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Electrochemical Surface Technology**

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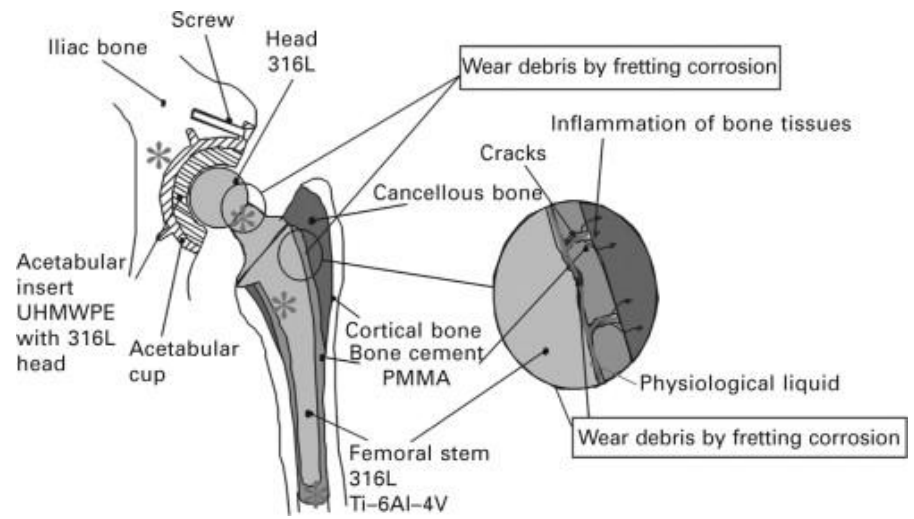
# **SURFACE MODIFICATION OF Ti- BASED MATERIALS FOR FOR BIOMEDICAL APPLICATION**

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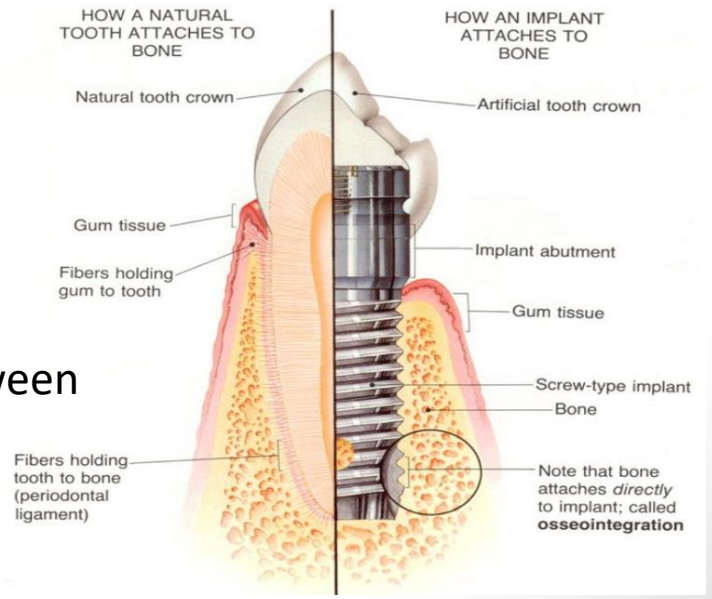
Premature implant failure is categorized into

- ❖ Aseptic loosening
- ❖ Septic loosening

Schematic aseptic loosening of a total hip replacement [1]



Schematic illustration of a dental implant [2]



In case of septic loosening, a bacterial biofilm between bone and implant prevents osseointegration

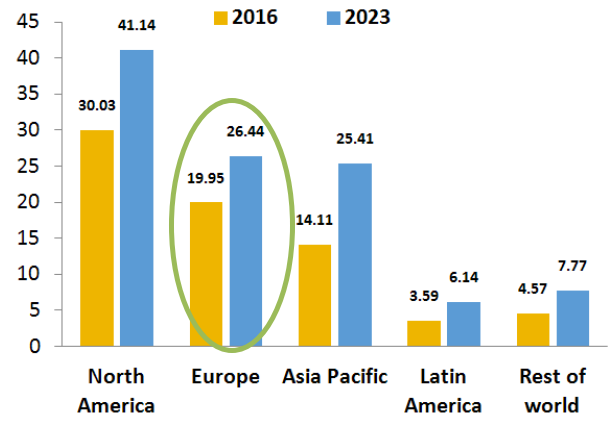
[1] Geringer, J.; Kim, K.; Boyer, B. (2011); 14 - fretting corrosion in biomedical implants. In *Tribocorrosion of passive metals and coatings*. Landolt, D.; Mischler, S., Eds.; Woodhead Publishing: pp 401-423.

[2] Carvalho, R. (2018), Dental implants: Factors that can lead to implant failure, indication and contraindication of dental implants related to local and systemic diseases in adult patients. <http://www.nyu.edu/classes/keefe/evergreenenergy/carvalho.pdf>

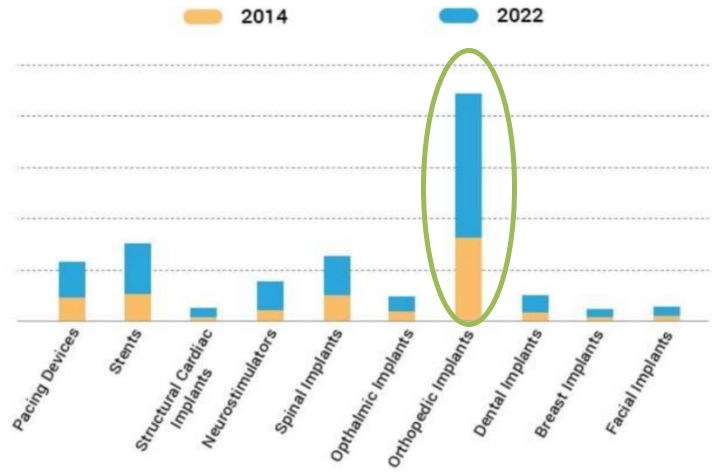
# Motivation- Orthopedic implant market development



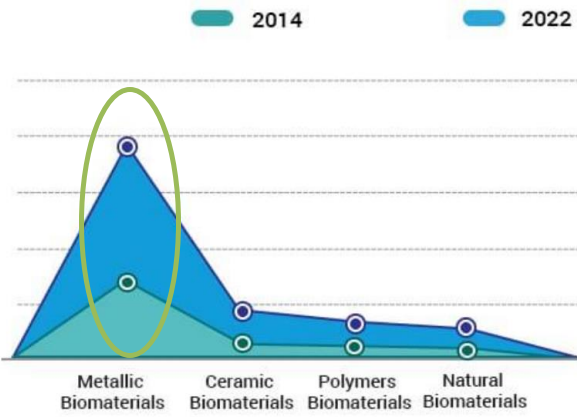
- ❖ Global market value: \$72,25 bn (2016) → \$106,9 bn (2023)
- ❖ Market value by region: Europe 2<sup>nd</sup> highest with \$19,95 bn in 2016, forecasted \$26,44 bn in 2023 [3]



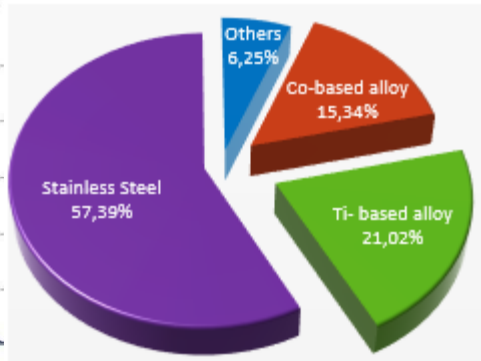
- ❖ Fastest growing market by product: orthopedic implants [4]



- ❖ Fastest growing market by material: metallic biomaterials [5]



- ❖ Market share 2016 [6]



- ❖ Minor orthopedic replacement (Shoulder, wrist, ankle and foot joints) [7]:

- Market growth: \$1,5 bn (2017) → \$2,2 bn (2021)
- Annual growth of 7% expected
- Driving force: higher rate of osteoarthritis, rheumatoid arthritis, fractures, failed previous joint replacement surgeries, infections by multi-drug resistant bacteria

[3] BIS Research. Total global implants market value by region in 2016 and a forecast for 2023 (in billion U.S. dollars)\*. <https://www.statista.com/statistics/800833/implants-market-value-worldwide-by-region/> (accessed 5/30/2018).  
 [4] BIS Research. Total global implants market value in 2016 and a forecast for 2023 (in billion U.S. dollars)\*. <https://www.statista.com/statistics/800812/implants-market-value-worldwide/> (accessed 6/7/2018).  
 [5] Tatkare, D. Medical Implants Market By Type (Orthopedic Implants, cardiac implants, Stents, Spinal Implants, Neurostimulators, dental implants, Breast Implants, facial Implants) and By Materials (Metallic, Ceramic, Polymers, Natural) - Global Opportunity Analysis and Industry Forecast, 2014 - 2022 allied market research: 2016.  
 [6] Technavio Research. Biomedical Metal Market - Global Forecasts and Opportunity. <https://www.businesswire.com/news/home/20170620006368/en/Biomedical-Metal-Market---Global-Forecasts-Opportunity> (accessed 14/06/2018).  
 [7] Medical Design & Outsourcing. Minor orthopedic implant market to be worth \$2.2 billion by 2021, analysts say. <https://www.medicaldesignandoutsourcing.com/minor-orthopedic-implant-market-to-be-worth-2-2-billion-by-2021-analysts-say/> (accessed 05/06/2018).

Researchers agree that usage of antibiotic prophylaxis in implant surgeries (dip coated implants, antibiotic therapies) is required to achieve high long-term survival and success rates of implants.



## Multi-drug resistant bacteria (MDRB)



### ❖ Orthopedic implants[8]:

- 10% premature failures with up to 2,5 % related to infections (rest related to aseptic loosening due to insufficient osseointegration)
- 20 % of revision surgeries are complicated by infections

### ❖ Dental implants:

- 14,4 % Periimplantitis within the 1st five years (increasing infections beyond five years) [9]
- Postoperative infections [10] diagnosed within the 1st month:
- removal/replacement surgeries: 77,3% due to antibiotic therapy failure
- failure before prosthetic loading: 54.6%

→ **Currently, no effective applied procedure exists to address postoperative infections**, which lead to removal, replacement and in the worst case amputation.

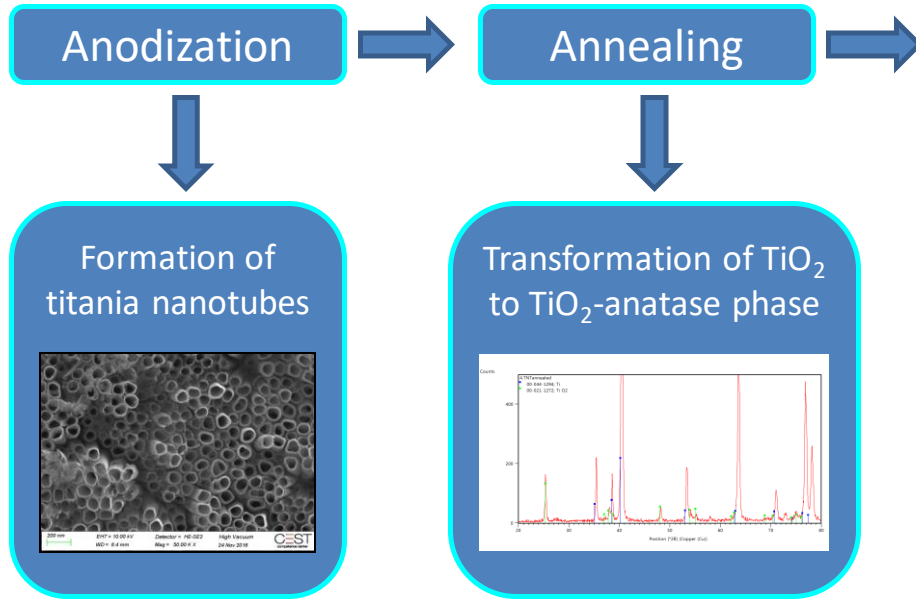
[8] Lentino, J. R. Prosthetic Joint Infections: Bane of Orthopedists, Challenge for Infectious Disease Specialists. *Clinical Infectious Diseases* 2003, 36 (9), 1157-1161. DOI: 10.1086/374554.

[9] Norowski, P. A.; Bumgardner, J. D. Biomaterial and antibiotic strategies for peri-implantitis: A review. *Journal of Biomedical Materials Research Part B: Applied Biomaterials* 2009, 88B (2), 530-543. DOI: 10.1002/jbm.b.31152.

[10] Camps-Font O., F. R., Valmaseda-Castellón E., Gay-Escoda C. Postoperative Infections After Dental Implant Placement: Prevalence, Clinical Features, and Treatment. *Implant Dent.* 2015, 24 (6), 713-9. DOI: 10.1097/ID.0000000000000325.

## Defined nano-topography

greater bone-implant contact area,  
guidance of the implant vs. cell interaction



❖ **Uniform circular shape with a diameter of 100 nm**

antibacterial efficiency without use of pharmaceuticals  
promotes new bone formation and bone growth [11, 12]

### Electrodeposition

- Se**  

SEM image showing a porous structure with circular pores. XRD pattern showing peaks for Se.
- Ag<sub>2</sub>Se**  

SEM image showing a porous structure with circular pores. XRD pattern showing peaks for Ag<sub>2</sub>Se.
- Cu<sub>2</sub>Se**  

SEM image showing a porous structure with circular pores. XRD pattern showing peaks for Cu<sub>2</sub>Se.

### Electro-chemical deposition

- Se-HAp**  

SEM image showing a porous structure with circular pores. XRD pattern showing peaks for Se-HAp.

11. Xu, Z., et al., *Increased Mesenchymal Stem Cell Response and Decreased Staphylococcus aureus Adhesion on Titania Nanotubes without Pharmaceuticals*. BioMed Research International, 2015. **2015**: p. 9

12. Oh, S., et al., *Stem cell fate dictated solely by altered nanotube dimension*. Proceedings of the National Academy of Sciences of the United States of America, 2009. **106**(7): p. 2130-2135





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*Research article*

## **Surface modification of Ti6Al4V alloy for implants by anodization and electrodeposition**

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*Thank you for your attention!*

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