Hierarchical Ti Surface Structure and Cu Nanoparticle Coating To Inhibit Oral Bacteria and Peri-implantitis

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Introduction

- Oral biofilms (dental plaque): complex polymicrobial communities formed by adhesion and proliferation of mostly bacteria and fungi on teeth, dentures, implants, and other restorative materials
  - Early colonizing bacteria such as ***Streptococcus sanguinis*** and ***Staphylococcus aureus*** create a favorable environment for adhesion of more pathogenic species which cause many diseases
- Biofilm formation on titanium (Ti) dental implant abutments can lead to peri-implant mucositis and peri-implantitis
- Mature biofilms are difficult to remove
  - Target early inhibition of bacterial adhesion and biofilm formation

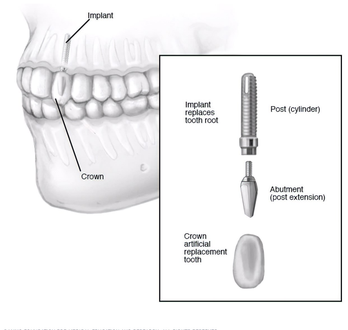

Figure 1: Diagram of dental implant structure; the implant post is placed into the jawbone below the gums, the abutment connects to the post and supports the prosthetic tooth replacement. Dental Implant Surgery - Mayo Clinic, 19 Jan. 2019, www.mayoclinic.org/tests-procedures/dental-implant-surgery/about/pac-20384622.

Scientific Premise

- Prior Ti surface modification methods to inhibit bacterial proliferation:
  - Nanoparticles (NP) in a coating
    - Copper nanoparticles (CuNP) had best compromise between antibacterial properties and cytotoxicity compared to other tested metal NPs (Heidenau et al., 2005)
  - Creation of hierarchical structure (nanofeatures on microstructures)
    - Significantly inhibited bacterial adhesion compared to control (Huang et al., 2014)

Hypothesis

The coating of CuNPs on hierarchically structured Ti implant abutments will inhibit the proliferation of bacteria

Fabrication

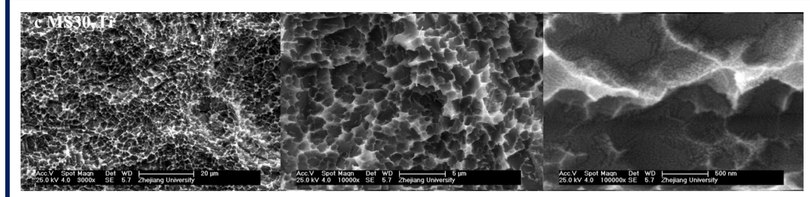

Figure 2: (Above) SEM image of hierarchical surface morphology on Ti sample. Created by sandblasting for 30s, then acid-etching in boiling HCl/H_2SO_4 mixture for 1m, then acid-etching in room temperature HCl/H_2SO_4 mixture for 30m. (Huang et al., 2014)

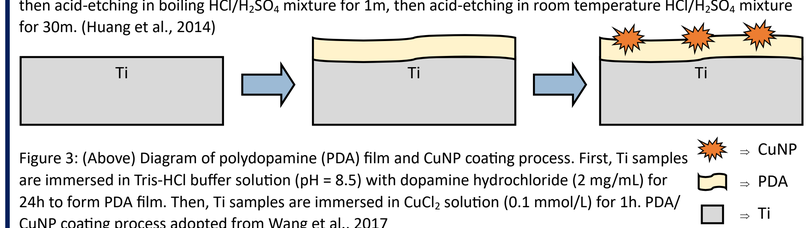

Figure 3: (Above) Diagram of polydopamine (PDA) film and CuNP coating process. First, Ti samples are immersed in Tris-HCl buffer solution (pH = 8.5) with dopamine hydrochloride (2 mg/mL) for 24h to form PDA film. Then, Ti samples are immersed in $CuCl_2$ solution (0.1 mmol/L) for 1h. PDA/CuNP coating process adopted from Wang et al., 2017

Tests

- **Surface characterization**
  - Examine surface morphology using FESEM and AFM
  - Confirm attachment of PDA/CuNP using XPS
- **Antibacterial properties**
  - Incubate samples with *S. aureus* and *S. sanguinis* suspensions, determine CFUs
  - Image attachment patterns and biofilm formation w/SEM and CLSM
- **Biocompatibility**
  - CuNP release test
  - Preosteoblast and fibroblast adherence and proliferation assessment

Expected Results

- **Surface characterization**
  - Can expect little change to topography even after PDA/CuNP coating
  - In XPS, presence of peaks of N and Cu, indicating successful coating of PDA and CuNP
- **Antibacterial properties**
  - Expect reduced CFUs, adhesion, and biofilm formation on hierarchical structured PDA/CuNP compared to controls
- **Biocompatibility**
  - Non-toxic levels of CuNP release and no cytotoxicity

Discussion

- Would provide unique insight on the combination of antibacterial methods to combat oral biofilms and peri-implantitis
- Biocompatibility must be confirmed before *in vivo* trials

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Questions? Email: heoj@sas.upenn.edu

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