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Influence of Oscillation Drilling on Screw Purchase: A Biomechanical Pilot Study

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ABSTRACT

Introduction. Oscillation drilling (OD) commonly is used in orthopaedic surgery to minimize soft tissue damage and control drill advancement, thereby reducing the risk of "plunging" through cortical bone. However, its effect on screw purchase compared to forward drilling (FD) remains unstudied. The purpose of this study was to compare maximal insertional torque (MIT), a proxy for screw purchase, following OD and FD in a synthetic bone model.

Methods. Pilot holes were drilled into synthetic femoral shaft models using OD and FD with three drill bit sizes (2.0 mm, 2.6 mm, and 3.2 mm). Corresponding self-tapping stainless-steel screws (2.7 mm, 3.5 mm, and 4.5 mm) were inserted into the pilot holes. MIT was measured during screw insertion using an axial torsion testing device, with five trials per condition.

Results. For 2.7 mm screws, mean MIT was 195.8 ± 47.0 N·cm (FD) versus 232.8 ± 11.8 N·cm (OD); for 3.5 mm screws, 336.8 ± 100.6 N·cm (FD) versus 357.4 ± 150.7 N·cm (OD); and for 4.5 mm screws, 943.5 ± 551.8 N·cm (FD) versus 1089.2 ± 232.2 N·cm (OD). No statistically significant differences in MIT were found between FD and OD across screw sizes ($p = 0.85$), although MIT increased significantly with the 4.5 mm screws ($p < 0.001$).

Conclusions. OD and FD produced comparable screw purchase across screw sizes, suggesting that either technique may be used without compromising fixation strength in orthopaedic applications.

INTRODUCTION

Drills used in orthopaedic surgery typically offer forward drilling (FD), oscillation drilling (OD), and reverse modes. OD frequently is employed to reduce soft tissue entanglement and to provide greater control over drill advancement, thereby minimizing the risk of "plunging" through cortical bone. Despite its widespread use, the biomechanical effects of OD on screw fixation remain underexplored in the orthopaedic literature, which has focused primarily on thermal necrosis, drill speed or feed rate, and predrilling.[1,2] One study using K-wires reported greater heat generation during OD compared with FD,[3] but no published studies to date have directly compared OD and FD in the context of screw insertion.

Screw purchase, the mechanical stability of a screw in bone, depends on factors such as pilot hole size, screw thread diameter, core diameter, and screw pitch. Maximal insertional torque (MIT) is a validated surrogate for screw purchase.[4,5] Authors of the present study examined the influence of pilot hole drilling technique (OD vs FD) on MIT across different screw sizes. We hypothesized that screw purchase would not differ significantly between drilling modes. Testing was conducted in a synthetic bone model using standard orthopaedic screws and drill bits.

METHODS

Study Design and Materials. Authors of this biomechanical study compared MIT of screws inserted into pilot holes created by OD versus FD in a synthetic femoral shaft model. Three drill bit sizes (2.0 mm, 2.6 mm, and 3.2 mm) were paired with self-tapping stainless steel cortical screws (2.7 mm, 3.5 mm, and 4.5 mm, respectively), all 34 mm in length (Stryker Corp., Kalamazoo, MI). The synthetic femoral shaft analogue (Sawbones®, Vashon Island, WA) featured a 7 mm cortical shell and 16 mm intramedullary canal, resulting in a 30 mm outer diameter, dimensions consistent with midshaft femoral models used in prior screw purchase studies.[5]

Biomechanical Test Procedure. Pilot holes were drilled at a constant speed (revolutions per minute) alternating between OD and FD, using standard orthopaedic principles. Five screws of each size were inserted bicortically (2 mm beyond the far cortex) through a washer simulating a fracture plate to allow maximal screw head compression and prevent countersinking.[6] Insertions were performed at 10 revolutions per minute under a constant 22.2 N downward load. MIT was recorded using an ElectroForce 3220 axial torsion system (TA Instruments, New Castle, DE) in accordance with ASTM F543-23 testing standards.

Data Analysis. A total of 30 trials (five OD and five FD per screw size) were conducted. Due to budgetary constraints and small sample size, no power analysis was performed. Statistical analyses included ANOVA with bootstrapping to assess the effects of screw size and drilling technique on prevailing torque, stratified by screw size, with bivariate comparisons conducted using Bonferroni post-hoc tests. Missing data were not imputed. Analyses were conducted using IBM SPSS (Statistical Package for the Social Sciences) version 29 (IBM Corp., Armonk, NY), with data compiled in Microsoft Excel (Microsoft Corp., Redmond, WA). Statistical significance was set at $p < 0.05$.

RESULTS

Prevailing Torque. Figure 1 shows the average prevailing torque by screw size and drilling technique. Torque measures with the FD technique appeared linear. Mean values ranged from 113.5 Newton-centimeters [N-cm; 95% confidence interval (CI) was (65.2, 148.9) with 999 bootstrap samples] for the 2.7 mm screws to 281.6 N-cm [95% CI (181.5, 381.7) with 1,000 bootstrap samples] for the 4.5 mm screws. Increasing torque by screw size also was noted for the OD technique; however, OD was not available for the 4.5 mm screws due to equipment limitations. No statistical differences were observed between FD and OD (t_{19} = 0.122; p = 0.904).

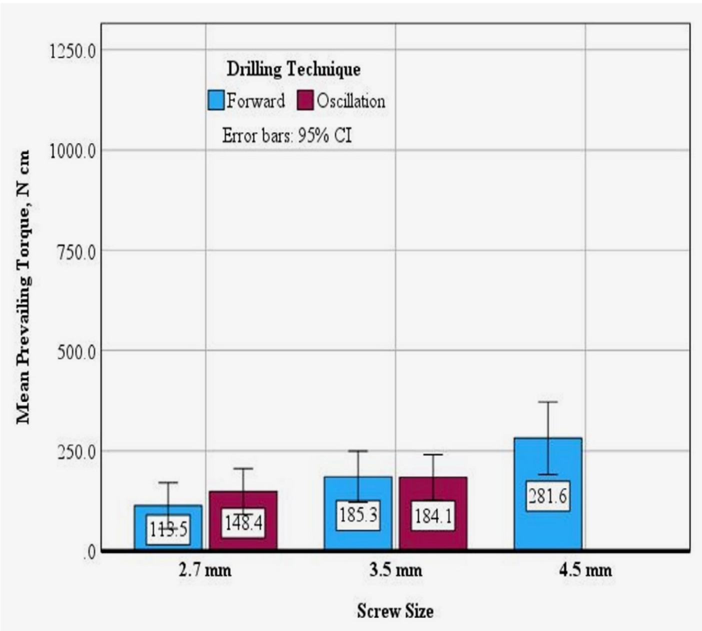

Figure 1. Mean prevailing screw torque by screw size and drilling technique.

Results from analysis of variance (ANOVA) for prevailing torque by screw size and drilling mode showed significant differences by screw size (F_2 = 5.995, p = 0.011). Results by drilling mode were F_1 = 0.368, p = 0.553, with an interaction effect of F_2 = 0.422, p = 0.525. Adjusted *R* squared was 0.296, such that approximately 1/3 of the data variability were accounted for with this model. Post-hoc tests indicated significant torque differences occurred between the 2.7 mm screws and the 4.5 mm screws where the mean difference was 150.7 N-cm [p = 0.016; the 95% CI, based on 604 bootstrap samples, was (37.9, 262.3)].

Maximal Insertional Torque (MIT). Figure 2 shows the average MIT by screw size and drilling technique. MIT measures increased by screw size and were larger for OD than for FD. Mean values ranged from 195.8 N-cm [95% CI (151.2, 229.2) with 1,000 bootstrap samples] for the 2.7 mm screws with the FD technique to 1089.2 N-cm [95% CI (881.3, 1215. 6) with 1,000 bootstrap samples] for the 4.5 mm screws with OD. Comparisons for OD and FD showed no statistically significant differences (t_{19} = 0.192, p = 0.850). However, MIT variability was notably higher for 4.5 mm screws with FD where the standard deviation was 551.8. Most of these latter trials exceeded the Bose ElectroForce torque capacity (680 N-cm) and required a calibrated torque wrench to determine MIT. Failure modes included screw head stripping (53%) and screw-bone interface stripping (40%).

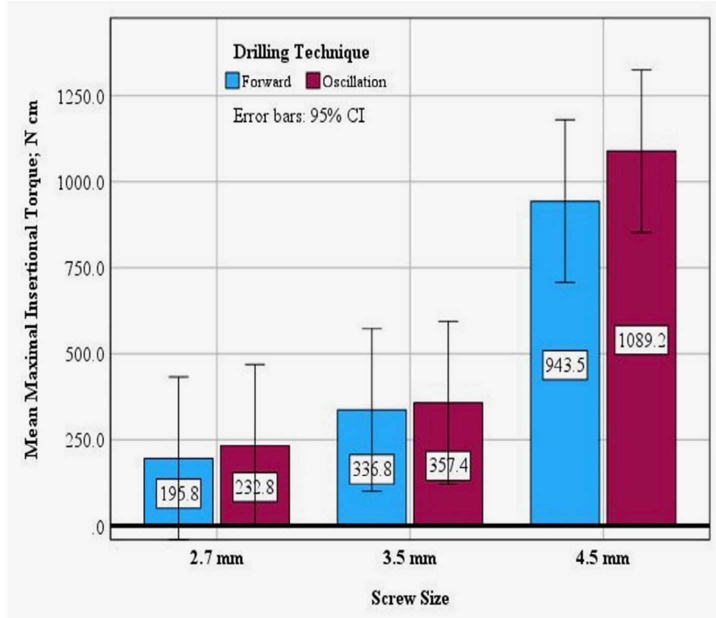

Figure 2. Mean maximal insertional torque (MIT) by screw size and drilling technique.

DISCUSSION

Our findings show that OD and FD to be biomechanically equivalent for screw purchase in a synthetic bone model, supporting our hypothesis that these drilling modes may be used interchangeably in orthopaedic surgery without compromising fixation strength. While prior studies have focused on heat generation during OD with K-wires and drill bits,[2,3] our findings suggest that any thermal effects do not impair screw purchase. The significant influence of screw size on purchase is consistent with prior work from our institution,[5] reflecting greater thread engagement with larger screws. Trends in prevailing torque data further supported the equivalence of OD and FD, despite equipment limitations encountered with the largest screw size.

Limitations. This study has several limitations. High variability in the 4.5 mm trials (SD up to 551.8 N·cm) and equipment limits (680 N·cm capacity) underestimated MIT and prevented prevailing torque capture for these screws. The use of a manual torque wrench introduced additional variability, while offset holes resulted in premature screw stripping (53%) and interface stripping (40%), potentially biasing results. Future studies could address these issues with a redesigned fixture for offset clamping and a servo-hydraulic frame with higher torque capacity, though this may reduce sensitivity. The synthetic bone model lacked cancellous bone and biologic variability, limiting clinical translation. Finally, the small sample size (n = 5 per test condition) and absence of a formal power analysis restrict generalizability, despite the use of bootstrapping.

Clinical Relevance. These findings suggest that OD and FD provide comparable screw purchase across the tested screw sizes, offering surgeons flexibility in drilling technique without compromising fixation strength. This may be particularly relevant for surgical training, where OD can be advantageous in preventing soft tissue entanglement or drill plunge.

CONCLUSIONS

OD and FD were biomechanically equivalent for screw purchase in this synthetic bone model, indicating that either technique may be used without compromising fixation strength. Larger studies using biologic models and improved biomechanical fixtures are needed to validate these findings.

ARTICLE INFORMATION

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