DETERMINATION OF POISSON’S RATIO AND HOOP STRAIN OF MORSELLISED BONE GRAFT UNDER UNI-AXIAL COMPRESSIVE LOADING

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INTRODUCTION:
Although impaction bone grafting (IBG) with the use of bone graft and cement has been used for over ten years, per and post operative femoral fractures and stem subsidence are still major complications in IBG. Heal et al. [1] summarised various reports reviewing 35 per-operative and 14 post-operative femoral fractures occurring in a total of 399 revision hip arthroplasties. Orinstein et al. [2] reported an incidence of 15% (21 of 144) and 6% (9 of 144) of peri- and post-operative fractures. Thus per-operative fractures occur more commonly than post-operative fractures. The initial stability is achieved by consolidation of graft material and initial graft compaction per-operatively. Preventing per-operative fractures is an important criterion during IBG. The aim of this study was to investigate the influence of axial force, hoop strain, Poisson’s ratio and recoil existing in the femur using a simple experimental model.

MATERIALS AND METHODS:
Porcine graft was used as it presents similar mechanical properties to human graft [3]. Porcine femoral heads were used, soft tissue and articular cartilage were removed by a scalpel and a Norwich bone mill was employed to mill the femoral heads. The graft was inspected to ensure there were no cortical fragments. The graft was then stored at −25°C and defrosted thoroughly at room temperature for two hours before use. A fixed volume of 10 cc of graft was employed in this study.

A die-plunger test was employed for uni-axial compression testing (Figure 1). Two strain gauges were mounted on a thin walled aluminium die. The ratio of internal diameter and wall thickness of the die was 19 so that hoop strain could be estimated by thin wall cylinder theory. A clearance of 0.5 mm between the plunger and die was used for fluid escape (e.g. blood and fat).

Two sets of graft material were used: normal and defatted. Defatted graft was prepared by soaking the graft in water at 35°C for 20 mins. Pre-conditioning was preformed by pre-loading the graft to 250 N. Two different loading rates (7.5 mm/s and 60 mm/s) were used to demonstrate the time dependent properties. A fixed volume of 10 cc of graft was employed in this study.

Figure 1 : Rig design.

RESULTS AND DISCUSSION:
The mean hoop strains measured are depicted in the interval plots in Figure 2. The loading rate, followed by defatting, contributed the most for fluid escape (e.g. blood and fat).

The amount of graft recoil was also measured by a vernier caliper and was defined by the change of volume after impaction when the plunger was removed. Graft recoil of approximately 40% was found. However, there were no significant factors related to graft recoil. The recoil was found to be only dependent on the final positions of the plunger, but independent to the impaction methods. Dunlop et al. [4] proposed that the defatted graft has exactly the same particle-size distribution as it does in the pre-washed state. Therefore, the shape of neo-medullary canal changes depended on the volume of the graft and the final stem position only. A lower amount of recoil is desirable as the shape of the neo-medullary canal changes immediately when the proximal impactor is removed. Overall, the general observation was that: the TCPR, hoop strain and axial force increased when the graft was defatted. However, the values of the standard error were similar and this suggested that the repeatability did not improve when defatted graft was used.

Table 1: A = Defatting, B = Pre-loading, C = Ramp.  Pareto analysis (α = 0.05) shows the relationship and interactions between targets and effects, ‘*+’ statistical significance, ‘*’ not statistical significance.

CONCLUSIONS:
High loading rates and graft defatting can significantly increase both hoop and axial force. The TCPR provides the concept of graft volume change during axial movement and allows an estimation of the shear modulus, in which the stiffness can be found by uni-axial testing. The amount of recoil is only dependent on the amount of graft and final plunger position, but independent on the impaction methods.

REFERENCES: