 N, 150 N, and 250 N. Interfragmentary displacements at the far cortex and the maximum Von Mises stress at the center of the plate were determined for each construct under axial compressive load.

**RESULTS**: Results displayed relative insensitivity of interfragmentary displacements and maximum plate stress to changes in bone geometry, bone properties, and plate-bone frictional coefficients. However, results were sensitive to changing the plate material to titanium rather than stainless steel, resulting in increased interfragmentary displacement and stresses at the plate center. Stresses and interfragmentary motions generally increased with an increased inner working length. The largest interfragmentary motions and stresses occurred in constructs with larger working lengths and a 2 mm plate-bone offset. (Fig. 1). The lowest stresses and interfragmentary motions were observed in constructs with shorter working lengths and a 0 mm plate-bone offset (Fig. 1). Constructs with plate-bone contact had consistent interfragmentary motion and stresses that did not depend on working length. This contact emerged in the 0 mm plate-bone offset for all loading magnitudes but only in the 150 N and 250 N loads for the 1 mm and 2 mm plate-bone offsets.

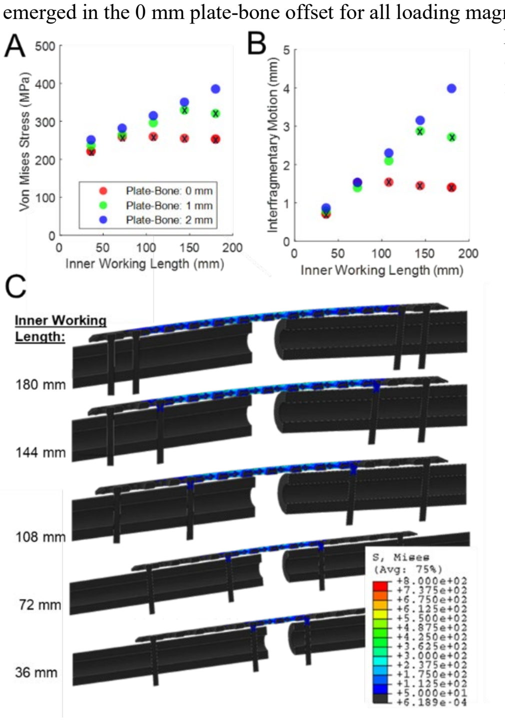


Figure 1. Plots of each plate-bone distance with a 25 mm fracture gap at 150 N of axial loading for each working length with Von Mises stress (A) and interfragmentary motion (B). The simulation results for the 1 mm plate-bone offset at 150 N for each working length (C). Cases with contact contain an "x" within the plotted point.

**DISCUSSION:** This work aimed to investigate the effects of different bridge plating constructs on a segmented transverse cut long-bone fracture, determining the effects on interfragmentary motion and Von Mises stresses of the plate center through plate-bone contact. Plate-bone contact appeared to reduce interfragmentary motions and stresses, stabilizing them even when the inner working length was increased. This contact occurred during the bending that occurred, displacing the near cortex towards the plate (Fig. 1C). Interestingly, in some cases with larger inner working lengths, plate-bone contact occurred under lower loads, thereby maintaining stresses and interfragmentary motions at lower magnitudes than constructs with shorter working lengths. The plate-bone contact effectively caused a decrease in working length and altered the general biomechanics of the construct where longer working lengths caused greater structural deformation. While initially maintaining low stresses and proper interfragmentary motions is crucial for early postoperative healing, there is a trade-off. This study showed that larger plate-bone offset increased interfragmentary motion and stress, which is similar to the findings of a previous study[2] and the distance of plate-bone is also related to the contact of plate-bone. Plate-bone contact could potentially restrict periosteal blood supply, which is also vital for biological fracture healing. The limitations of this study were that simulations are based on simplified generic bone and fracture scenarios, with the study focusing solely on surgical variables and using linear elastic simulations.

**SIGNIFICANCE/CLINICAL RELEVANCE**: This study of bridge plate fracture fixation reveals the interplay between screw position, plate-bone offset, and fracture gap in determining interfragmentary motion and plate stress important for successful union of fractures.

References:

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