Laser Surface Modification of the Orthopedic Bio-Metal, Cobalt Chromium Alloy

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Abstract: Post-surgical site infections are common after medical implant placement. Infections in tissue surrounding an implant can cause patient suffering, medical device failure, and can potentially spread systematically. Post-operational infection associated with orthopedic implants is a critical and escalating problem which demands urgent attention for a decrease of occurrences. Implant related infections can require a patient to undergo additional surgeries following the initial implant placement surgery. Another challenge that exists for implant placement, due to orthopedic injuries, is tissue integration. Each year, there are more than 30,000 revision surgeries partially due to poor orthopedic implant fixation with bone. In order to combat infection, biomaterials and functional coatings used for medical implants are evaluated either for their ability to resist infection (resist bacterial adhesion and biofilm formation) or for their ability for tissue integration (to support tissue cell adhesion and proliferation). No viable clinical technology currently exists to address both these issues simultaneously. Our hypothesis is that laser micro-nano machining can create surface topographies on orthopedic implant surfaces that could provide a platform for simultaneous tissue integration and therapeutic delivery for biofilm prevention. This study explores the role of laser micro-nano machining in creating surface topographies on an orthopedic relevant bio-metal, cobalt chromium (Co-Cr) alloy. Co-Cr alloys are extensively used for orthopedic and dentistry applications. Laser modified Co-Cr samples were compared to other laser modified bio-metals, such as titanium. Co-Cr alloy and Ti were cut into 1cm x 1cm squares and were then modified using a nanosecond pulsed laser. A CoherentTM Avia 355X nanosecond pulsed laser with pulse energy of 95 μJ, spot size of 130 μm, line width of 100 μm, scan rate of 200 mm/min, and repetition rate of 20 kHz was used to raster scan the coupons with an overlap of 23%. A lens with a focal length of 10 cm was used for the experiments with the actual experimentation done at a defocused distance of 0.5 mm. Bare metal (control) and surface modified samples were characterized using optical microscopy and scanning electron microscopy (SEM). Optical and SEM results clearly show a radically different surface morphology for laser patterned samples when compared to control samples. Since laser parameters were kept constant, response varied for each material type. At 300X magnification, SEM results clearly show a ~100 μm width of the raster patterned zone of varying geometry. Ti seems to have a more uniform surface pattern when compared to Co-Cr alloy suggesting a need to further optimize Co-Cr alloy laser parameters. In summary, our results demonstrate the effect of laser treatment in creating micro-nano structured surface topographies on Ti and Co-Cr alloy which can be subsequently modified to address current orthopedic clinical needs.

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