Effects of Programmed Local Delivery from a Micro/Nano-Hierarchical Surface on Titanium Implant on Infection Clearance and Osteogenic Induction in an Infected Bone Defect

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Objective

The two major causes for implant failure are postoperative infection and poor osteogenesis. Initial period of osseointegration is regulated by immunocytes and osteogenic-related cells resulting in inflammatory response and tissue healing. The healing phase can be influenced by various environmental factors and biological cascade effect. To synthetically orchestrate bone-promoting factors on biomaterial surface, we built a dual delivery system coated on a titanium surface (abbreviated as AH-Sr-AgNPs).

Experimental section

Initial period of bone healing goes through several stages, which is influenced by various environmental factors. We built $\text{Sr}^{2+}/\text{Ag}^+$ dual delivery system on the micro-nano surface of trabecular-like titanium (Ti) implant by using protonation effect of alkali-heat treatment (AH) and oxidation-reduction quality of polydopamine (PDA). This multifunctional local delivery system orchestrates several bone healing stages by killing bacteria, regulating macrophage polarization, and stimulating osteoblast differentiation.

Results

Both in vitro and in vivo assays show that AH-Sr-AgNPs-modified surface renders a microenvironment adverse for bacterial survival and favorable for macrophage polarization (M2), which further promotes the differentiation of preosteoblasts.

Infected New Zealand rabbit femoral metaphysis defect model is used to confirm the osteogenic property of AH-Sr-AgNPs implants through micro-CT, histological, and histomorphometric analyses. In addition, relatively lower bone formation was calculated under the application of AP20187, indicating macrophages played the pivotal role in the early bone healing process.

Conclusion

These findings demonstrate that the programmed surface with dual delivery of Sr^{2+} and Ag^+ has the potential of achieving an enhanced osteogenic outcome through favorable immunoregulation.