In-vitro study of screw fixation in augmented cancellous bone models

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Introduction: Screw fixation failure in osteoporotic cancellous bone represents a surgical challenge. Augmentation of screw purchase with injectable biomaterials has been proposed, in these cases, to increase the strength of the fixation [1]. This study investigated the biomechanical conditions that improve fixation strength in an in-vitro model of osteoporotic bone with and without augmentation with injectable bone cement as well as to explore the effect of a cortical shell. It was suggested that the presence of a cortical shell is a significant factor in pullout strength of a screw [2].

Materials and Methods: An open pore foam model (Sawbones® material 1521-59) was utilised to simulate osteoporotic bone. Cancellous bone screws (Stryker 325460S \( \Phi 5 \) mm x 60mm, thread length 20 mm, pitch 2 mm), were inserted in the cancellous bone blocks to model 4 different clinical scenarios: a) screw purchase through cancellous bone only; b) screw purchase in cancellous bone traversing a cortical layer; c) screw purchase through augmented cancellous bone and, finally, d) screw purchase through augmented cancellous bone and traversing cortical layer.

In each experiment the cancellous screw was inserted into the bone block using the appropriate surgical tooling. The insertion depth for each screw was standardised to 20 mm through a pre drilled 3.5 mm pilot hole. The cortical layer was simulated by application of a Perspex layer 2 mm thick to the uppermost side of each block.

Care was taken to avoid engagement between the threads of the cancellous screw and the cortical layer. This was achieved by creating a fenestration into the cortex having the same diameter as the screw. HydroSet™ cement (Stryker) was utilised as the injection material in the augmented experiments. The cement was mixed following the manufacturer’s instructions at a room temperature of 21°C; it was transferred into a syringe and injected at 2 minutes from the start of mixing through a gauge 10 cannula in retrograde fashion into the screw pilot hole. The cancellous screw was inserted into the cement at 5 minutes from the start of mixing, when the cement was still characterised by a doughy consistency. Following screw insertion the bone blocks were immersed in PBS and stored at 37°C until the time of testing (12 minutes from the start of mixing). The bone blocks were mounted onto the jig shown in

A schematic representation of the 4 different test configurations adopted.

\[ \text{Pull-out force for each test configuration.} \]

and screws were extracted using a materials testing machine equipped with a 1kN load cell and at a speed of 5mm/minute. Ten screw pull-out tests were carried out for each of the test configurations. The maximum pull-out force was recorded for each experiment. Statistical analysis of the results was undertaken using a one-way ANOVA and LSD post-hoc test.

Results: The mean pullout strength and standard deviations for each of the test configurations are shown in . The experimental results showed the benefits of augmentation with a four-fold increase in pullout strength in the augmented foam without a cortical layer and nearly fourteen-fold increase with the augmentation in the presence of a cortical layer. A statistically significant increase in pull-out strength in open pore foam was achieved with the augmented specimens compared to the non-augmented ones. In both non augmented cases the failure modality occurred through shear of the trabeculae supporting the screw. In the augmented cancellous foam, failure occurred again, through shear of the trabeculae but this time at the cement-bone interface. In the case of the added cortical layer failure occurred through shear of the cement.

Discussion: Screw augmentation with injectable biomaterials is beneficial as it increases the strength of fixation in poor quality bone by increasing the number of trabeculae resisting the load and, in the presence of a cortical layer it can lead to the formation of a cement plug supporting the screw.


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