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Bacteriostatic behavior of silicon nitride, polyether ether ketone and titanium biomaterials

Statement of the Problem: Perioperative and latent infections are leading causes of revision surgery for orthopedic devices. They are a growing problem due to the rising antibiotic resistance of bacteria to germicidal therapies. An *in vitro* test was developed to compare biofilm formation on three biomaterials, Polyether Ether Ketone (PEEK), a titanium alloy (Ti6Al4V-ELI) and a series of surface-modulated silicon nitride (Si_3N_4) bioceramics using Gram-positive *Staphylococcus epidermidis (S. epidermidis*) and Gram-negative *Escherichia coli (E. coli).*

Methods: Several variants of Si_3N_4 (Amedica Corp., Salt Lake City, UT, USA), PEEK (ASTM D6262) and Ti-alloy (ASTM F136) discs (Ø12.7 mm × 1 mm) were characterized, cleaned, UV sterilized and exposed to 10^5 bacteria cultures of either *S. epidermidis* (ATCC 14990) or E. coli (ATCC 25922) for 24 and 48 hours. They were then vortexed, plated and incubated at 37°C for 24-48 hours, followed by comparative bacterial colony counting.

Results: The two bacterial biofilm tests are presented in Figure 1 and 2 for *S. epidermidis* and *E. coli*, respectively. A two-tailed, heteroscedastic student's t-test (95% confidence) was used to determine statistical significance. The highest density of CFUs was always found on the PEEK biomaterial, followed by the Ti-alloy and then the various Si_3N_4 substrates. Biofilm growth on PEEK was between 2-3 orders of magnitude greater than on the Ti-alloy or any of the Si_3N_4 materials (all $p<0.005$). Ti6Al4V also had more bacteria than the Si_3N_4 samples, but it was not significant in all cases.

Conclusion: Development of bacteriostatic biomaterials is one of many important prosthetic device strategies to combat PJI. Si_3N_4 shows considerable promise in its inherent ability to inhibit bacterial attachment and biofilm formation and as a result, it represents a significant advancement over traditional biomaterials.

Discussion: Attachment of bacteria to biomaterial surfaces is complex and correlations to single parameters are often difficult to assess. A multivariate approach is necessary because microbial adhesion is not only related to the bacterial strain itself, but also affected by the biomaterial's surface topography, charging, wetting behavior, chemistry and the *in vivo* environment (e.g., serum proteins, nutrients and fluid-flow conditions). In each of these categories, the various Si_3N_4 materials examined within this study appear to have appropriate surface and chemical characteristics to inhibit biofilm establishment, including sub-micron and nanoscale topography, improved wetting, large negative surface charge and elutable functional moieties.

Biography

Bryan J McEntire is a Chief Technology Officer for Amedica Corporation. He has previously served as the Vice President of Manufacturing and Vice President of Research. He has received his BS and MBA degrees in Materials Science and Engineering and Operations Management, respectively from the University of Utah and his PhD from the Kyoto Institute of Technology. He has more than 35 years of industrial experience in research, development and production of advanced ceramics, including positions at Ceramatec, Salt Lake City, USA, Saint-Gobain Industrial Ceramics Corporation, Northboro, MA and E Granby, USA, Applied Materials Corporation, Santa Clara, USA and at Amedica Corporation, USA. He is the author and co-author of over 65 peer reviewed publications and holds 8 patents. He is an Emeritus Member and Fellow of the American Ceramic Society.

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