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Biocompatibility of Nano-Crystalline Coatings Produced by Ion Beam Assisted Deposition (IBAD)

Raheleh Miralami
University of Nebraska Medical Center, raheleh.miralami@unmc.edu

Geoffrey M. Thiele
University of Nebraska Medical Center, gthiele@unmc.edu

J. Graham Sharp
University of Nebraska Medical Center, jsharp@unmc.edu

Fereydoon Namavar
University of Nebraska Medical Center, fnamavar@unmc.edu

Kevin L. Garvin
University of Nebraska Medical Center, kgarvin@unmc.edu

BIOCOMPATIBILITY OF NANO-CRYSTALLINE COATINGS PRODUCED BY ION BEAM ASSISTED DEPOSITION (IBAD)

Raheleh Miralami[1], Geoffrey M Thiele[2], John G Sharp[3], Fereydoon Namavar[1], Kevin L Garvin[1].

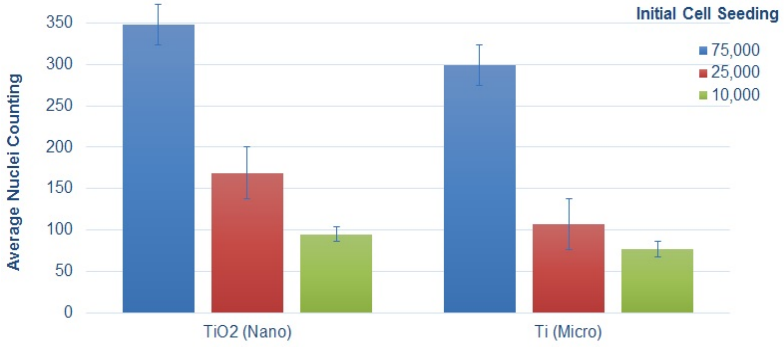
[1]Department of Orthopaedic Surgery and Rehabilitation, University of Nebraska Medical Center, Omaha, NE;
[2]Department of Internal Medicine – Rheumatology, University of Nebraska Medical Center, Omaha, NE;
[3]Department of Genetics, Cell Biology and Anatomy, University of Nebraska Medical Center, Omaha, NE;

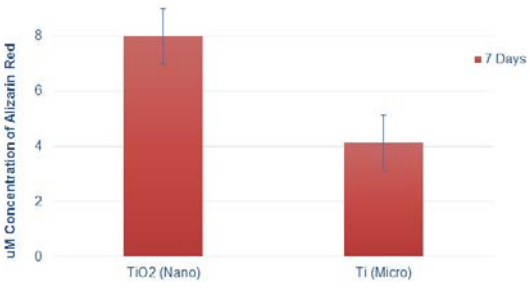
Introduction: Due to progressive nature of the arthritic disease, total joint arthroplasty is the treatment of choice when all treatments providing relief of arthritic symptoms fail. The annual Medicare expenditures for both hip and knee arthroplasties are around $3 billion while 10-20% need revision surgery within 15-20 years (1). Thus, there is a serious need to accommodate such overload. It has been shown that if it is possible to improve implant osteointegration properties, then implant longevity will be increased and the necessity of revision surgery will be decreased (2). Thus, it would be beneficial to develop a surface that encourages bone forming cell's adhesion and growth. One way to manipulate surface modifications on the implants is using ion beam assisted deposition (IBAD) technique. Therefore, it was the hypothesis of this study that applying IBAD techniques will change the surface topography and increase initial cell adhesion, survival, growth and proliferation.

Methods and Materials: The engineered nano-crystal films produced by the ion beam assisted deposition (IBAD) technique have hydrophilic properties. In this technique, physical vapor deposition gets combined with concurrent ion beam bombardment in a high vacuum environment to stich the nano-film to the substrate (3). By IBDA technique, nano-films (with 3 to 70 nm grain size) with characteristics that affect the wettability and mechanical properties can be produced (3).
In this study, Nano-crystalline titanium oxide produced by IBAD technique was compared with orthopaedic grade titanium to see if any enhanced cell adhesion and proliferation could be observed. In this regard, human osteosarcoma cell line (SAOS-2) with osteoblastic properties was used. To compare cell adhesion and growth, DAPI (6-diamidino-2-phenylindole) - stained nuclei were counted using ImageJ software. Immunofluorescence staining was also applied to monitor actin stress fiber shapes in order to compare cells morphology and actin remodeling at focal adhesion sites on the surfaces. And finally, alizarin red assay was used to detect calcium compounds on surfaces using a standard plate reader which is an indication of successful in-vitro bone formation.
All data presented were derived from 3 independent experiments and within each experiment 3 separate samples were analyzed. Statistical significant differences between different substrates for alizarin red experiment were evaluated using ANOVA with post-hoc Bonferroni's multiple comparison tests.

Results: The results indicate that Nano TiO_2 is superior in supporting cells adhesion and proliferation compared to micro Ti. Also more calcium deposition (significant difference) was observed by the cells cultured on the nano surfaces.

Conclusion: This study showed that Nano-crystalline surface (TiO_2) is superior to micro-crystalline Ti in cell adhesion, proliferation and calcium deposition. Therefore, enhanced bone formation ability from those surfaces is expected. It also indicates that surface topography which was altered by IBAD technique, affects cell's interaction and therefore, it plays a crucial role in biocompatibility of nano-engineered surfaces.





Rreferences:

1) Kane, R., Saleh, K., Wilt, T., Bershadsky, B. (2005) The functional outcomes of total knee arthroplasty. The Journal of bone and joint surgery American volume 87(8):1719-24.
2) Kalbacova, M., Rezek, B., Baresova, V., et al. (2009). Acta Biomater. 5 (8) 3076-85.
3) F. Namavar; C.L. Cheung; R.F. Sabirianov; et. al, Orthopaedic Research Society San Francisco Feb 2012, Nano Lett. 2008, 8,988-996.