Coating of Carbon Fibre Reinforced PEEK Implants with Titanium by Vapour Plasma Spraying for Improved Bone Apposition

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Introduction: The success of an orthopaedic implant depends on several factors, such as implant material properties, design and fixation technique as well as bone apposition around the implant. Polyetheretherketone (PEEK) is a composite thermoplastic biomaterial exhibiting biochemical and biomechanical properties suitable for load-bearing orthopaedic implants. Two advantages of carbon fibre reinforced PEEK (CFR PEEK) is its increased biomechanical properties and superior wear resistance. These properties are required for long-term orthopedic implants such as joint prosthesis and spinal cages.

However the hydrophobic surface of CFR PEEK implants induces the deposition of a peri-implant fibrous capsule preventing bone apposition which is unfavourable for stable anchorage of implants. Nevertheless this tissue reaction can be avoided by coating PEEK implants with materials known to encourage bone tissue ongrowth such as hydroxyapatite or titanium. Vacuum-plasma sprayed (VPS) titanium coatings have been successfully applied on CFR PEEK implants and it has been suggested that the biological performance of these coating should be investigated in vivo (Ha 1997).

The objectives of the present study was to compare the bone apposition on uncoated CFR PEEK screws to VPS Titanium coated CFR PEEK screws by investigating implant torque removal and bone/implant contact area.

We hypothesized that VPS titanium coated implants would have an increased torque removal and increased bone implant contact area when compared to uncoated CFR PEEK screws.

Materials and Methods: Twenty healthy mature adult female Swiss Alpine Sheep were included in this study. They were part of a larger study investigating bone healing using a tibia critical size defect model. In this model, a 7-hole custom made CFR PEEK plate and a 7 hole LCP were applied on the medial and cranial aspect of the tibia respectively. The CFR PEEK plate was locked with randomly chosen uncoated or VPS titanium coated CFR PEEK screws. Screw treatment was alternated between the two proximal and two distal holes of the CFR PEEK plate (the middle three holes remained empty). The sheep were euthanized 6 months postoperatively. The proximal screws were left in situ for histomorphometric analysis and torque removal measurements were performed on remaining screws using a Mecmesin AFTI torque-screwdriver (Mecmesin, Slinfold, UK), equipped with a 10Nm torque-cell. Data were captured at 100Hz and the peak torque was recorded.

Longitudinal sections of screws were fixed, dehydrated and embedded in methyl methacrylate. Sections (200 μm) were then cut, glued onto plastic opaque slides, ground down to a thickness of 80 μm and stained with Giemsa Eosin. Digital measurements of tissue/screw and bone/screw interface were recorded for each screw and percentage bone ongrowth was calculated.

Torque removal data and the percentage of bone on growth were compared between uncoated and VPS titanium coated screws using a Student t-test. P < 0.05 was considered significant.

Results: Torque measurements: The mean torque removal of the titanium VPS coated screws was significantly greater than that of uncoated screws (4.97 ± 1.54 Nm versus 2.3 ± 0.81 Nm; P < 0.001). None of the uncoated screws failed during torque removal and all the coated screws failed during torque removal.

Histology: the VPS titanium coated CF PEEK screws had a significantly higher percentage of bone/screw interface than uncoated CF PEEK screws (50% versus 1%; P<0.001) markedly more bone on growth compared to non coated CF PEEK screws.

Discussion: CF PEEK is becoming more frequently used in orthopaedics and traumatology due to its favourable characteristics despite poor bone ongrowth to the implants. Modifying the surface of the implant can expand the indications for CFR PEEK to include situations where good bone ongrowth is required. In this study VPS titanium coating was successful in modifying the surface to improve bone ongrowth.

Figure 1: Torque removal measurements show a significant difference between coated VPS coated screws and untreated CFR PEEK screws. VPS coated screws failed at the recorded torque; uncoated screws were removed at the recorded torque.