Introduction: Impaction bone grafting is widely used for revision hip replacement. It involves impaction of morsellised cancellous bone graft into the femur to form a neo-medullary canal. It is carried by impacting with a proximal phantom impactor. Per-operative femoral fracture is one of the concerns in impaction grafting [1]. One of the parameters that can be used to determine the possibility of fracturing the femur is the amount of stress exerted on the femur. Various authors have [1-6] studied the viscoelastic properties of bone graft. However, no study has attempted to understand the effects on the stress and the amount of recoil in the graft at different impaction rates. In terms of the clinical situation, high stress should be avoided to minimise the risk of per-operative femoral fracture however good consolidation of the graft is also essential for stable fixation. High graft recoil should also be avoided as the shape of the neo-medullary canal depends on the amount of graft deformation when the proximal phantom impactor is removed. The aim of this study was to evaluate the stress and the recoil of MCB under different impaction rates.

Materials and Methods: Porcine graft was employed in this study as it has similar mechanical properties to human graft [2,3]. Porcine femoral heads were cleared of soft tissue and articular cartilage with a scalpel and a Norwich bone mill was used 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 cm³ of graft was employed in this study. The MCB was then inserted carefully into a die for compression. The die has an internal and external diameter of 20.0 mm and 44.0 mm respectively (i.e. a thick cylinder). The plunger has a diameter of 20.0 mm and was a close sliding fit in the die. A porous disc is placed at the base of the die to allow fluid escape (Fig 1). A uni-axial compressive test was then carried out. Seven different rates of impaction were used (5, 10, 20, 30, 40, 50 and 60 mm/s). Ten experiments were performed on each of the settings (i.e. n=10). The graft was then compressed to a thickness of 8 mm. After compression, the graft was left in the die for 120 seconds to allow for stress relaxation. The graft was then extracted and the thickness was measured immediately using a vernier calliper. During the experiment, the loading history of the axial force vs. displacement was also monitored and recorded. This allowed analysis of the stress applied to the graft at different stages during impaction. Recoil is defined as the percentage change of strain in the graft. It provides an indication of the deformation of the shape of the neo-medullary canal when the phantom stem is removed. As the thickness of the graft is not uniform in the neo-medullary canal, a high level of recoil could lead to misalignment of the implant during stem insertion. A lower amount of recoil is always desired. However, this was proven to be independent to the rate of impaction.

Results: The maximum mean forces generated ranged from 5.3 kN (equivalent to 16.9 MPa) to 8.6 kN (equivalent to 27.3 MPa) at 5 mm/s and 60 mm/s respectively. This was equivalent to about 7 to 11 times body weight (Body weight=750 N). The measured forces were then transformed into stresses as shown in Fig 2 (left). As can be seen, the amount of the maximum stress increased with the rate of impaction. Statistical software package (Minitab 14.20) was used to perform statistical analysis. It was shown that there was significant difference (Student’s t-test, P<0.00) between loading rates of 5 mm/s and 60 mm/s on the amount of stress. Fig 2 (right) depicts the amount of graft recoil after 120 seconds of stress relaxation. It was found that the amount of graft recoil was about 45% and was independent of the rate of the impaction. Statistical test (Student’s t-test) also showed that there was no significant difference (P>0.28) between impaction rates of 5 mm/s and 60 mm/s.

Discussion: Since morsellised bone graft is a viscoelastic material [2], the blood, fat and marrow contribute the viscous components whilst the bone matrix demonstrates the elastic component of the graft. As a result, bone graft is a time dependent material. The viscoelastic properties are also affected by the rate of fluid escape. A lower impaction rate gives the graft more time for the blood and marrow to penetrate the porous graft matrix. Therefore, the higher the impaction rate, the higher the resulting measured stress. A high level of compression was employed so that the viscoelastic properties could be fully evaluated. In the clinical situation, high impaction energy is required for fully impacting the stem into desired position [7]. This could potentially be accomplished by lower impaction rate, high energy (e.g. using a larger drop mass and lower dropping height). The amount of recoil is a measure of the deformation of the graft. It provides an indication of the deformation of the shape of the neo-medullary canal when the phantom stem is removed. As the thickness of the graft is not uniform in the neo-medullary canal, a high level of recoil could lead to misalignment of the implant during stem insertion. A lower amount of recoil is always desired. However, this was proven to be independent to the rate of impaction.