Hydrophilic implants generated using a low-cost dielectric barrier discharge plasma device at the time of placement exhibit increased osseointegration in an animal pre-clinical study: An effect that is sex-dependent

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Abstract

Objectives

Increased wettability of titanium and titanium alloy surfaces due to processing and storage methods increases osteoprogenitor cell differentiation and osseointegration compared to microroughness alone. Implants that are exposed to air have a hydrophobic surface due to adsorption of atmospheric hydrocarbons, which can limit overall implant success. Dielectric barrier discharge plasma (DBD) is one method to increase surface hydrophilicity. Although current DBD methods yield a hydrophilic surface, adsorbed hydrocarbons rapidly restore hydrophobicity. We demonstrated that application of DBD to implants previously packaged in a vacuum, generates a hydrophilic surface that supports osteoblastic differentiation in vitro and this can be done immediately prior to use. In the present study, we tested the hypothesis that DBD treatment to alter surface wettability at the time of implant placement will improve osseointegration in vivo.

Materials and methods

Twenty male and sixteen female rabbits were used in a preclinical trans-axial femur model of osseointegration. Control and DBD treatment implants were inserted randomized per hind limb in each rabbit (1 implant/hind-limb). At 6 weeks post-surgery, bone-to-implant contact, adjacent bone volume, and torque to failure were assessed by micro-CT, calcified histology, and mechanical testing.

Results

DBD plasma treatment of vacuum-sealed implants increased surface wettability and did not change surface chemistry or roughness. Peak torque and torsional energy, and bone-to-implant contact increased with DBD treatment in males. In contrast, female rabbits showed increased osseointegration equal to DBD treated male implants regardless of DBD plasma treatment.

Conclusion

DBD treatment is an effective method to enhance osseointegration by increasing surface wettability; however, this response is sex dependent. In healthy female patients, DBD treatment may not be necessary but in older patients or patients with compromised bone, this treatment could be an effective measure to ensure implant success.

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Benchtop plasma treatment of titanium surfaces enhances cell response

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Abstract

Objective

Modifications to implant surface properties, including topography, chemistry, and wettability, alter immune response, osteoblast differentiation of bone marrow stromal cells (MSCs), and implant integration *in vivo*. Dielectric barrier discharge (DBD) plasma treatment has been used to sterilize surfaces and remove adsorbed carbon, improving wettability. However, unless it is used immediately prior to placement, ambient atmospheric hydrocarbons rapidly adhere to the surface, thereby reducing its hydrophilicity. Moreover, this method is not practical in many clinical settings. The aim of this study was to evaluate the effectiveness of an on-site benchtop modification technique for implants at time of placement, consisting of a DBD plasma that is used to sterilize implants that are pre-packaged in a vacuum. Effects of the plasma-treatment on implant surface properties and cellular response of MSCs and osteoblasts were assessed *in vitro*.

Methods

Titanium-aluminum-vanadium implant surfaces were grit-blasted (GB) or grit-blasted and acid-etched (AE), and packaged under vacuum. AE surfaces were also plasma-treated using the benchtop device (GB + AE) and then removed from the vacuum. GB surface morphology was altered with AE but AE microroughness was not changed with the plasma-treatment. Plasma-treatment increased the surface wettability, but did not alter surface atomic concentrations of titanium, oxygen, or carbon.

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Results

MSCs and osteoblast-like cells (MG63 s) produced increased concentrations of osteocalcin, osteopontin, and osteoprotegerin after plasma-treatment of AE surfaces compared to non-plasma-treated AE surfaces; production of IL6 was reduced and IL10 was. Aging GB + AE surfaces for 7 days after plasma-treatment but still in the vacuum environment reduced the effectiveness of plasma on cellular response.

Significance

Overall, these data suggest that application of benchtop plasma at the time of implant placement can alter the surface free energy of an implant surface without modifying surface chemical composition and enhance the differentiation and activity of MSCs and osteoblasts that are in contact with these implant surfaces.

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