WHAT DO SURGEONS HEAR AND FEEL WHEN BREACHING CORTICAL WALLS AND HOW DO BREACHES AFFECT SCREW PURCHASE?

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Introduction

Freehand pedicle screw insertion is performed without intraoperative image guidance; thus, the procedure is reliant on intricate knowledge of vertebral landmarks and bone anatomy in conjunction with sense perception. Distinct audible vibration patterns created during pilot hole drilling are used to deduce whether the bit has perforated cortical walls. Tactile feedback during screw insertion, which is the feeling of torque in the hands, is used to determine if screws have breached cortical bone. The danger of screw breaching is iatrogenic injury and a potential increased risk of screw loosening and non-union. A large proportion of spine surgeons do not perform preoperative bone mineral density (BMD) scans routinely [1]. Thus, in a clinical setting, surgeons rely on these perceptions to identify breach as well as to judge the quality of bone under fixation and the extent of screw purchase. This study investigated breach diagnosis using acoustic emission (A_E) and torsional (T) profiling. Furthermore, it aimed to determine how breached screws influence fixation stability, defined using maximum insertion torque (T_{Max}), pull-out force (F_{Max}), stiffness (S), energy (E) and displacement (d).

Methods

In vitro experimental testing was conducted on 58 ovine lumbar vertebrae. Specimens were prepared and all external soft tissues were resected. Samples were randomly subdivided into three trajectory groups: Normal Insertion, N_I (n = 26), Major Lateral Breach, B_{ML} (n = 16) and Major Medial Breach, B_{MM} (n = 16). A novel rotation mechanism was used to induce breaches. Pilot holes were drilled at 1250 rpm into bones utilising an orthopedic drill and 2.5 mm surgical drill bit. A_E was captured at a frequency of 48 kHz by a custom sound sensor module. Medical grade titanium, self-tapping pedicle screws (4.5 mm x 32 mm), having cylindrical shape and possessing singular thread, were inserted at 6.0 rpm following predrilled trajectories using a specialised mechanical system. Throughout insertion, screw depth and torque were digitally recorded. A universal electromechanical test machine with custom-made fixtures was used to destructively pull screws out of bones. Screws were evulsed at 5 mm/min, whilst force and displacement data were recorded at 50 Hz. Data was collated and stratified by insertion group. All factors were subjected to one-way ANOVA analyses, which revealed statistically significant decreases in fixation properties between breached and non-breached trajectories. Tukey Kramer tests assessed post-hoc significant differences between means.

Results

Separate, one-way ANOVAs revealed that the overall effect of insertion trajectory was not significant for T_{Max} (p = 0.10) nor A_E (p = 0.40). The overall effect of insertion trajectory was significant for all pull-out test factors (p <0.01), except for stiffness (p = 0.06). Post-hoc tests indicated there were significant reductions in pull-out factors relative to N_I as summarised in Figure 1.

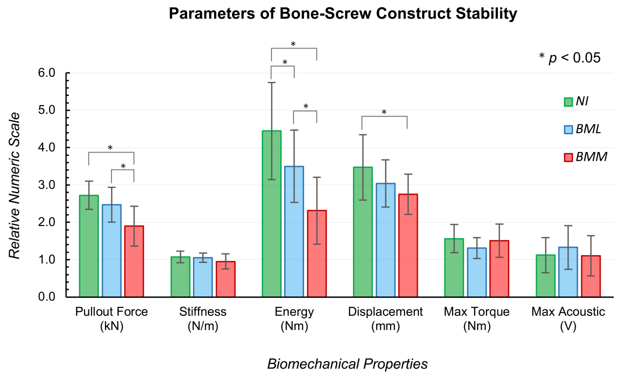

Figure 1: Mean (± SD) of biomechanical properties derived from screw insertion and pull-out tests.

Discussion

Means of A_E and T_{Max} did not differ by trajectory, however, individual insertion curves revealed specific information about the tool path through bone and breach incidence. Each group had a unique insertion profile, which is valuable in delineating distinctive resistance patterns experienced by surgeons when drilling or screwing in vertebrae. High A_E and T occur at the moment of cortical wall perforation; thus, these variables could be used to accurately identify breach. Strong signal variations provoked by changes in local tissue properties, such as density and microarchitecture, facilitate rapid detection of different material environments. Using A_E and T for continuous monitoring of cortical walls may reduce the number of dangerous breaches that have been demonstrated to significantly decrease the mechanical integrity of the bone-screw construct.

References

1. Dipaola, C. P. et al., 2009. Survey of Spine Surgeons on Attitudes regarding Osteoporosis and Osteomalacia Screening and Treatment for Fractures, Fusion Surgery, and Pseudoarthrosis. *The Spine Journal* , 9(7), pp. 537- 44.