Antimicrobial and Bone Growth Responses to Porous Tantalum Coatings

David A. Glocker, John L. Greco and Mark Romach

Isoflux Incorporated

Thomas J. Webster

Chair and Professor

Department of Chemical Engineering

Northeastern University

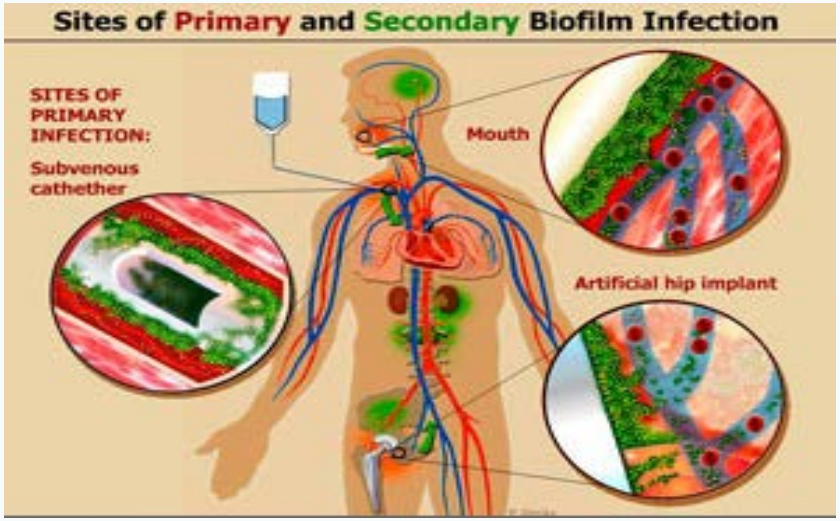
Northeastern University

Isoflux BIOMED

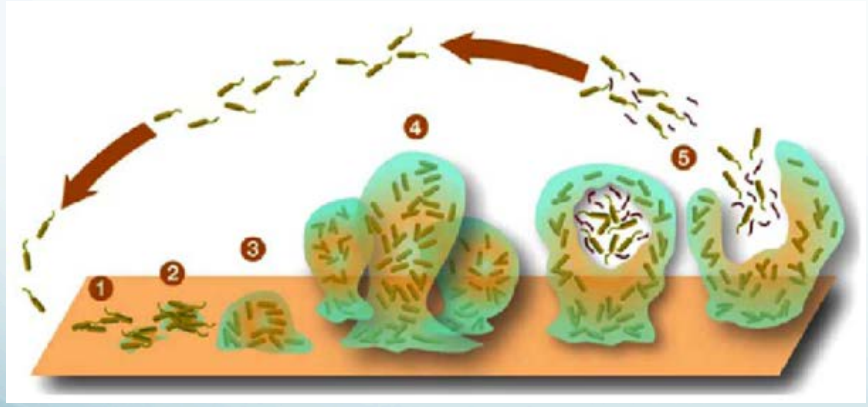
Outline

- Introduction and Background
- Experimental Procedures
  - Tantalum Deposition Conditions and Coating Properties
  - Antimicrobial and Bone Growth Measurements
- Experimental Results
- Conclusions

Bacterial Biofilm



Common sites of biofilm infection.[1]



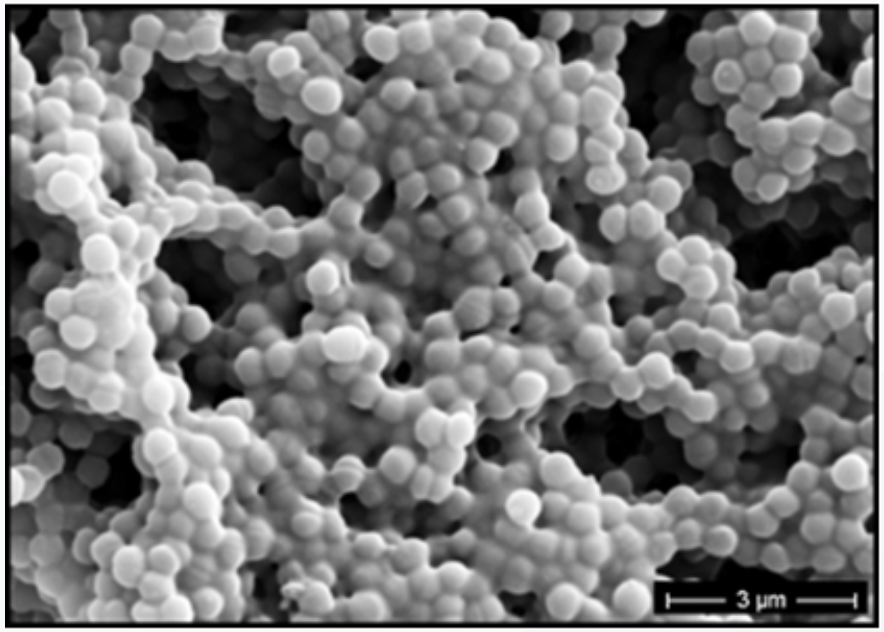
The biofilm life cycle.[2]

- Hydrated polymeric matrix[3]
- More tolerant to antibiotic therapies than planktonic bacteria
- Easy to form but hard to treat
- Causes wide-spread infections[4]

[1] Center for Biofilm Engineering, Montana State University, P. Dirckx. Used with permission.
[2] Cunningham, A. B., et al. Biofilm hypertextbook, Montana State University Center for Biofilm Engineering, 2005.
[3] Costerton JW, et al. Science. 1999;284:1318-1322. [4] Costerton JW. Int J Antimicrob. 1999;11:217-221.

Staphylococcus Aureus

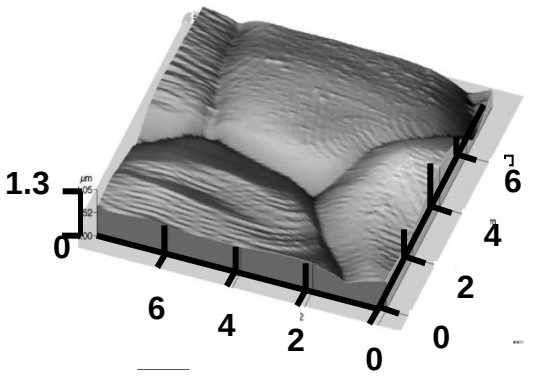
- Numerous infections, such as orthopedic, pimples, impetigo, pneumonia, endocarditis and sepsis
  - ***11 million outpatients, US[5]***
- Medical Devices
  - Catheters
  - Orthopedic prostheses
  - Contact lenses



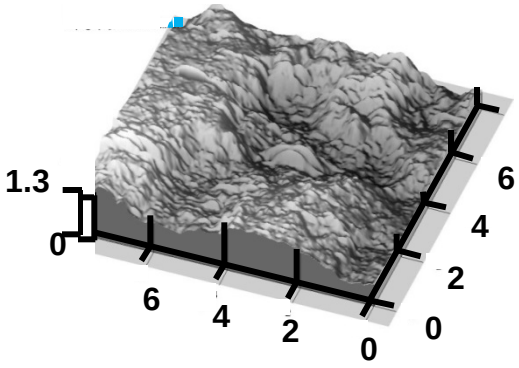
SEM of Staphylococcus Aureus biofilm[6]

[5] Martinez LR, et al. J Invest Dermatol. 2009; 129(10):2463-2469.
[6] E. Swogger, Center for Biofilm Engineering, Montana State University, Bozeman

Nano-structured Medical Materials



Today's Implant



Nano-structured Implant

Dimensions in Microns

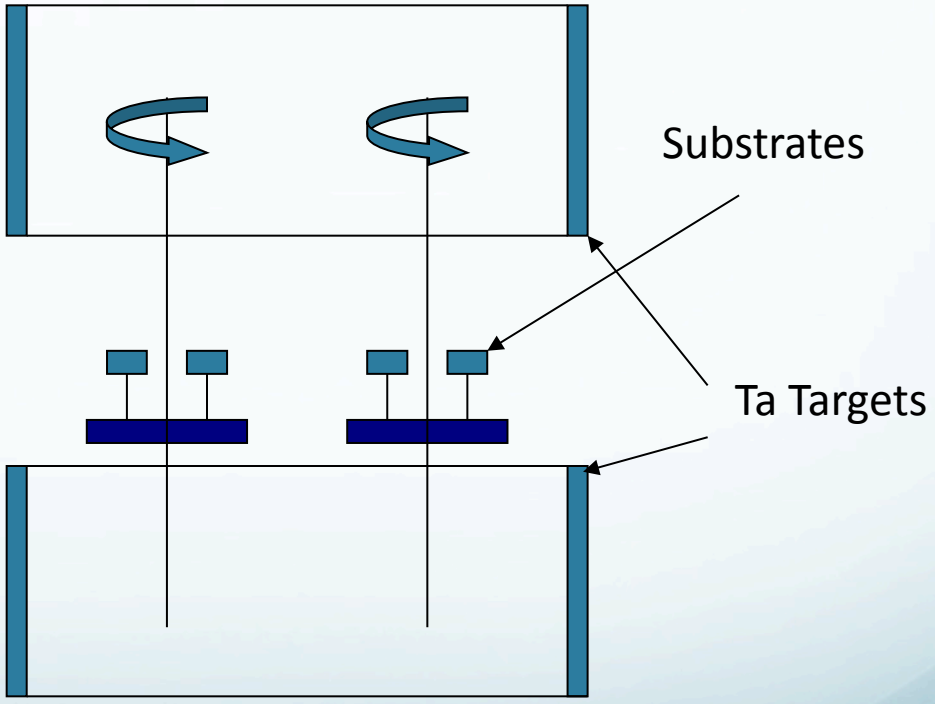
Compared to today's implants, nano-structured materials possess enhanced:

- Surface area
- Radiopacity
- Catalytic effects
- Optical properties
- Mechanical strength
- Electrical properties
- Surface properties that may decrease bacteria function

T. J. Webster, in Advances in Chemical Engineering Vol. 27, Academic Press, NY, pgs. 125-166, 2001.

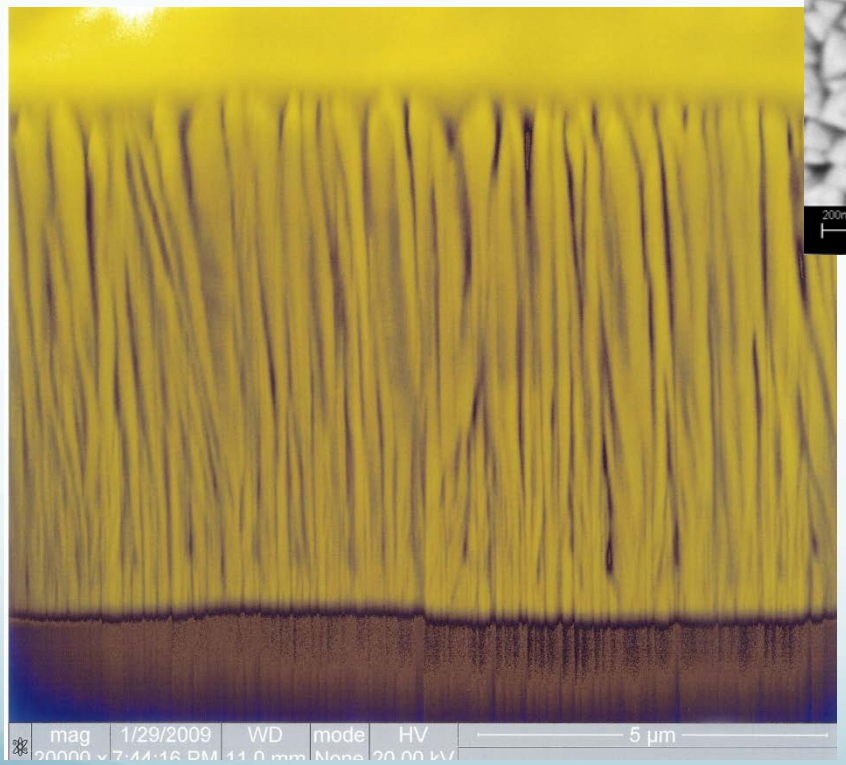
Tantalum Deposition Conditions

- Two Ta inverted cylindrical targets, ϕ 33 cm by 10 cm high, separated by 10 cm
- Total power: 2 kW DC
- Pressure: 8 mT Kr
- Deposition Rate: 33 nm/min
- Thickness: 10 mm
- Substrates: Ti or PEEK

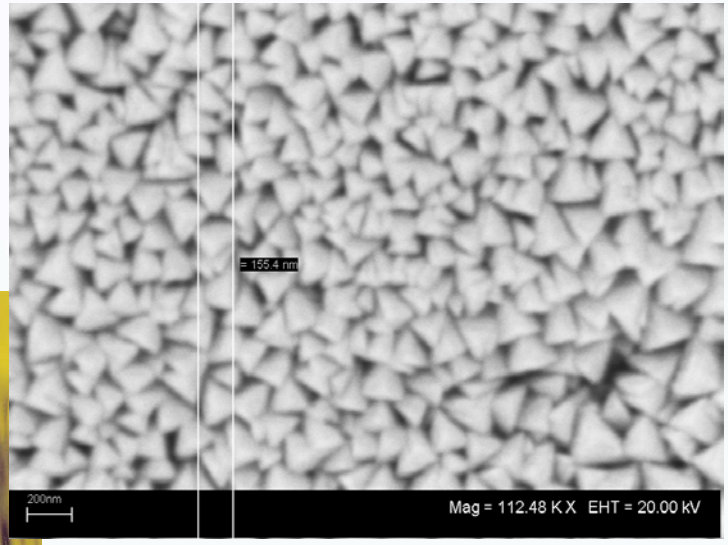


Resulting Coating Properties

- Extreme Zone 1 structure



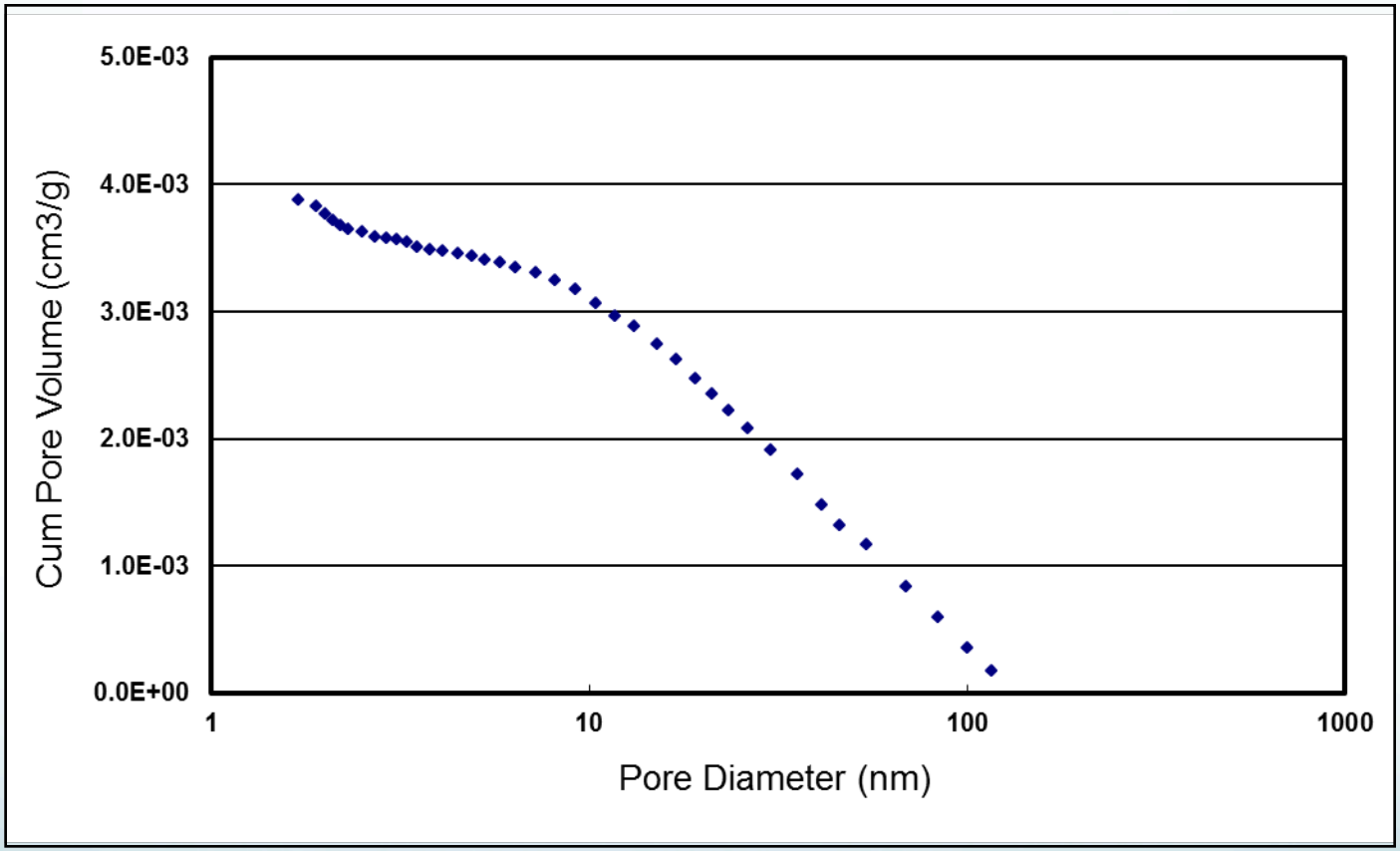
10 µm



155 nm

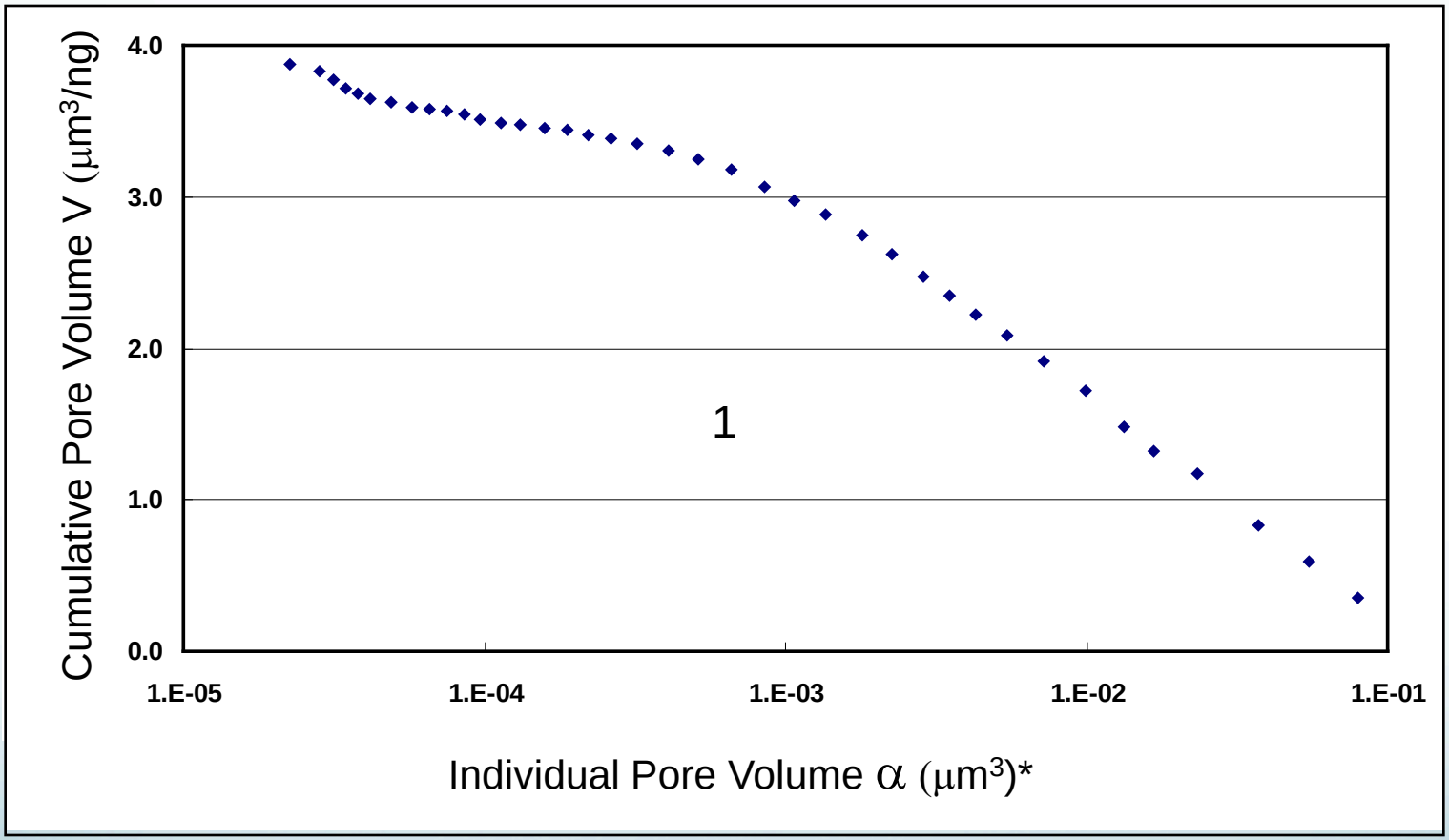
Coating Pore Size Distribution

BET Nitrogen Adsorption Isotherms



Coating Pore Size Distribution

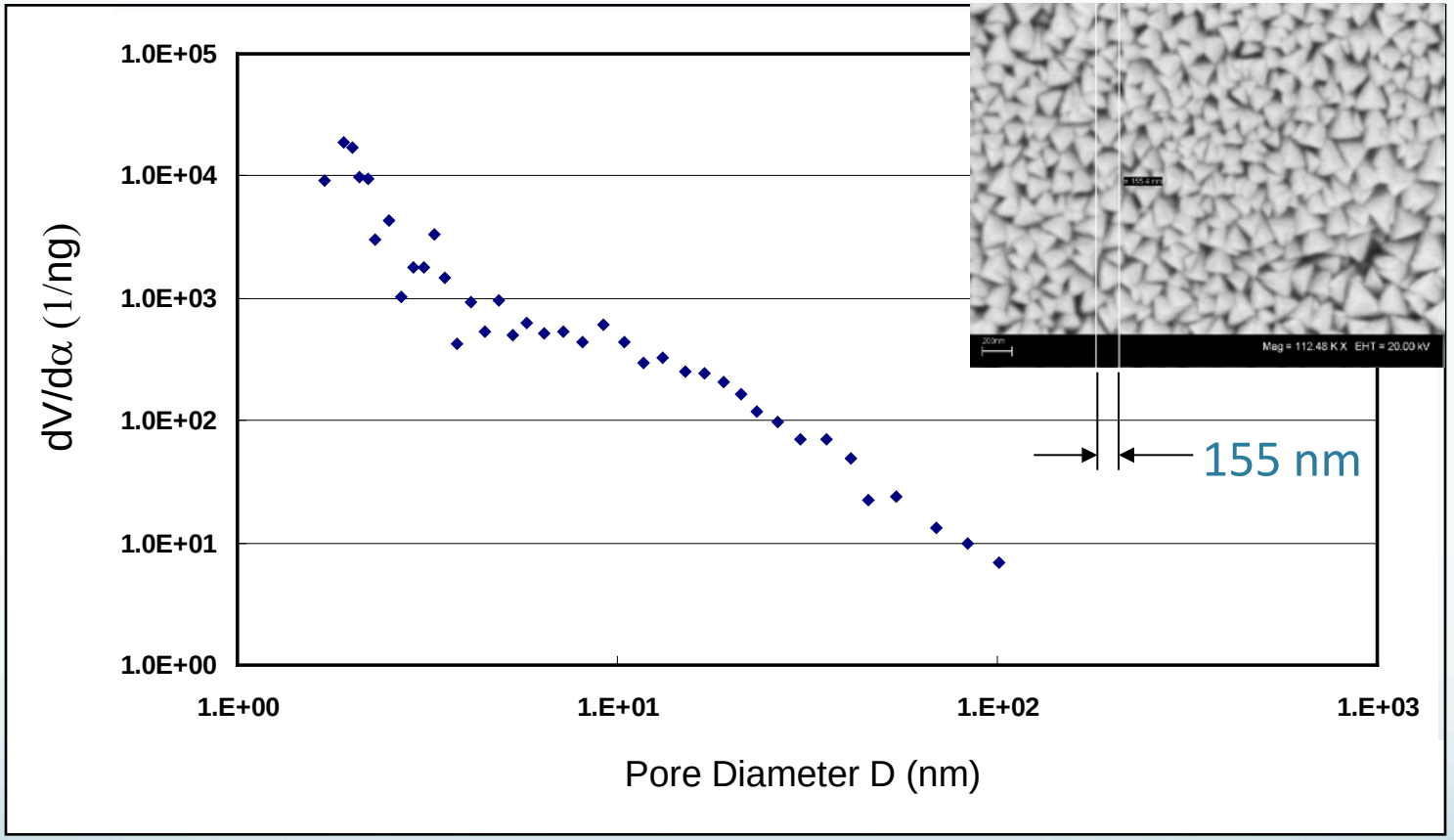
Cumulative Pore Volume vs. Individual Pore Volume



*Assuming cylindrical pores and a 10 μm thick coating

Coating Pore Size Distribution

Number of Pores vs. Pore Diameter

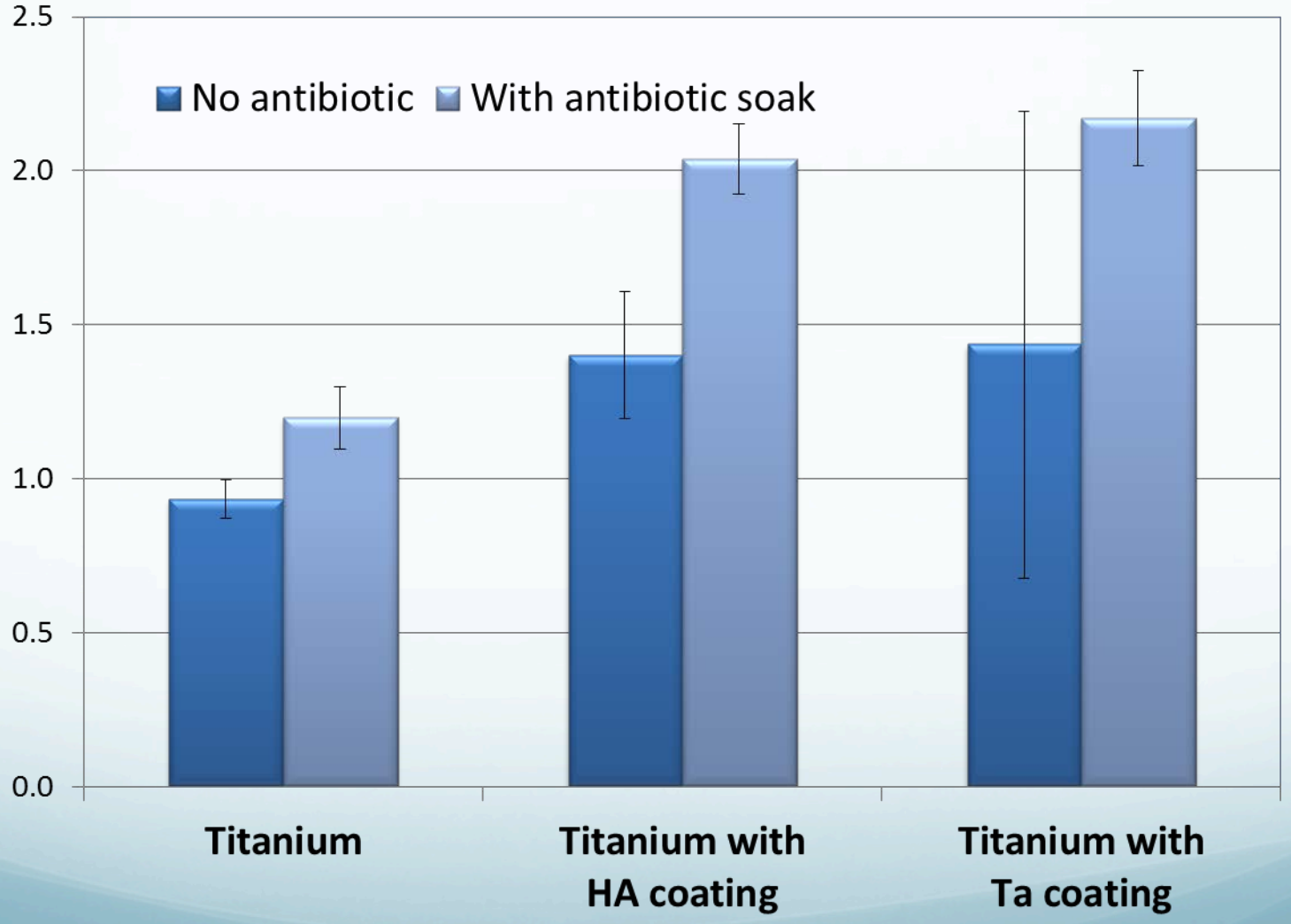


(1 g ~ 5 X 10^9 μm^2)

In vivo Infection Model

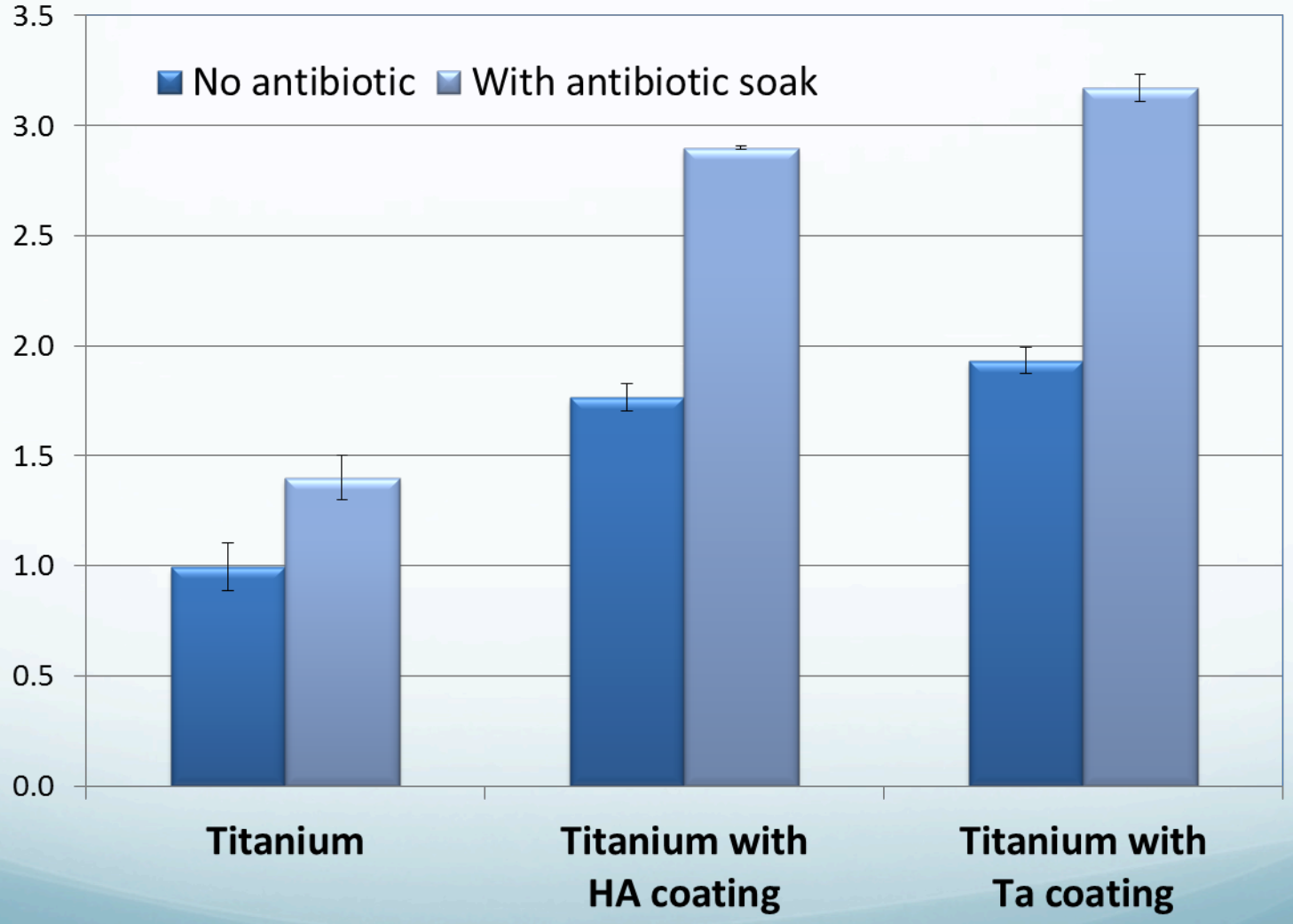
- To determine the ability of bone to grow on the proposed materials in the presence of bacteria:
  - Some samples were used as-is while some were soaked in antibiotics
  - Samples were then inoculated with 10^5 *Staph. epidermidis* colony forming units and implanted into rat calvial defects
  - After 1 or 4 weeks, samples with juxtaposed bone were removed and tested for bone push-out strength

Improved Push-Out Strength for Coated Titanium (1 Week)



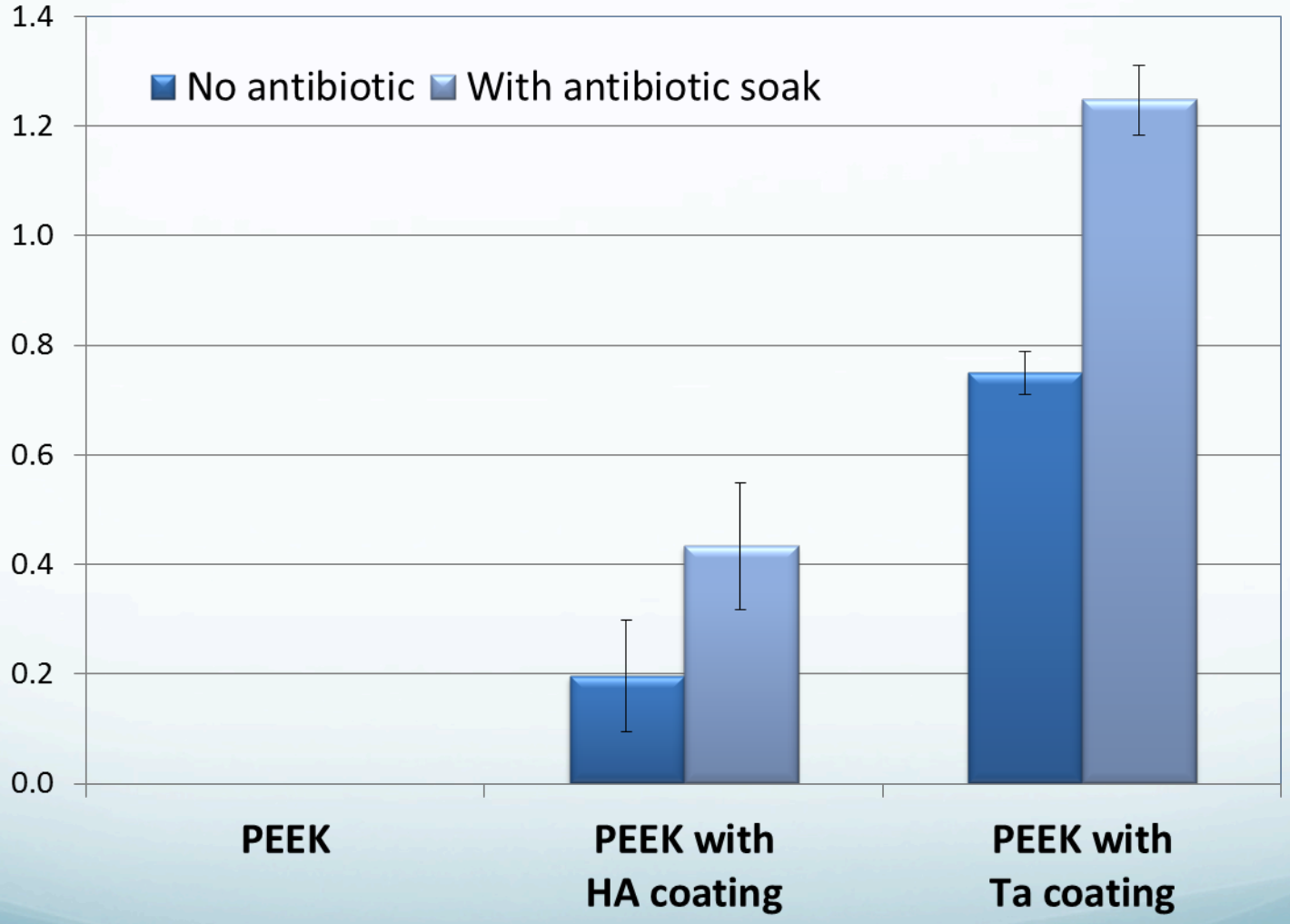
Y axis = push-out strength in Mpa. Data = mean ± SEM; N = 3.

Improved Push-Out Strength for Coated Titanium (4 Weeks)



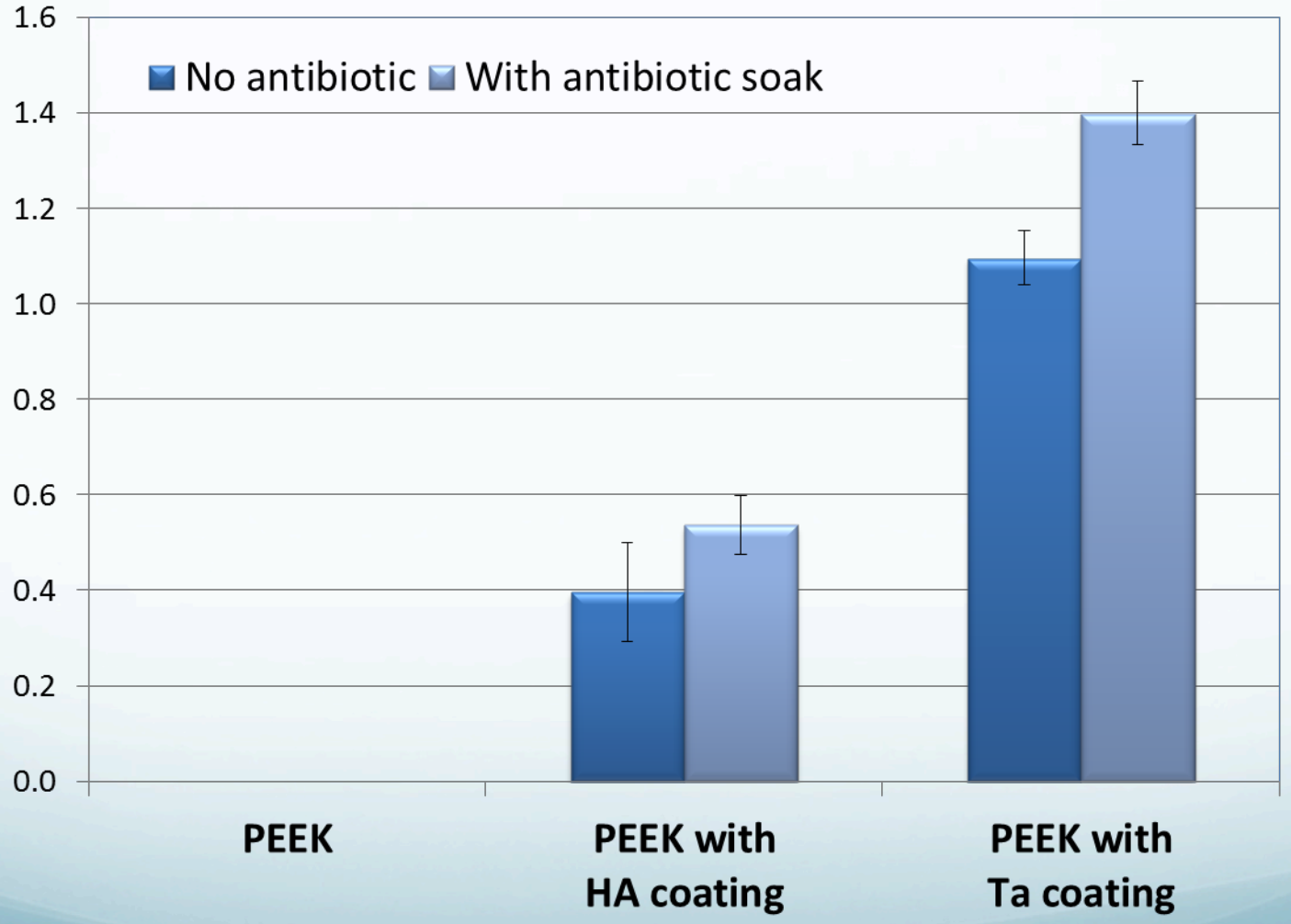
Y axis = push-out strength in Mpa. Data = mean ± SEM; N = 3.

Improved Push-Out Strength for Coated PEEK (1 Week)



Y axis = push-out strength in MPa. Data = mean ± SEM; N = 3.
Isoflux TA coating $p < 0.0004$ compared to PEEK without coating.

Improved Push-Out Strength for Coated PEEK (4 Weeks)



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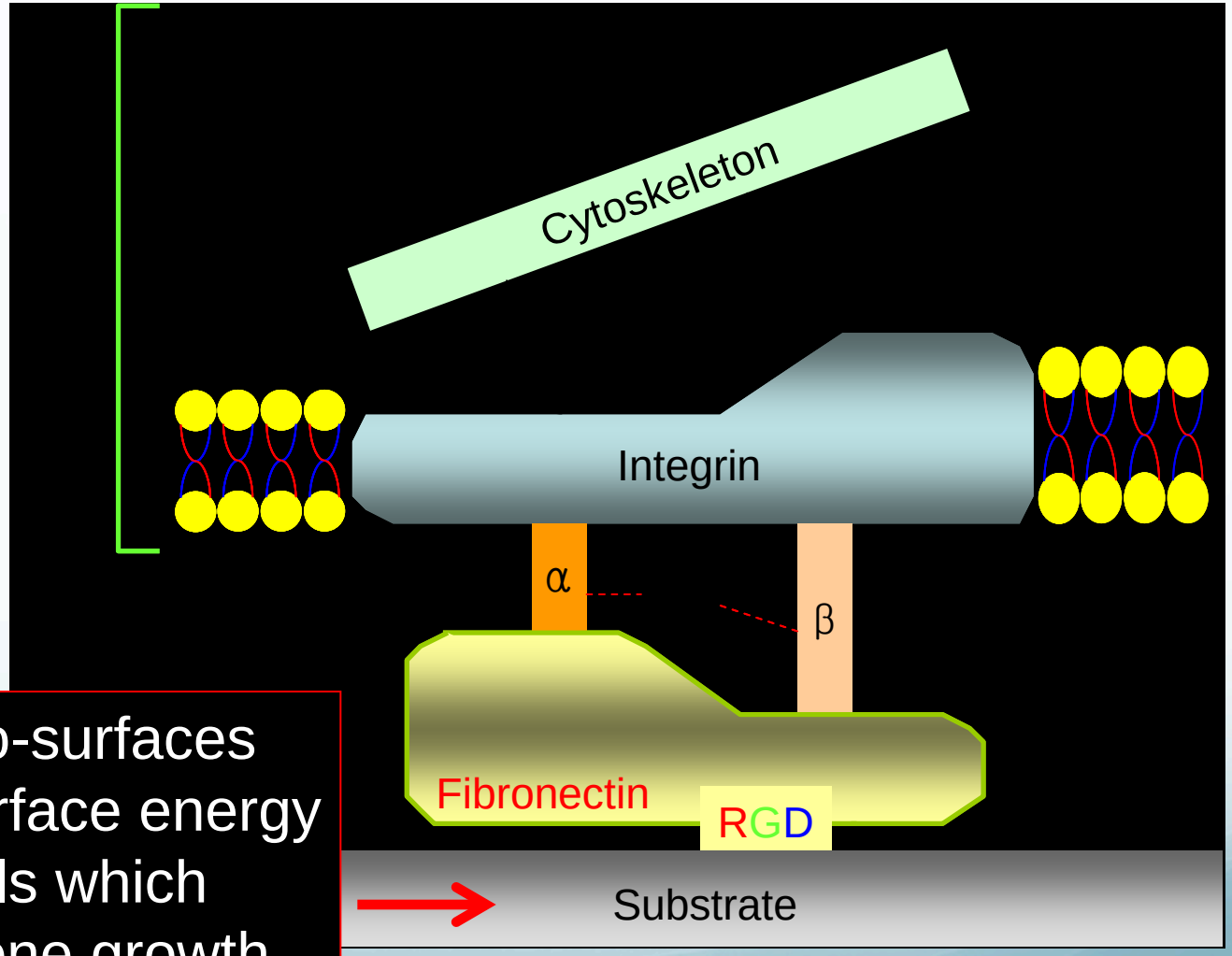
Increasing Bone Growth and Decreasing Bacteria Growth on Nanofeatured Materials



Create nano-surfaces to increase surface energy on materials which increases bone growth

Conclusions

- Nanoporous tantalum coated materials improved bone growth in the presence of bacteria to significantly improve push-out strength.
- Future studies should determine the exact mechanism of increased bone growth and decreased bacteria growth on the proposed materials.

Thank You!