Introduction
In vitro mechanical testing (impactions) was performed on freeze-dried irradiated morsellised grafts in a prospect of their potential use for the procedure of impaction bone grafting. The freeze-dried bone is a time honoured bone substitute used in a comprehensive range of orthopedic surgeries for the past two decades. But however its use in the revision hip arthroplasty for replacement of bone loss (impaction bone grafting) has been advised against due to the expected deleterious effects of irradiation and a lack of knowledge about its mechanical properties on impaction. With its existing advantages over the fresh frozen allograft in terms of availability, minimal risk of disease transfer and low immunogenicity, a comparative mechanical study with the fresh frozen morsellised grafts was done to have its prospective placement in revision hip arthroplasties with bone stock loss. The grafts were impacted to very high limits to know their mechanical outcome.

Materials and methods
A paired study was carried out on six human femoral heads harvested during primary arthroplasties. These heads were split into two halves in the frontal plane. One half of each head was processed and the other half was used as fresh frozen control (FF). Morsellizing was done for both groups with the same mill (Noviomagnus, Spierings, Nijmegen, NL). For the processed bone (FD) half heads were defatted, prion inactivated then morsellised. Morsels of bone were then freeze-dried and irradiated.

On calculating percentage weight loss at every stage of the treatment, it was calculated that 5 g of FF corresponded to 1.75 g FD morsellized grafts due to the loss of marrow and moisture (Figure 1). Eighteen samples of each type were randomly selected for the experiment. FD samples were rehydrated for 30 minutes in normal saline before the tests.

For each of the 36 samples, impaction procedure was performed by putting the sample in 14 mm diam. aluminium tube. A solid cylinder (impactor) was delivering a constant shock to the grafts when struck by a mass (455 g) falling over 1 meter. The impaction was interrupted regularly (at 1, 3, 5, 10, 20 and every 10 impactions up to 150) to measure the height of the column of morsellized grafts and its elastic modulus (Emod). Moreover, the procedure was stopped at 3 impactions for 4 samples, 10 for 4 samples and 50 for 4 samples. Only 6 out of the 18 samples in each group received 150 impactions. At 150 impactions the Emod of both types of grafts was the same (Figure 3). The rise in Emod was faster for the FD than for the FF. For example, 3 impactions were needed to reach a modulus of 45 MPa with the FD grafts when 50 impactions were necessary to have the same Emod with the FF control.

Results
Height: The FD samples of morsellized grafts deformed significantly more (p<0.05) than their fresh frozen controls and fitted a log scale of the number of impactions.

Stiffness: When compared to their fresh frozen control, the FD samples reached a significantly higher modulus at 3, 10 and 50 impactions (p<0.05). The compaction of FD grafts was obviously faster than the FF grafts. The treatment and lack of marrow is probably responsible for the fact that this material is more easily compacted. Well compacted layers of morsellized grafts have a higher compressive stiffness and such a state is reached with less hammer shocks on the processed bone than on fresh frozen.

Discussion
The present results demonstrated that the processed freeze-dried morsellised allograft is mechanically superior to the fresh frozen morsellized allograft in terms that it will become at least as stiff as the fresh bone, but much faster. The treatment and lack of marrow is probably responsible for the fact that this material is more easily compacted. Well compacted layers of morsellized grafts have a higher compressive stiffness and such a state is reached with less hammer shocks on the processed bone than on fresh frozen. This could have its clinical implications in saving surgical time, energy and minimising the intra-operative complications of femoral cortex fractures otherwise common during the impaction bone grafting procedure.

References
1. Slooff T.J.J.H et al. AAOS Instructional Course lectures 48, 79-89, 1999

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