Role of implant material and surface topography on infection susceptibility in a rabbit fracture model

Willem-Jan Metsemakers, Tanja Schmid, Stephan Zeiter, Manuela Ernst, Iris Keller, Nicolo Cosmelli, Daniel Arens, T. Fintan Moriarty, R. Geoff Richards


Introduction: Implant-related infection is one of the most important complications in musculoskeletal trauma surgery today. All strategies that help to reduce these complications, will not only lead to a faster resumption of activities, it also helps to reduce the financial burden of overall healthcare costs. The fixation device used and its design can influence the susceptibility to infection. In the present study, we focussed on the role of implant material and surface topography as influencing factors on the development of implant-related infection.

Methods: The implants included were: standard Electropolished Stainless Steel (EPSS), standard Titanium (Ti-S), roughened Stainless Steel (RSS) and surface polished Titanium (Ti-P). Construct stability and load till failure of the Ti-P implants was compared to that of the Ti-S implants in a cadaver model. In the in vivo study a contaminated humeral fracture model was used in rabbits (Figure 1 and 2). The inoculation was performed with a clinical Staphylococcus aureus strain. Each rabbit received one of three inocula, aimed at determining the infection rate low (2 x 10^3 colony-forming units (CFU)), medium (2 x 10^4 CFU) and high dose (2 x 10^5 CFU) of bacteria.

Results: No significant differences were observed between Ti-S and Ti-P regarding failure load and stiffness. Of the 72 rabbits included in the in vivo study, 50 developed an infection. The ID50, which is indicative of the infection susceptibility based on the outcome of each dose was found to be: EPSS 3.89 x 10^3 CFU; RSS 8.23 x 10^4 CFU; Ti-S 5.66 x 10^4 CFU; Ti-P 3.41 x 10^4 CFU. Overall, bacterial counts increased with increasing inoculum, particularly between the lowest inoculum and the two higher inocula. Interestingly, when using a high inoculation dose, lower bacterial counts (greater than 100-fold) were found colonizing the Ti-S implants samples compared with RSS implants (p < 0.001). Similarly, the bacterial counts on the bone samples in the Ti-S group were lower (approximately 10-fold) in comparison with both RSS and EPSS groups at the high inoculation dose (p < 0.005) (Figure 3).

Conclusion: In a preclinical in vivo model incorporating fracture biomechanics, we could not identify any significant differences in susceptibility to infection when comparing titanium and steel with conventional or modified topographies. The finding that Ti-S has a lower bacterial burden compared to both EPSS and RSS, but only when using a high bacterial inoculate, is interesting and indicates material may not influence the infection risk, but rather the infection severity. The high bacterial load in these particular animals mimics open fracture cases, where the use of titanium implants could be considered a potential benefit. Furthermore, Ti-P implants with potential to reduce complications associated with tissue adherence in the clinical setting, are not expected to affect the infection rate, moreover they do not seem to influence implant stability.

Significance: The study provided definitive preclinical proof that implant material, or surface topography, of fracture fixation devices does not play a significant role in infection susceptibility. Although, the finding that Ti-S has a lower bacterial burden compared to both EPSS and RSS at high bacterial loads, which mimics open fracture cases, could imply the use of standard titanium implants in these cases.

Figure 1. Surgical procedure: contaminated humeral fracture model in rabbits.

Figure 2. The four LCP implants used in are shown as a SEM-image and regular light microscopic image. Implants included were (upper left) Ti-S; (upper right) Ti-P; (lower left) EPSS; (lower right) RSS (scale bar 50 μm).

Figure 3. Quantitative bacteriological culture was performed on all implants, soft and hard tissue samples from all animals. Results are expressed as the actual numbers of CFUs retrieved. The horizontal line represents the median value per group. Statistical analyses on the on the numbers of CFUs were performed by Kruskal-Wallis test. Differences not significant unless stated (***, p<0.001 and *, p<0.005).