Combination Approach for Limiting Epithelial Downgrowth Around the Percutaneous Implants: Use of Biomimetic Coatings in Conjunction with Negative Pressure Wound Therapy

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Statement of purpose: Amputation of limbs can lead to functional limitations to the patients. Unfortunately the current standard of care, a socket type prosthetic suspension system, can be considered suboptimal. These patients however can greatly benefit from an alternative attachment system, percutaneous osseointegrated docking system (PODS). This system functionally connects an osseointegrated exoprosthesis to the artificial limb through a percutaneous post [1]. The major limitation of this PODS technology is the high rate of periprosthetic infection [2]; which often results from inadequate skin-seal and continuous epithelial downgrowth at the soft tissue-implant interface. Biomimetic material coatings and a negative pressure wound therapy (NPWT) have previously been shown to limit the skin downgrowth rate, independently to each other [3,4]. It was therefore hypothesized that these techniques, in combination, will further limit the ongoing healing cascades and prevent the observed downgrowth around these devices. In this study, we investigated the efficacy of two biomimetic coatings, collagen Type 1 and hydroxyapatite (HA), to prevent epithelial downgrowth under the influence of a continuous negative pressure therapy regime.

Materials and Methods: Thirty percutaneous devices were fabricated from medical grade titanium alloy, the subdermal barrier portions were porous coated with commercially pure titanium, then further coated with either collagen Type 1 (n=10) or HA (n=10), or left as untreated controls (n=10). Using an established single-stage protocol, these implants were surgically placed subdermally in guinea pig backs [4]. Five animals from each group were subjected to a four-week NPWT regime, which consisted of -80mmHg continuous negative pressure to the interface, while remaining five animals received no NPWT. Four weeks post-implantation, animals were sacrificed; the implants and surrounding tissues were harvested, and processed for further histological analyses. The downgrowth rate was calculated as percentage of exposed porous or coated surface to the total distal attachment surface of the device.

Results and Discussion: A representative set of photomicrographs and the downgrowth data are given in Figs 1 and 2. Remarkably, NPWT and HA devices showed a statistically significant reduction ($p \leq 0.014$) in downgrowth when compared to the HA coated only group. However, there were no statistical significance ($p \geq 0.806$) found between the collagen coated and control groups. However, when NPWT was used, all implant types had improved downgrowth outcomes ($P<0.05$).

Based on the literature, it appeared that epithelial downgrowth and the healing around the percutaneous devices are interconnected. Each parameter therefore needs to be considered and optimized during the design and experimental protocol development stages for ultimately preventing the downgrowth. Previously, it was shown that the porous coated devices promoted soft tissue inter-digitation and limited shear forces at the interface, and hence the downgrowth [5]. Using the same implant system, the combination approach of biomimetic coating with NPWT further limited the downgrowth.

It is well known that the NPWT removes accumulation of pro inflammatory proteins away from the wound-bed and improves the blood supply to the area [6-7]. Thus, it was also expected to limit the host immune responses and overall downgrowth at the percutaneous interface. Data indicated that NPWT indeed improved the downgrowth outcome. Although both biomimetic coatings were expected to improve the downgrowth outcome, it was found that only HA was effective. The data indicated that there might be a specific mechanism that is dominant in promoting cellular adhesion to the device surface, indicating a need for further research.

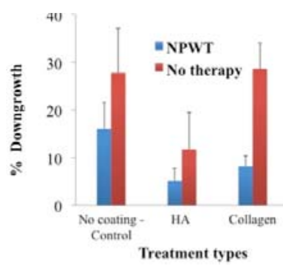

Figure 1: A bar chart showing the downgrowth rates with and without bio-mimetic surface coating and NPWT.

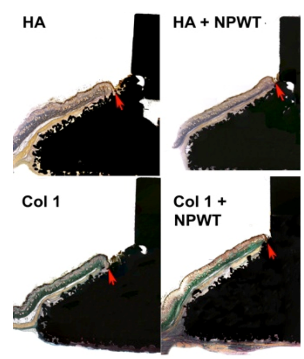

Fig. 2: A representative set of images of trichrome stained skin-implant interface. Red arrows – relative position of epithelial at 1 month post surgery.

Conclusion: The combination approach of biomimetic surface coating with NWPT appeared to be an effective option for preventing downgrowth in percutaneous device applications. Further targeted research is however needed to fully realize its clinical potential.

References:

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