Introduction:
Fixation in arthroplasty is paramount for long-term clinical success. Uncemented fixation requires bone ongrowth and/or ingrowth to metal substrates and/or bioactive ceramic surface coatings such as hydroxyapatite (HA) which facilitates osseointegration through osteoconduction [1]. Whilst the physicochemical properties of HA, such as microporosity [2] and crystallinity [3] are known to influence the progression and extent of osseointegration, there remains no consensus on optimal coating composition, thickness, or crystallinity.

This study examined the effects which substrate macrostructure has on osseointegration and mechanical fixation in an ovine model. A rough HA plasma-coated substrate was evaluated based on shear strength, histomorphometry and histology.

Materials and Methods:
The substrate assessed in this study is shown in Figure 1. Cylindrical dowels (8.5mm diameter, 20mm length) were prepared for bilateral cortical and cancellous implantation in an ovine hindlimb model [4]. The coating assessed in this study consisted of rough Ti particles on a CoCr substrate with an outer HA coating (100µm) applied by plasma spraying. A smooth CoCr with no coating served as the control.

The cylindrical dowels were press-fit into 8.0mm defects drilled bilaterally into the cancellous bone of the distal femur and proximal tibia (n=4 per animal). For cortical implantation, 8.5mm bicortical defects were drilled into the tibial midshaft and dowels implanted in line-to-line fashion (n=2 per animal). A total of 12 adult wethers (1.5 years) were used in this study. Implants of each type were evaluated after 4 and 12 weeks in situ. The cortical implants and surrounding cortex were sectioned perpendicular to the long axis of the implant in preparation for mechanical pushout testing using a Beuhler low speed saw fitted with a diamond wafering blade. Implants were tested for implant-bone interface shear strength using a standard push-out test [4, 5]. Specimens were tested at 5mm/min using a servo-hydraulic testing machine (MTS, Minneapolis, MA).

Following mechanical testing cortical specimens were embedded in PMMA and sectioned through the long axis of the implant using a Beuhler linear precision saw; one half then stained for histological analysis (H&E) and the remaining half prepared for electron microscopy (SEM). Scanning electron microscopy (SEM) of the cancellous sections showed significant bone ongrowth at 4 weeks (Figure 2) proceeding by 12 weeks post-operatively. Failure of the HA-substrate interface was not observed in any of the mechanically tested cortical specimens at either timepoint. Shear strength (Figure 3) of the bone-implant interface increased with time for the rough Ti and HA implant, although this difference was found not to be significant (P>0.05). Conversely, the control group (CoCr only) exhibited a decrease from 4 to 12 weeks. The rough Ti and HA coating showed significantly higher shear strength than the control coating at both timepoints (P<0.001).

Discussion:
Direct bony attachment to a substrate is a prerequisite for long-term success in uncemented fixation. The current study supports a rapid integration with the host bone when using a rough titanium and hydroxyapatite coating on a CoCr substrate. The benefits of the HA coating were evident as early as 4 weeks with a high shear strength and intimate contact between the HA and bone. Electron microscopy and histology at 12 weeks demonstrated a direct bone-implant interface with no intervening fibrous tissue and no demonstrable evidence of HA resorption. Bone appeared to preferentially attach to the HA coating supporting the osteoconductive potential of this coating.

References:

Figures:
- Figure 1 SEM of surface coatings. 10x magnification - Rough Ti and HA on CoCr substrate.
- Figure 2 Back-scatter SEM of the cancellous implantation site depicting bone ongrowth at 12 weeks post-operatively.
- Figure 3 Shear strength (MPa) at the implant-bone interface (Mean±SE).