

Finite Element Analysis Is a Useful Tool in the Development of Orthopedic Screw Drivers

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INTRODUCTION: Screw drivers are essential instruments used in orthopedic trauma surgery. In procedures where small, cannulated screws are used, e.g., hand surgery, drivers often need to be cannulated to accommodate the use of guide wires. Consequently, drivers used in these applications have little remaining wall thickness in critical cross-sections around the tip, with small margins of safety between driver torsional strength and the torque required to fully seat even the longest screws in a set without premature driver breakage. Finite Element Analysis (FEA) offers a valuable tool for design engineers to develop strength-optimized driver tips and improve existing designs. In this study, we evaluated yield torque for different configurations of cannulated Headless Compression Screw drivers (Acutrak 3 system, Acumed®), using FEA to identify the worst-case driver for subsequent confirmation through mechanical bench testing. Based on model risk, only discretization errors were evaluated following ASME V&V 40¹. Physical tests were carried out to verify the FEA results.

METHODS: For the FEA simulation, ANSYS WORKBENCH 2022R1 was utilized. T6 (Nano), T7 (Micro), and T8 (Mini) size driver models were assessed. Each driver is available as standard cannulated, stick fit cannulated, and solid core. FEA setup was in accordance with ASTM F543-23² Annex 1. Drivers and broach models, representing screw heads, were utilized. Broach models were considered rigid. All degrees of freedom of the broach models were constrained. The hexalobe feature of the driver was then inserted into the broach. A frictional contact was defined between the driver and the hexalobe broach, with a co-efficient of friction of 0.16. Rotational displacement was applied on the other end of the driver to simulate torque application via a driver handle. Linear material properties were utilized for the drivers, which were modeled using a second order hex dominant mesh. Critical regions were identified where average cross-sectional equivalent von-Mises stresses were highest. Yield torque was defined as the moment at which the average equivalent von-Mises stress over a critical cross-section equaled the yield strength of the material. Since the yield torque is derived from average equivalent von-Mises stress across critical cross section, equivalent von-Mises stress values were considered as QOI (Quantity of Interest). Bench testing was conducted on n=5 drivers per size, using a biaxial material test system (Instron® E10000).

RESULTS: In the verification of FEA model credibility factors, the Discretization Error displayed less than 5% variation for subsequent iterations. This indicates negligible variance in QOI. As expected, solid core drivers were observed as the strongest among the driver families. Cannulated stick fit drivers were slightly stronger than their non-stick fit counterparts, owing to their tapered tip design, which increases cross-sectional area. T6, T7, and T8 non-stick fit drivers showed yield torque values of 0.52 N-m, 0.9 N-m, and 1.24 N-m, respectively. Each driver reached the yield limit at a cross section close to the top surface of the broach. Drivers also failed in this region in both static and dynamic bench tests. The yield torque variation between FEA and physical testing was less than 2% for the T6, T7, and T8 cannulated non-stick fit drivers.

DISCUSSION: The presented FEA simulation was carried out to identify the worst-case driver for bench testing (static and cyclic). Verification activities were carried out and documented, demonstrating a high degree of alignment with physical test outcomes and thereby establishing credibility of the FEA model. Based on previously conducted insertion torque testing per ASTM F543-23, the driver strength is adequate to fully insert the longest screws contained in the Acutrak 3 system. T8 cannulated non-stick fit drivers had the smallest factor of safety (2.7). It is important to note that safety factors may be reduced under real-world conditions, where worn drivers, despite being labeled as single-use, may be reused, unusually strong bone may be encountered, or manual operation as opposed to insertion via test machine can introduce bending moments in addition to the axial driving torque.

SIGNIFICANCE/CLINICAL RELEVANCE: A verified FEA model can aid in the development and design optimization process of orthopedic instruments, such as screw drivers. This holds the potential to reduce the need for physical testing, shorten product development cycles and, ultimately, contribute to accelerating improvements in orthopedic patient care.

REFERENCES: [1] Assessing Credibility of Computational Modeling Through Verification and Validation: Application to Medical Devices, ASME V&V 40, 2018. [2] ASTM F543-23, Standard Specification and Test Methods for Metallic Medical Bone Screws. 2023.

FIGURES:

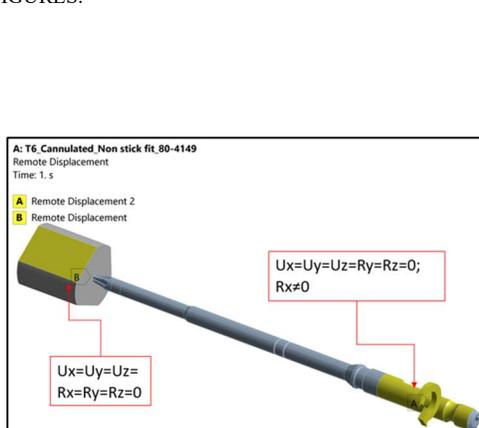


Figure 1. FEA Setup

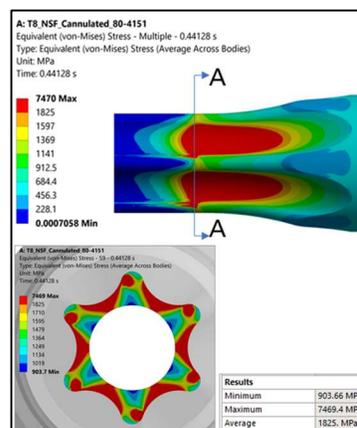


Figure 2. T8 Hexalobe Driver cannulated nonstick fit – Equivalent von-Mises stress across critical section

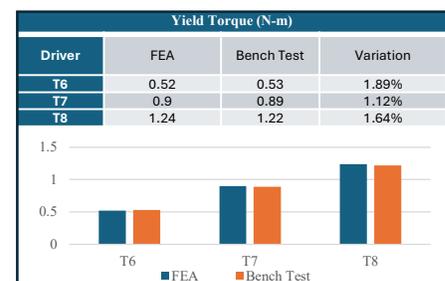


Figure 3. Yield torque, physical test vs FEA