Introduction
In many situations there remains a need to develop enhanced bony attachment and integration for the fixation of prosthetic implants. The more rapid and greater bone integration to the implant surface results in a reduction of adverse forces which induce micromotion and loosening. This is particularly important in situations where bone healing is compromised or initial implant stability is difficult to achieve. Also, tissue ingrowth may protect the bone-implant interface against wear particle-induced osteolysis. Porous metals have proven to be very effective in encouraging the ingrowth of bone within its structure and for the attachment of implants to the bony skeleton. The aim of this study was to investigate bone ingrowth and the strength of fixation in engineered porous titanium trabecular-like mesh implant (Trabeculite™) in an ovine animal model.

Methods
Trabeculite is unique in that implants can be made where the porosity strength and modulus can be changed according to the application. In this study we assessed bone ingrowth into completely porous implants and into implants with a solid central rod. Skeletally mature commercially cross-bred female sheep weighing between 70 and 80kg received one large cylindrical porous (70% by weight) Trabeculite™ implant measuring 15 x 20mm into the medial condyle of both the right and left femur. Animals also received three smaller cylinders (6 x 20mm) with a solid central core into the proximal, mid and distal region of their right tibia. Sheep were sacrificed at 4 weeks and at 12 weeks post-operatively. Bone ingrowth into the implants was assessed histologically and using back scattered Scanning Electron Microscopy. Strength of fixation was quantified using push-out mechanical tests.

Results
In the 12 week group all implants within the tibia were completely covered by a layer of bone. In contrast, the ends of the implants in the 4 week sample group could still be observed. Results for mechanical tests demonstrated a mean push out of 527N (±338N) in the 4 week sample group (Fig. 2). These implants pushed out cleanly from within the cortical bone. In comparison, the mean push out strength for the 12 week samples was 3137N (±657N). In one case, the load required to push-out the tibial specimen was more than what the machine could apply (5000N) and in two cases fracture of bone within the clamps occurred before failure of the implant.

Histological and scanning electron back-scattered analysis revealed that at 12 weeks in tibial specimens, up to 73% of the available bone ingrowth area was occupied with bone with the largest amount of bone ingrowth within the cortex of the implant. There was little or no bone ingrowth and the mesh was occupied by bone marrow. Osseointegration of the titanium alloy mesh occurred within the cortical bone as demonstrated using backscattered electron microscopy as seen in figure 4. Femoral specimens examined at 12 weeks demonstrated an average of 21% of the available in-growth area occupied by bone. Ingrowth occurred predominantly towards the periphery of the specimen with little or no bone seen in the centre of the implant. The parts of the implant that were ingrown demonstrated regions of both bone contact and areas where a halo of soft tissue had formed around the metal mesh (Fig 4).

Discussion
The push out tests demonstrated how well the implants were mechanically integrated into the surrounding bone. At 12 weeks bone ingrowth into the tibial specimens was extensive with over 70% of the available area grown in by bone adjacent to the cortices. In the 12 week specimens the bone used to secure the implant in the testing apparatus failed before the implant interface. In the larger specimens positioned in the cancellous bone in the distal femur, bone ingrowth was much less and was restricted to the periphery of the implant. The implant within the femoral condyles does not induce as greater bone formation as that seen in the tibial specimens. The reason for this is unclear but may be due to the way the stresses are transmitted from the surrounding cancellous bone to the implant. We hypothesized that in situations where stresses are low the well integrated mesh, because of its low structural stiffness, may transfer the load in a physiological manner and within the centre of the mesh there may be no requirement for bone to form. In more loaded situations in the tibial cortex the mesh became extensively ingrown. We therefore conclude that Trabeculite supports extensive bone formation within the mesh and the concept of trabecular mesh should be tested in a fully load bearing implant.

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References