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Controlled release of dopamine coatings on titanium bidirectionally regulate osteoclastic and osteogenic response behaviors

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Introduction

Bone diseases, for example, osteoporosis, cause excessive differentiation of osteoclasts and decreased bone formation, resulting in imbalance of bone remodeling and poor osseointegration, which can be considered a relative contraindication for titanium implants. Dopamine (DA) might provide a solution to this problem by inhibiting osteoclasts and promoting osteoblasts at different concentrations. However, current commercial implants cannot load bone-active molecules, such as DA. Therefore, this study aimed to develop a surface modification method for implants to achieve a controlled release of DA and enhance the resistance of titanium implants to bone resorption and bone regeneration.

Methods

DA-loaded alginate-arginine-glycine-aspartic acid (RGD) (AlgR) coatings on a vateritemodified titanium surface were assembled.

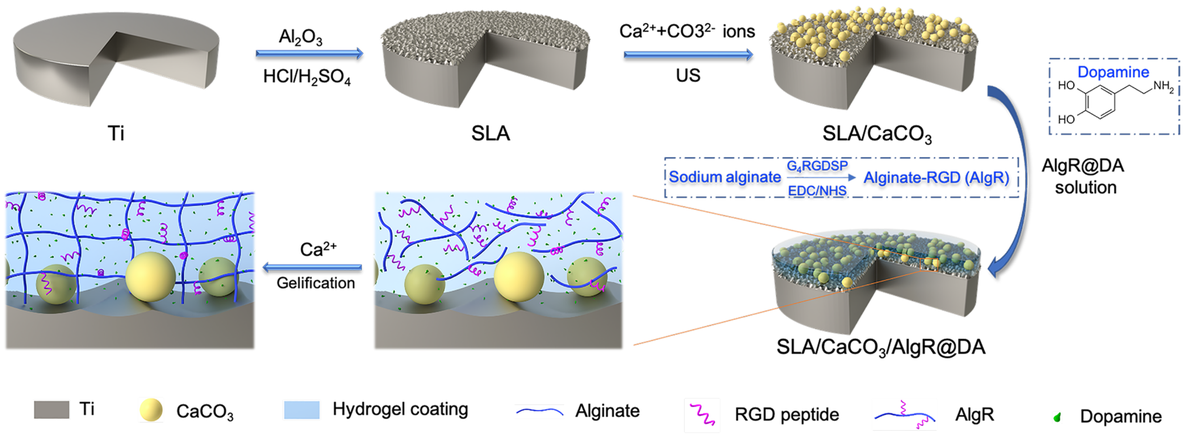

Fig. 1. Schematic of the step-by-step fabrication of AlgR@DA hydrogel coatings by the $CaCO_3$ mineralization of SLA titanium surfaces.

Results and Discussion

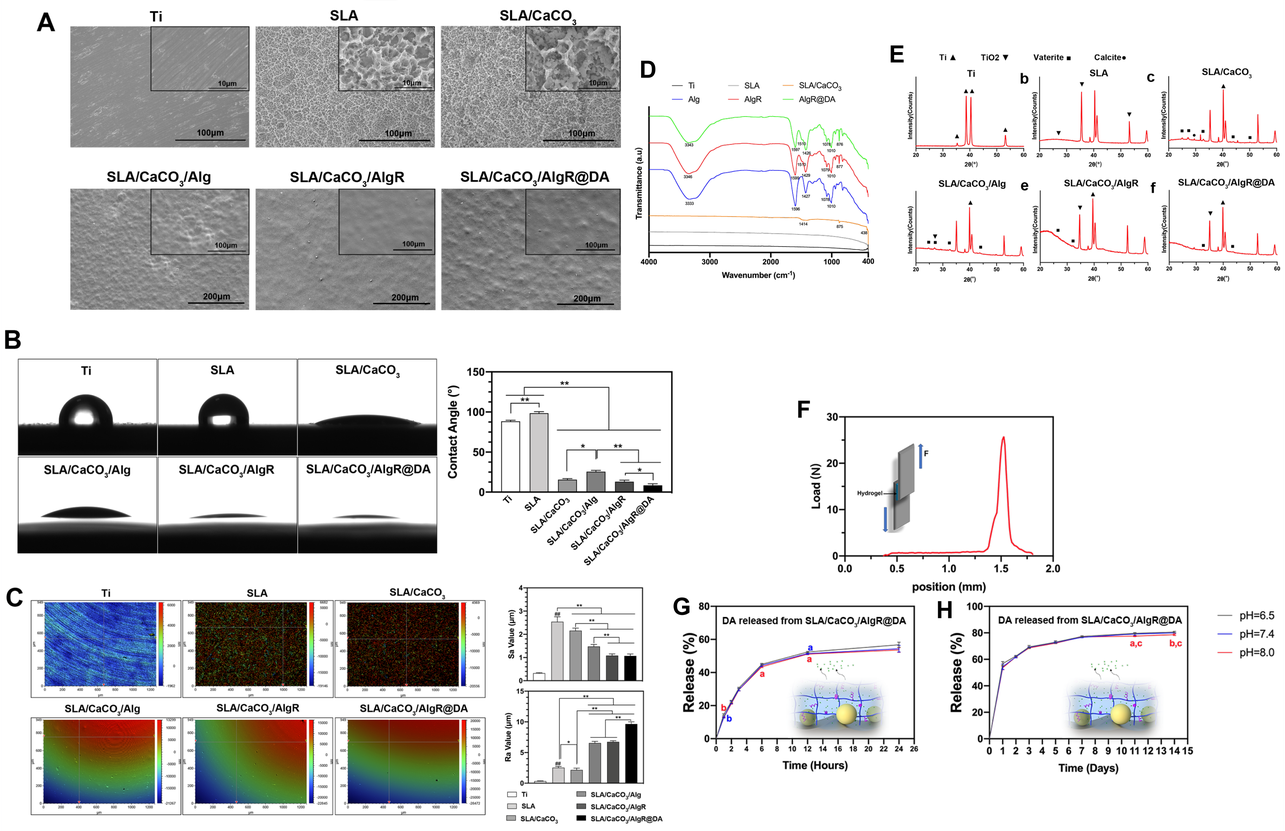

Fig. 2. SEM (A), WCA (B) , 2D optical microscopy images (C) FTIR spectra (D) and X-ray diffraction (XRD) patterns (E)of Ti, SLA, $SLA/CaCO_3$, $SLA/CaCO_3$/Alg, $SLA/CaCO_3$/AlgR, $SLA/CaCO_3$ /AlgR@DA and the quantitative results for each. Adhesive strength (F) and release profiles (G-H) of hydrogel coatings.

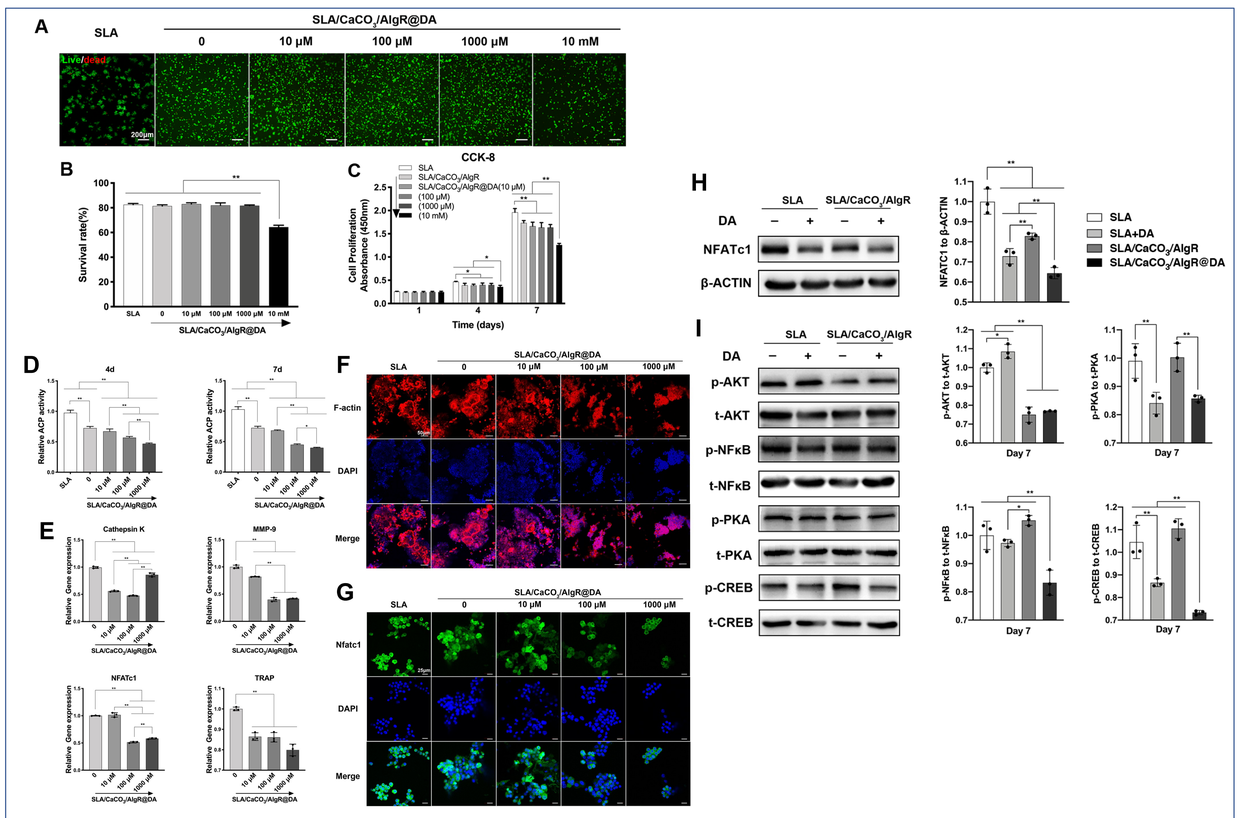

Fig. 3. Alginate-RGD coatings actively cooperated with dopamine to inhibit osteoclastogenesis.

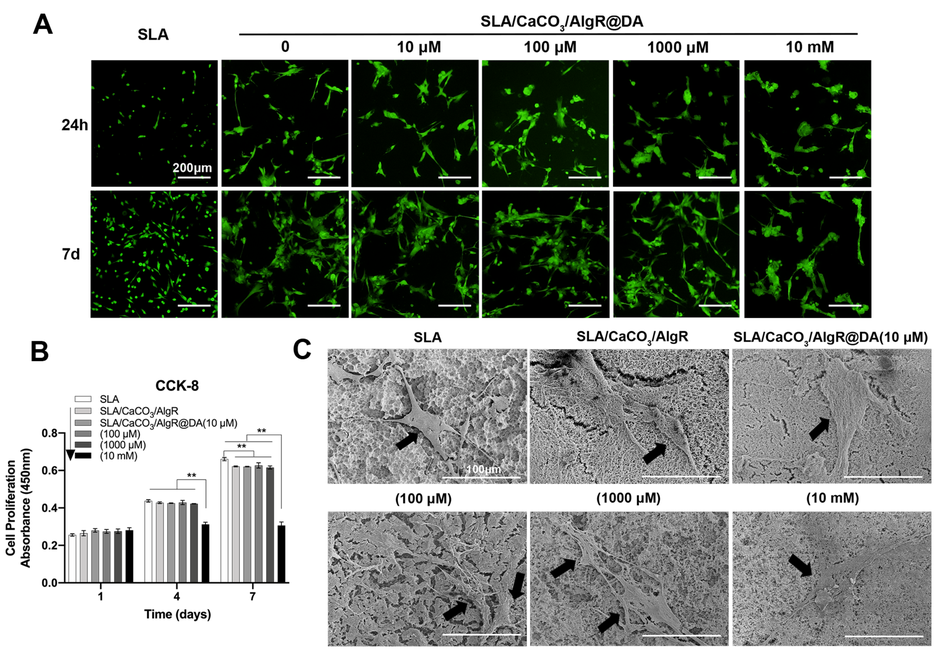

Fig. 4. Dopamine-loaded coatings enhanced bone marrow mesenchymal stem cells adhesion and osteogenic differentiation.

Conclusion

In this study, we successfully fabricated a bioactive hydrogel layer on a rough titanium surface that continuously and steadily released DA, which is an active small-molecule drug. The experimental results show that the RGD-coupled, alginate hydrogel coating inhibits TRAP activity and that DA released into the microenvironment further impairs the formation and differentiation of osteoclasts while promoting the adhe sion and osteogenic differentiation of BMSCs. Based on the results of functional experiments, the optimal DA loading concentration to regulate the balance between bone resorption and osteogenesis is 100 μM. This method has great potential in solving the problems around the implant in patients with metabolic bone-related diseases.