ANODIC PLASMA CHEMICAL COATING OF TITANIUM SCHANZ SCREWS REDUCES PIN LOOSENING

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Introduction: Infection and bone resorption are clinical problems associated with orthopaedic implant materials and their surfaces. Surfaces that promote osteointegration tend to have lower instances of infection and prevent loosening of the implant.

Anodic plasma-chemical coating (APC) is a coating technique that includes the incorporation of high amounts of calcium and phosphates into an oxide film on titanium surfaces. This coating technique has shown to substantially increase the adhesion between the coating and titanium when compared to traditional coatings such as plasma-sprayed hydroxyapatite [1]. However, the advantages of this highly adhesive coating can only be beneficial if it also promotes osteointegration and reduces the instances of infection and bone resorption around the implant. This study compares the clinical performance, i.e. infection and loosening, of this APC coating on physiologically loaded bone pins relative to the clinical standard of anodized titanium pins.

Methods: An ovine model with a 6mm gap tibial osteotomy stabilized with an external fixator was chosen for this study as this clinical situation has a high incidence of infection and bone resorption. The external fixator consisted of a unilateral connecting rod made from carbon fiber reinforced epoxy resin with four titanium self-tapping Schanz screws (Seldrill,Synthes). The locations of the Schanz screws were labeled P1, P2, D3 and D4, where letters denote bone fragment (Proximal or Distal) and screws are numbered from proximal to distal. Two different Schanz screw surface types, i.e. anodized titanium and APC coated titanium, were studied. The four Schanz screws in each fixator had the same surface. This created two analysis groups of Ti and APC, each with six mature Swiss Alpine sheep.

During the 12 week observation period, in vivo clinical and biomechanical analysis of pin sites and fracture healing were performed. The biomechanical analysis included weekly pin track infection assessment based on a modified Chekkettes and Otterburne grading scheme [2]. Biweekly radiographs were taken and radiolucency at the pin sites was graded. At sacrifice, bacteriology was performed on obviously infected pin sites. Biomechanical assessment included weekly measurements of the in vivo tibial bending stiffness to assess the progression of fracture healing [3]. Insertion and extraction torques for the screws were also measured during surgery and at sacrifice, respectively, to assess osteointegration. For histological assessment of bone growth, two fluorescent markers were injected subcutaneously at post-operative weeks six and ten.

Parametric and non-parametric statistical analyses (as indicated with the results) were performed with a significance level of p = 0.05. All experiments were approved by the Animal Experimentation Commission of the Canton of Graubunden, Switzerland.

Results: Statistical analysis of the pin track and radiolucency gradings were performed for the data collected at six, eight and twelve weeks. Friedman tests indicated that results were significantly influenced by pin location and block-wise Wilcoxon tests were performed. There was a trend for the APC to have lower pin track grades, but this was not based on a modified Chekkettes and Otterburne grading scheme [2]. Biweekly radiographs were taken and radiolucency at the pin sites was graded. At sacrifice, bacteriology was performed on obviously infected pin sites. Biomechanical assessment included weekly measurements of the in vivo tibial bending stiffness to assess the progression of fracture healing [3]. Insertion and extraction torques for the screws were also measured during surgery and at sacrifice, respectively, to assess osteointegration. For histological assessment of bone growth, two fluorescent markers were injected subcutaneously at post-operative weeks six and ten.

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Discussion: This study used Schanz screws as an implant to test whether anodic plasma coating of calcium and phosphate ions to the surface of titanium improves osteointegration. Since the pins were used for external fixation of a gap osteotomy under weight-bearing, the interface between the implant and bone experienced physiological conditions, e.g. deformations, micro-motion, etc. Under such conditions, the APC coating promoted better osteointegration and reduced bone resorption when compared to the accepted standard of anodised titanium. The APC coated also showed a tendency for lower infection than Ti, but this was difficult to assess as infections rates with titanium in this model are already so low. Although an improvement in pin loosening did not influence bone healing, this study has shown that the APC coating improves the overall clinical performance of titanium.

The APC coating has obvious application for removable loaded implants. Reduced bone resorption about the pins would preserve structural integrity of implant/bone construct. Yet the removal force is not so high that bone would be significantly damaged during removal. The coating also has application for non-removable implants, such as hip prostheses, where good bone integration into the implant without progressive resorption is essential for success.


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Table 1. Progression of bone healing within the gap

<table>
<thead>
<tr>
<th>Healing Progression</th>
<th>Ti</th>
<th>APC</th>
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<tbody>
<tr>
<td>Normal</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Slight Delay</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Moderate Delay</td>
<td>3</td>
<td>2</td>
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Figure 1. Bone pin extraction torques (mean ± SE)