ESTABLISHING OPTIMUM SCREW TIGHTENING TO MAXIMISE PULLOUT FORCE IN FRACTURE FIXATION

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Introduction

Fracture fixation is one of the most common operations performed around the world. Despite this, fixation failure is seen in 15-40% of cases, especially in osteoporotic fractures [1]. There are three main factors involved in construct stability that therefore contribute to fracture healing; bone density, screw design and screw insertion technique.

Evidence shows that screw insertion technique can be poor, with surgeons inaccurately predicting the stripping torque [2,3]. Further to this, there is limited information on the optimum area between seating torque and stripping torque with regards to construct stability and fracture healing [4].

The aim of this project was to identify what the optimum tightness (percentage of the maximum torque) is as a function of pullout force.

Methods

Bovine tibiae from 4-5 month old calves were sourced from a local abattoir. The diaphyses were segmented into 15 mm wide sections. Drill holes (2.5 mm) were sited using an automated drill. Specimens had 6-8 holes drilled with a minimum of 8 mm between holes. Cortical thickness was measured using digital calipers on either side of the drill hole and averaged. Bone density was measured before pullout testing using CT scanning (X Tec, XT H 225 ST, Nikon Metrology UK Ltd, Derby UK).

Cortical screws, 3.5 mm diameter (Stryker, Newbury, UK), were inserted using a screwdriver attached to a digital torque meter (Torqueleader, MHH engineering co. ltd, Guildford, UK). The screw head was tightened against a slotted washer until the desired torque value was reached. Stripping torque was measured in preliminary drill holes of various cortical thicknesses to establish what the maximum value would be for further tests. Theoretical calculations were used to confirm the expected stripping torque [4].

The washer was removed and the specimen placed on an Instron machine (Instron, High Wycombe, UK) for axial tensile testing; this was performed at 5 mm/min displacement, recording at 20 Hz until the maximum force was seen. Tests were repeated 21 times with data recorded using BlueHill 3 (Bluehill, Instron, High Wycombe, UK).

Results

Cortical thickness was found to directly correlate with pullout force ($R=0.754$, $p<0.001$) and this was used to perform linear regression on the raw data to adjust for differences in cortical thickness in the samples (pale grey data points on Figure 1). Mean bone density was 1.74 g/cm^3. Maximum pullout force was seen with insertion torques of 70-75% of the maximum for that cortical thickness, with torques past this point leading to reduced axial pullout force.

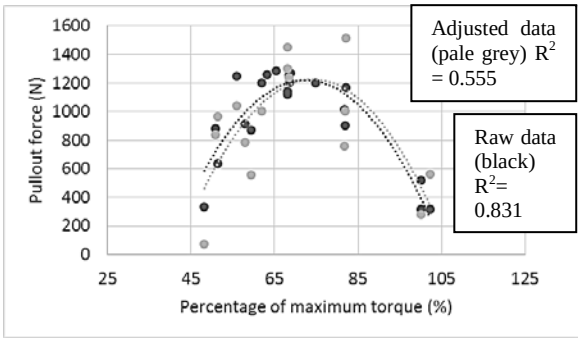

Figure 1: Pullout force as a function of percentage of maximum torque

Discussion

Whilst further assessment is needed regarding the effect of known confounding factors, such as cortical thickness and density, this data shows that exceeding 75% of the stripping torque reduces the chance of obtaining the optimum screw-bone construct. Given that torque limiting screwdrivers are routinely available in theatres, this study justifies more actively targeting the optimum zone of screw tightness given the observed reduction in pullout force seen when it is exceeded.

References

1. Hemlund et al, Arch Osteoporos, 8(1-2):136, 2013
2. Feroz Dinah et al, Geriatr Orthop Surg Rehabil 2(3):86–89, 2011
3. Stoesz et al, J Orthop Trauma, 28(1):e1–e7, 2014
4. Exp Meth in Ortho Biomech, Ch 6, Ed Zdero. 2017

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