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In vivo evaluation of speek coated titanium implants for dental applications

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ABSTRACT

Titanium is the metal of choice for dental implants because of its biocompatibility and excellent osteointegration. In this study, the effect of the coating of titanium implants with sulphonated polyether ether ketone (SPEEK) was evaluated by in-vivo studies. The Ti implant samples were divided into 2 groups. The first group consisted of 5 Ti implants were coated with SPEEK while the second group was comprised of uncoated Ti implants which acted as the control group. These implants were implanted into rat tibia and were observed for 3 weeks. The rats were euthanised after 3 weeks, and the implants along with the attached bone were harvested and studied under a microscope. The histologic studies showed evidence of higher inflammatory response in the bone samples of coated implants when compared with the uncoated implants. The higher inflammatory response could be due to the presence of a solvent or a high percentage of sulphonation. Although the results of the study do not support the coating of SPEEK over the implants, further studies are warranted using varying degrees of sulphonation and different solvents.

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INTRODUCTION

The goal of modern dentistry is to restore the patient to normal function, speech, health and aesthetics. Restoring lost teeth using dental implants have gained wide popularity both amongst the practitioners as well as the patients due to their obvious benefits. Several research groups around the world are focussing on developing advanced implant systems which have better clinical predictability. Currently, commercially pure titanium and Ti–Al–Valloy have become the gold standard in implant dentistry, although ceramic materials with the use of zirconium dioxide and innovative metallic alloys are attracting increasing interest in implantology (Altuna, P *et al.,* 2016; Sivaraman, K *et al.,* 2018).

The main route adopted by research and industry to enhance osseointegration has traditionally entailed roughening techniques, with good outcomes in terms of bone to implant interlock. Jemat, A *et al.,* 2015 have reviewed the different surface modifications and their effects on titanium dental implants. Common roughening techniques, usually subtractive, are based on mechanical (grit blasting), chemical (acid or alkaline etch), electrochemical (anodization) and physical methods (plasma spray) (Olin, P. S., & Buhite, R. J. 2006). Other novel ways of surface modification, which are yet to explore, include Layer-by-Layer technique and bioactive polymer coating (Liu, X., *et al.,* 2004).

Sulfonated polyether ether ketone (SPEEK)

SPEEK has been demonstrated to be a biocompatible and bioactive polymer and has been experimentally proved to be useful as a bone graft material (Kalambettu, A., & Dharmalingam, S.

2014; Aravind, K., *et al.,* 2014). However, SPEEK has not been studied as an implantable material. In our earlier work, we had reported the mechanism of the coating of implants with SPEEK. In this study, we evaluated the biocompatibility of the SPEEK coated titanium implants with vis-à-vis the conventional uncoated titanium implants through in-vivo studies.

MATERIALS AND METHODS

Coating of the metals with SPEEK and implantation in rats.

The Ti implant samples were divided into 2 groups. The first group consisted of 5 Ti implants coated with SPEEK while the second group was comprised of 5 uncoated Ti implants which acted as the control group. The procedure for coating of the implants with SPEEK has been reported elsewhere. Briefly, 2g of SPEEK was dissolved in 15 ml of N-Methyl Pyrollidone in a magnetic stirrer. 5-ortho mini-implants were dipped into the solution for 2 minutes. After washing them repeatedly with deionized water, they were sterilized in an autoclave before implantation in the tibia of Wistar white rats. Image 1 shows the SPEEK coated and non-coated mini implants that were used in the study. Institutional animal ethical committee approval was obtained prior to the animal experiments. 5 Wistar white rats were chosen, and on the right tibia of each rat, one non-coated mini implant and one coated mini implant were surgically implanted 3 cm apart. After 3 weeks, the animals were euthanized, and the implants where surgical site was harvested for histologic studies. The retrieved implants were then washed with deionized water, dried and then analysed under SEM and Surface roughness was studied. The implants were evaluated for evidence of inflammation and osteointegration.

RESULTS AND DISCUSSION

The figures 1a and b show the images of the uncoated and coated implants. The surface of the implants was studied under a scanning electron microscope, and the images are shown in figure 2 a and b. In figure 2 b, the SPEEK coating can be seen as flakes completely covering the metal surface. However, the thickness of the coating was not uniform throughout the implant surface. The surface roughness of the implant before and after coating was evaluated using a surface profilometer. It was seen that the roughness increased by 4 µm after coating of the implant.

Figure 3 shows the site of implantation in the rat tibia. The histological studies showed that there was a mild inflammatory response along with osteoblasts in the coated samples (Figure 4b) when compared with the uncoated (figure 4a). However, the number of osteoblasts, as well as the density of bone, was higher in the case of uncoated implants. Though the coated samples were expected to elicit better osseointegration due to better cell signalling by the SPEEK, the results fell short of the expectations. Nonetheless, the observation of osteoblasts in the periphery of the implant surface supported the theory of better cell signalling by SPEEK. In a study by Zreiqat, H *et al.,* 2005 it was reported that the surface modification of Ti implants with alkoxide derived hydroxycarbonate apatite, enhanced the cell interaction between osteoblasts and the dental implant.

The presence of inflammatory cells with SPEEK coated implants could be a result of several factors. The most probable factors could either be the presence of a solvent (NMP) in the SPEEK residue or due to the high degree of sulphonation (24%) of the SPEEK. The observed results could also be explained by considering the effect of the surface coating on the hydrophilicity. Hydrophilic surfaces have very low contact angle values whereas hydrophobic ones reveal a contact angle of >90°C. Coating the surface with SPEEK makes the Ti surface more hydrophilic. Surface energy and wettability play an important role in the interaction with the proteins on the implant surface and influence strongly cell adhesion (Schwarz, F 2009). It is also known that macrophages would be involved in the aseptic necrosis of polymer-based orthopaedic prosthesis, which is primarily a response to polymer wear debris in the enclosed area of the implant site (Stanford, C. M. 2010, Lohmann, C. H *et al.,* 2000)

Nonetheless, this study shows that SPEEK coating on the implants could potentially improve their osteointegration. This is a pilot study, and it paves the way for further experimentation by altering the degree of sulphonation and using various solvents for the dissolving SPPEK. In addition, similar experiments could also be performed with other implants such as stainless steel and ceramic implants. However, further studies such as coating –implant bonding, the effect of varying the thickness of the coating, varying the degree of sulphonation, etc. are necessary to shed light on the SPEEK coated implants.

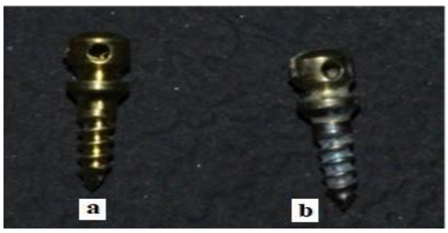

Figure 1: A non-coated implant; b-SPEEK coated implant

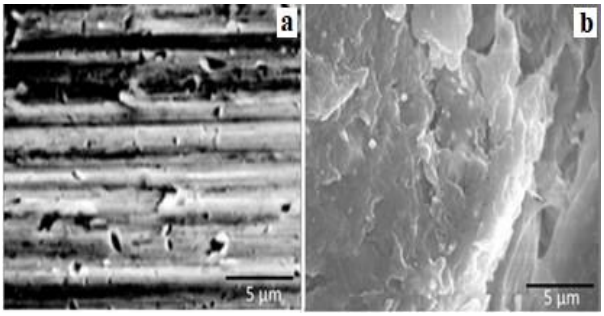

Figure 2: SEM image showing the surface of a- Non-coated implant; b- SPEEK coated implant

Figure 3: Photo of the site of implantation

Another technique of improving bioactivity includes biofunctionalization through direct integration of molecules into the coating material, which acts as a carrier system. Carriers currently in use are polylactide, polyglycolic acid, hydrogels, polypyrrole, and calcium phosphate/HA coating (Roach, P *et al.,* 2005, Tyler, B *et al.,* 2016).

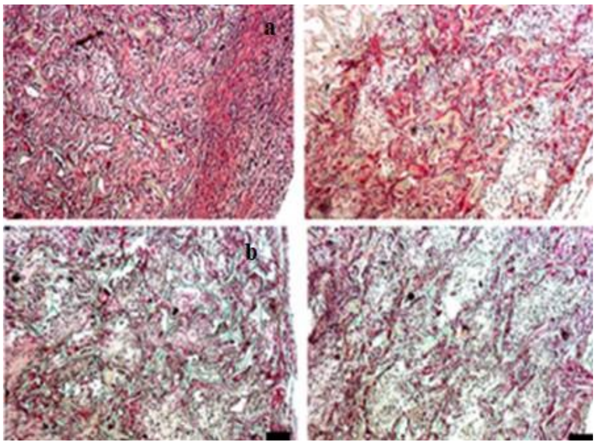

Figure 4: Photomicrograph of the histologic study of a- non-coated implant; b- SPEEK coated the implant

CONCLUSION

The main route adopted by research and industry to enhance osseointegration has traditionally entailed roughening techniques, with good outcomes in terms of bone to implant interlock. In the present pilot study, Titanium mini implants coated with sulphonated PEEK were evaluated for their biocompatibility through in-vivo studies. Although the histologic studies of the bone samples showed evidence of osteoblast proliferation around the surface modified implants, the presence of higher number of inflammatory cells when compared with the control group (uncoated samples) was a matter of concern. Nevertheless, this study showed that SPEEK coated implants need to be further evaluated through different techniques such as varying the degree of sulphonation, changing the solvent for SPEEK, time of immersion, etc.

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