INFLUENCE OF TITANIUM SURFACE ROUGHNESS ON A NANOSCALE ON THE ZETA POTENTIAL AND PLATELET ADHESION

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Introduction

Thromboembolic complications still arise on blood contacting surfaces like titanium in implants. Surface characteristics like charge and topography are known to have an influence on the subsequent deposition of proteins and platelets. A study of Borghi et al. [1] showed an influence of different surface roughness values on a nanoscale on the surface charge behavior of titanium without considering hemocompatibility aspects. Therefore, the aim of this study was to compare different surface roughness values in a nanoscale range in terms of platelet adhesion and surface charge.

Methods

Titanium samples with four different surface roughness levels were polished and roughened on a nanometer scale and R_a values were measured. Samples were tested for platelet adhesion (covered surface area (CSA), N=8) in flow chambers with human whole blood using fluorescence imaging and zeta potential measurements were conducted over a broad range of pH values and interpolated to obtain zeta potential values at the pH of blood (7.4, pH_{Blood}). Platelet adhesion tests were evaluated in terms of p-values and the Wilcoxon test effect size and the trend of the zeta potential values at pH_{Blood} and the CSA was compared for the different roughness values.

Results

R_a-values were between 35 (polished) and 156 nm. The CSA between the samples did not differ significantly. However, strong and medium effect sizes were present, and the polished sample had the lowest mean CSA, see Figure 1. A similar trend was observed for the zeta potential measurements at pH_{Blood}, with the polished surface showing the lowest value of -53 mV.

Discussion

Our findings introduce novel insights on the correlation of surface roughness, surface charge and platelet adhesion. Despite the deviations of the results of the platelet adhesion test (which is a commonly faced problem due to donor variability), the trend of our results is consistent with literature [2,3]. At the same time, the polished samples showed the most negative zeta potential at physiological blood pH of 7.4, which is also consistent with studies investigating similar surfaces in terms of surface roughness [4,5]. Interestingly, the interpolated zeta potentials for pH of 7.4 follow a similar trend as the mean CSA of platelets of our blood experiments, as depicted in Figure 1. This trend suggests that the change of zeta potential due to nanoscale roughness variation is an important factor on the extend of platelet adhesion on titanium surfaces. Smooth surfaces are generally considered less thrombogenic because of less geometric features protruding inside or outside of the surface baseline and due to less specific surface area [3]. However, our findings suggest that the decreasing surface charge due to a lower nanoscale roughness might be an additional explanation for the improved hemocompatibility.

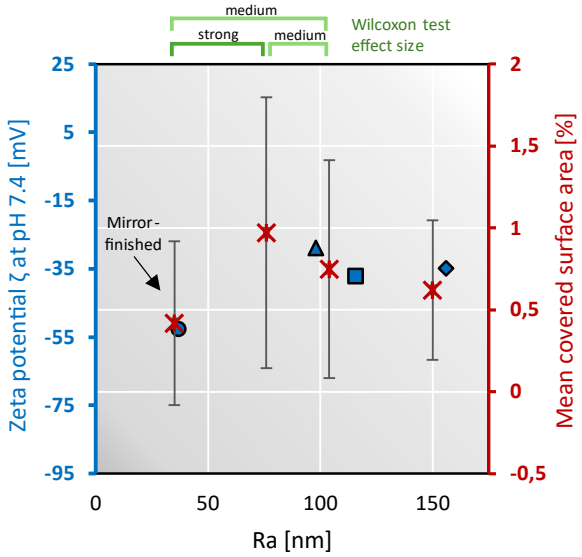

Figure 1: Zeta potential ζ at pH_{Blood} and mean covered surface area with platelets including standard deviation and Wilcoxon test effect sizes over roughness values R_a for all samples.

References

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