Fracture Compression Comparison of a Variable Pitch Locking Screw versus a Standard Locking Screw

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INTRODUCTION:
Two of the most common screw types used in orthopaedic fracture fixation are locking screws and lag screws. Standard locking screws (SLS) have threaded heads that lock into the internal fixation plates providing a rigid connection between plate and screw while cortical threads hold the bone in position. Lag screws are partially threaded at the screw end and are used to reduce two fragments, providing compression along the axis of the screw without the use of a threaded head or plate. Methods, such as the lag-by-technique approach, have been used to combine these two fixation methods by drilling a larger hole through the cortex closest to the plate (near cortex) and only threading into the far-cortex using a locking screw. However, the additional steps to perform this technique require more operating room time and pose concerns for more complex geometries. The design of a variable pitch locking screw (VPLS) aims to combine the locking-lag effect by having a locking head but a variable pitch down the screw shaft. The pitch of this screw increases down the shaft so that the second bone traverses more with each rotation than the first. The purpose of this study was to compare the fracture bone-bone compression and the plate-bone compression between a VPLS and a SLS in a cadaveric tibia model.

METHODS:
Six fresh-frozen cadaveric below-knee specimens were obtained (Anatomy Gifts Registry) and the tibias were dissected and stripped of all soft-tissue. Using a band saw, the bones were cut into three segments: (1) the anterior half, (2) proximal-posterior, and (3) distal-posterior. The proximal anterior half was fastened to extruded aluminum using a U-clamp while the distal anterior half was placed so that the remaining cortex faced downwards and the cut face upwards. The proximal-posterior segment was unused. The distal-posterior segment was laid flat onto the distal-anterior portion and a 7-hole locking plate was laid on the flat posterior aspect (Arthex Inc., Naples FL). Using the recommended drill guide, four 2.5 mm holes were drilled, one at each end of the plate and in two of the middle holes. The holes were then loosely fixed with 2 mm k-wires to prevent plate motion. A calibrated 4 kN capacity load-cell with a central thru-hole (FUTEK) was then placed in line with one of the central k-wires between distal-posterior and distal-anterior segments. Using two bone clamps on either side of the central k-wire, the plate was clamped onto the bones with a compressive force of 150 N. A single author, blinded to screw-type, was then handed a randomly assigned 50 mm long screw which was either a (1) VPLS (Kreulock Compression Screw, Arthrex), or (2) a SLS (Locking Screw, Arthrex Inc.). The screw was forwarded by hand downward through the guide-holes using the recommended driver until the locking head threads contacted the plate. Then, a digital torque wrench was used to forward the screws down until 3 Nm of torque was reached which was determined to be sufficient in providing a flush surface between the screw and the top of the plate (Fig. 1A). The same procedure was performed with the load cell between the plate and the bone to measure the plate-bone compression (Fig. 1B). Load measurements were taken at the following stages; (1) when the head of the screw made initial contact with the plate, (2) 1 Nm, (3) 2 Nm, (4) 3 Nm and (5) when the clamps were released. Each bone was tested 4 times, two bone-bone and two plate-bone, in adjacent holes in a randomized fashion. A paired, two-tailed student t-test was performed for the final stage of the unclamped constructs to test for statistical significance for both types of compression.

RESULTS:
At the final step of the procedure when the construct was unclamped, the compressive force between bones was significantly larger in the VPLS than in the SLS ($p = 0.0056$) (Fig. 2A). The compressive force was greater in the VPLS than the SLS for all measurements during the experiment. The plate-bone contact was comparable across all stages (Fig. 2B). The SLS bone-bone compression was consistently less than 150 N, the initial clamping force applied, while the VPLS consistently increased the compressive force past 150 N for every measurement stage.

DISCUSSION:
This work aimed to observe the effects of VPLS and SLS on the bone-bone and plate-bone compressive forces in locked plate distal tibia fracture fixation constructs. Bone-bone compressive forces are larger when using a VPLS when compared to a SLS while plate-bone compression is not significantly affected. The pitch transition in the VPLS seems to bring the two fracture fragments together in compression along the screw axis more than an SLS but not the plate and bone. Both the VPLS and SLS seem to compress the plate to the near cortex which is likely caused by a difference in pitch between the locking head and the shaft of the screw in both screw types. Under close visual observation, the screw types are noticeably different at the ends of the screws but close in pitch along the shaft near the head, which may provide reason for the comparable plate-bone compression results. There are inherent limitations to the cadaveric study involving no consideration for healing.

Figure 1

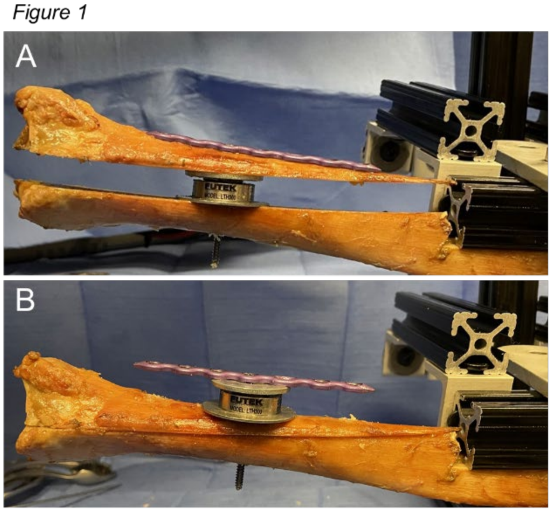

Figure 1: Experimental setup after final stage of screw insertion and the clamps removed for bone-bone compression (A) and plate-bone compression (B).

Figure 2

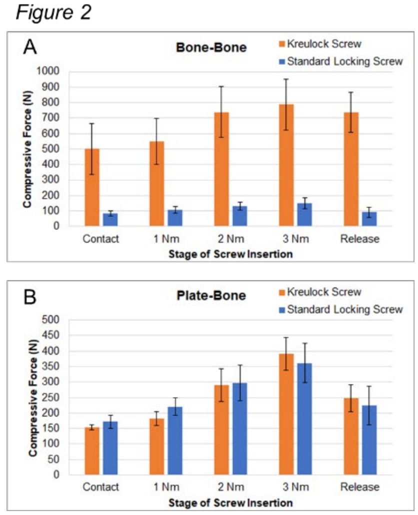

Figure 2: Plots of the average compressive forces for the bone-bone compression (A) and plate-bone compression (B). Error bars represent standard error of the means.

SIGNIFICANCE/CLINICAL RELEVANCE: The findings from this study display that a VPLS provides a similar relationship between plate and bone to an SLS in a locked plate scenario while significantly increasing the bone-bone compression which could provide for a more biomechanically stable construct under postoperative loading.

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