INTRODUCTION: Stable fracture fixation requires osseous integration, a process which is most often compromised by pintrack infections. Previous experimental studies have demonstrated that bony anchorage may be improved by means of various coatings. In addition, the mechanical loading of pins in external fixation is known to have an influence on the osseous integration. In a previous study that investigated fracture healing, a Poly(D,L-lactide) coating alone was shown to enhance bone healing.

The goal of this study was to analyze the influence of a Poly(D,L-lactide) coating and mechanical loading on osseous integration of Schanz’ screws and thereby reduce the risk of pin loosening in external fixation.

MATERIALS AND METHODS: Standardized osteotomies (3 mm fracture gap) of the right tibia were performed on twelve healthy female Merino sheep and stabilized by an AO mono-lateral fixator. The fixator consisted of three proximal and three distal Schanz’ screws and two carbon fiber rods. Additional Schanz’ screws were mounted on either side of the osteotomy gap. These additional screws were not connected to the fixator construct and therefore were mechanically unloaded. Each fixator consisted of two to three screws, coated by a 10µm thin biodegradable Poly(D,L-lactide) layer, that were randomly positioned. Ground reaction forces were measured in all animals throughout the experiment and X-rays were taken at weekly intervals. The sheep were sacrificed after 9 weeks and all screws were removed. The screws were then rolled back and forth across the surface of agar plates for microbiological analyses. Bone sections through the pintracks were taken for histological, histochemical and histomorphometrical analyses. The pintracks adjacent to the fracture site were excluded from these analyses due to callus effects.

Undecalcified sections, embedded in methylmethacrylate, were cut and stained with Masson-Goldner trichrome and Safranin-Orange/von Kossa. To visualize osteoclastic activity a staining method for TRAP (tartrate resistant acid phosphatase) was used. The histological sections were analyzed at the screw bone interface for the cortical bone reaction using a grading score that included histological, histochemical and histomorphometrical parameters. The parameters considered were: resorption areas around the screws, osteoclastic activity, bone density around the screw, periosteal and endosteal callus formation, cartilage, connective tissue and foreign body reactions at the screw entry site and at the screw-bone interface. The score graded the extent of osseous integration.

Quantitative Histomorphometry considered cortical bone density and periosteal and endosteal callus formation. Statistical methods consisted of a nonparametric analysis of longitudinal data.

RESULTS: During the first week animals unloaded the operated limb but returned to full weight bearing thereafter. Radiologically all animals showed regular callus formation and bone healing. Clinically, no signs of infections were visible. Microbiological analyses showed that coated screws amounted to 19% (4 out of 21) of severe pintrack infections by Staphylococcus aureus, whereas uncoated screws amounted to 32% (10 out of 31). Infected samples were excluded from further examination. Histological scoring of the residual samples demonstrated that significantly (p<0.05, Fig. 1) more osseous integration had occurred on coated screws. An intermediate tissue layer between screw and bone was observed more often in uncoated screws. In the Poly(D,L-lactide) coated screw group histomorphometrical analyses of the bone surrounding the Schanz’ screws revealed a significantly (p<0.05, Fig. 2) higher bone density at the far cortex than in the uncoated screw group (Fig. 2). Likewise there was significantly (p<0.05, Fig. 3) less osteoclastic activity seen near the screw-bone interface. Loaded screws showed more extensive new bone formation around the screw entry and exit sites, with less dense cortical bone at the screw entry site.

Fig. 2: Cortical bone density at the screw entry and exit sites of uncoated and coated screws (*p<0.05).

Fig. 3: Left side: osteoclasts per thread of the uncoated and coated screw groups (*p<0.05). Right side: Staining of acid phosphatase to visualize osteoclast activity.

DISCUSSION: Poly(D,L-lactide) coating alone was seen to enhance the process of fracture healing in rats. In the present study, Poly(D,L-lactide) coating of Schanz’ screws was found to enhance their osseous integration in sheep by causing less cortical remodeling and less osteoclastic activity in the cortices compared to uncoated screws. Additionally, it appears to reduce the instances of pintrack infections.

Mechanical conditions are essential for bone modeling and remodeling. In comparison to the unloaded screw group, loading increased the amount of callus formation seen at the screw entry and exit sites. Callus formation along the pintracks acts as a stabilizing factor allowing a closer bone-implant contact. In addition to the positive effect of the coating, the mechanical conditions appear to be beneficial to the osseous integration of a screw. Furthermore this study demonstrates a superior anchorage of screws at the far cortices, attributed to a higher cortex density and a lower osteoclastic activity compared to the near cortices. Higher drilling stress and higher loading conditions at the screw entry site may explain this observation.

In summary, the Poly(D,L-lactide) coating of Schanz’ screws demonstrated a superior osseous integration and reduced infection rates.


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