

Fatigue, Yield and Rotational Resistance of a Novel Secondary Fixation for the Femoral Head

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INTRODUCTION: Over 200,000 hip fractures occur annually in the United States, with the majority affecting women over the age of 50. More than 80% of these fractures are related to osteoporosis [1]. Because so many of these fractures occur in osteoporotic bone, it is essential to understand how osteoporosis in the proximal femur influences fixation strength and overall fracture stability. Loss of trabecular bone density is well documented to be inversely proportional to both bone strength and the strength of screw fixation [2,3]. Furthermore, trabecular density loss is regional and progresses over time in the proximal femur [3]. To improve fixation in osteoporotic bone, several authors have investigated augmentation with bone cement in clinical studies, achieving mechanical failure rates of less than 5% [4,5]. Rotational movement of the femoral head against the threads of a sliding compression screw, however, can still lead to fixation loosening. To address this, a secondary fixation device is being developed. Before it can be considered for clinical application, several questions regarding its performance must be answered. This device, the Halifax Nail, consists of three wires—referred to as tri-wires—which are deployed through the nail into the cancellous bone of the femoral head, positioned just below the threaded portion of the nail. The goal of this study is to address whether the fatigue resistance of the wires is sufficient to ensure safety.

METHODS: The lag screw was deployed into a drilled hole (the minimum size of the lag screw) in a foam block (Sawbones Block, Solid Foam, 15 PCF, 40 mm Thick, SKU:1522-02) approved for simulation of osteoporotic cancellous bone, ensuring that the thread in the foam was formed by the lag screw. Each deployed lag screw was separated from each other and the edges of the foam block according to ASTM F542-23. The end of the lag screw was loaded into the MTS upper clamp, and the foam block was secured via metal vice to the base, both aligned to the axis of the MTS ram. To measure the max torque the ram in displacement control rotated at 1 degree per second. Max torque and stiffness were measured. The ASTM staircase method was used to measure fatigue.

RESULTS SECTION: The lag screw was, deployed without tri-wires, demonstrated low resistance to rotation. When tri-wires were added, rotational stiffness increased by approximately 5.5-fold, and the torque to failure increased by about 1.4-fold compared to the nail alone. The tri-wire construct also exhibited sustained resistance beyond 100° of rotation, whereas the nail without tri-wires lost stability much earlier (Fig. 1). Under cyclic loading at ±14°, the tri-wire demonstrated fully elastic behavior with no evidence of plastic deformation in either the foam block or the screw itself, even after dissection (Fig. 2). These findings confirm that the tri-wire construct markedly enhances both stiffness and rotational stability in the cancellous bone model while maintaining strength and fatigue resistance well above clinically relevant demands.

DISCUSSION: In femoral neck fractures, early resistance to rotation is critical, as even minimal displacement can generate shear forces at the bony surfaces and compromise healing. The tri-wire construct of the Halifax Nail directly addresses this challenge by providing enhanced rigidity within the first few degrees of femoral head rotation, the range most relevant to clinical stability. Notably, the tri-wire does not undergo plastic deformation even at 24° of rotation—well beyond the expected physiologic range. The measured yield torque occurs only at 60° of rotation, a magnitude with no clinical relevance. In addition, fatigue testing would require cyclic loading at rotation levels far greater than those experienced in vivo, confirming that the construct's fatigue strength surpasses clinical demands. These findings highlight the mechanical resilience of the tri-wire and its functional role in ensuring rotational stability where it is most critical for healing.

SIGNIFICANCE/CLINICAL RELEVANCE: The Halifax Nail significantly enhances initial rotational stability in femoral neck fractures, a factor essential for bone healing. Its high strength and fatigue resistance ensure reliability well beyond clinically expected conditions, underscoring its potential to improve fixation outcomes.

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IMAGES AND TABLES:

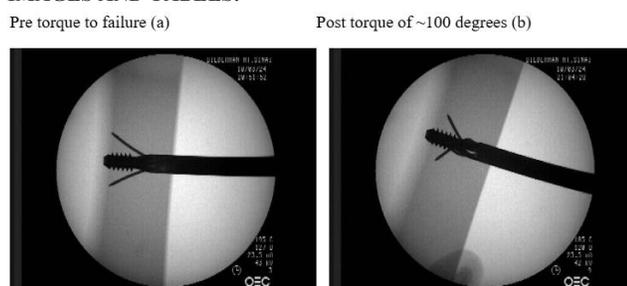


Fig.1. Confirmed permanent deformation of triwires after torque of over 100°.

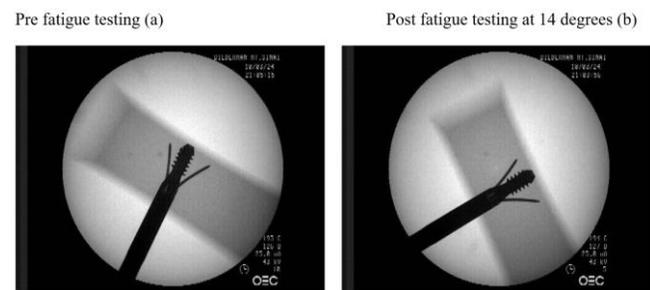


Fig. 2. Confirmation of no plastic deformation of triwires after fatigues testing at ±14°.