Preparation of Multifunctional Nanozymes and Their Research in the Repair of Keratitis

多功能纳米酶的制备及其在角膜炎的修复中的研究

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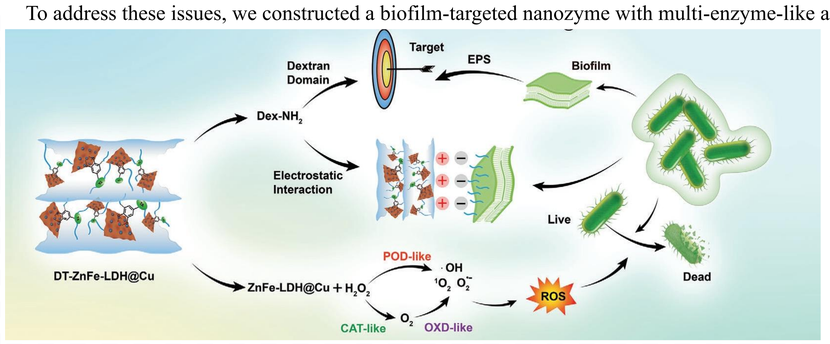
Introduction

Bacterial keratitis (BK) is a type of corneal inflammation resulting from bacterial infection in the eye. Currently available nanozymes lack sufficient catalytic activity and the ability to penetrate bacterial biofilms, limiting their efficacy against the treatment of BK.

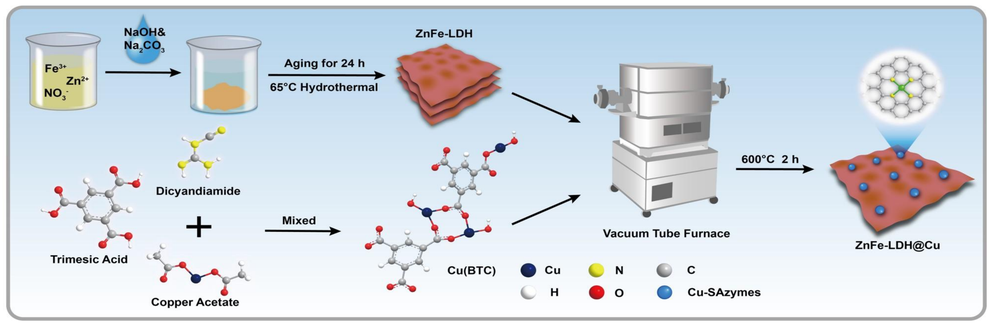
To address these issues, we constructed a biofilm-targeted nanozyme with multi-enzyme-like activities to treat BK caused by bacterial infection.



The peroxidase (POD)- and oxidase (OXD)-like activities of DT-ZnFeLDH@Cu enable it to generate ROS—hydroxyl radicals (·OH), superoxide anion radical ($O_2^{\bullet-}$), and singlet oxygen ($^1O_2$) —tokill bacteria in the biofilm within the wound. During the healing process as the biofilm shrinks, which the catalase (CAT)-like activity of DT-ZnFe-LDH@Cu plays more of a primary role in converting excess hydrogen peroxide (H_2O_2) into oxygen (O_2) to further alleviate the inflammatory response.

Experimental Details

ZnFe-LDH nanosheet arrays were synthesized by a coprecipitation method, and separately, ultra-thin 2D nanosheets of Cu-SAzymes were produced through a dicyandiamide-assisted pyrolysis strategy.



Characterization

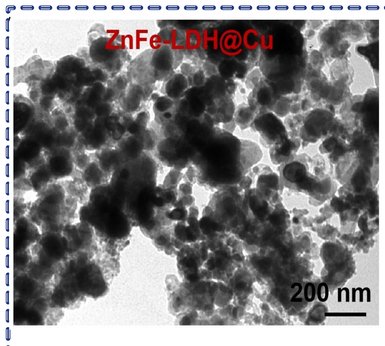


Fig.1 ZnFe-LDH@Cu Particle size analysis diagram.

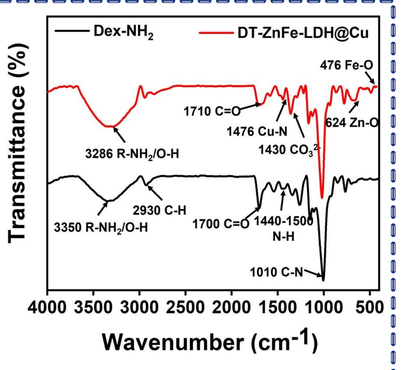


Fig. 2 FT-IR spectra of Dex-NH_2 and DT-ZnFeLDH@Cu.

Activity Analysis

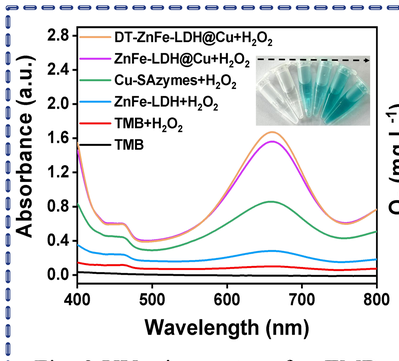


Fig. 3 UV–vis spectra of oxTMB by POD-like activity produced by different components.

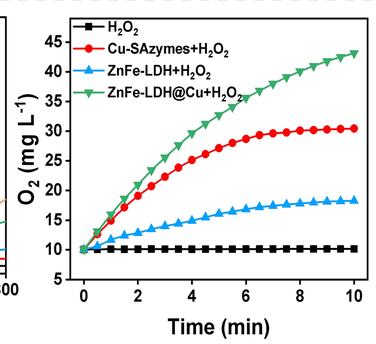


Fig. 4 Analysis of dissolved oxygen concentration of different component solutions with time extension.

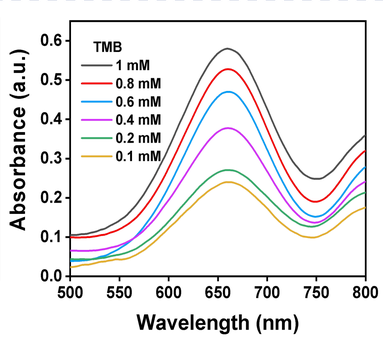


Fig 5 UV–vis spectra of ZnFe-LDH@Cu oxTMB at different concentrations.

In-vitro Experiment

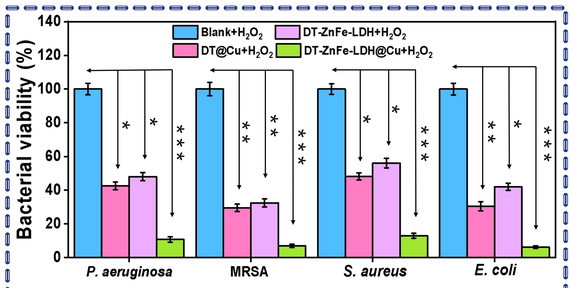


Fig.6 the corresponding quantitative results of P. aeruginosa, MRSA, S. aureus, and E. coli bacterial survival after different treatments. The OD600 of P. aeruginosa.

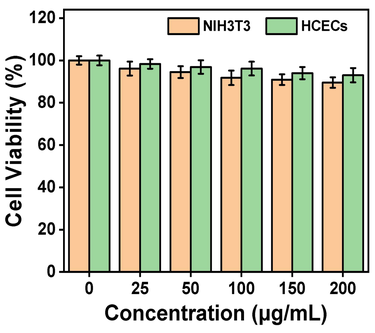


Fig. 7 The FDA staining images and the cell viability of HCECs and NIH/3T3 and after culturing with different concentrations of DT-ZnFe-LDH@Cu for 24 h.

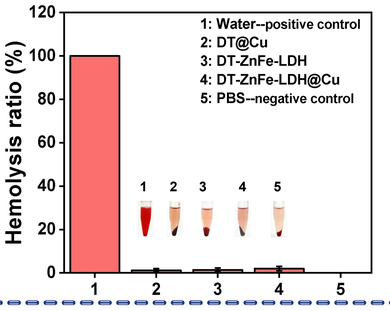


Fig.8 Hemolysis assay of red blood cells treated with different treatments.

Control Experiment

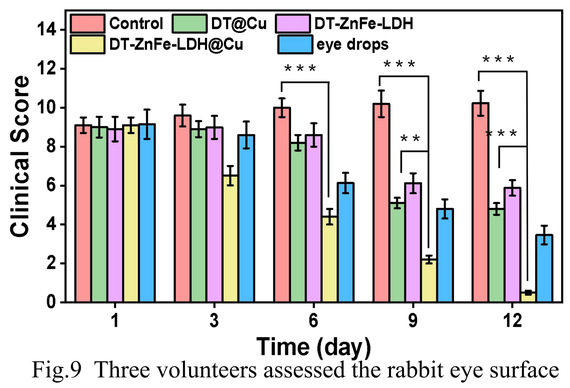


Fig.9 Three volunteers assessed the rabbit eye surface with a corresponding clinical score (0-12) based on three criteria (cloudy area, surface regularity, opacity density) and quantified the clinical score.

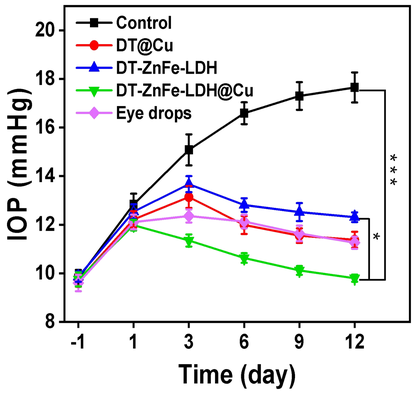


Fig.10 IOP of rabbits after different treatments.

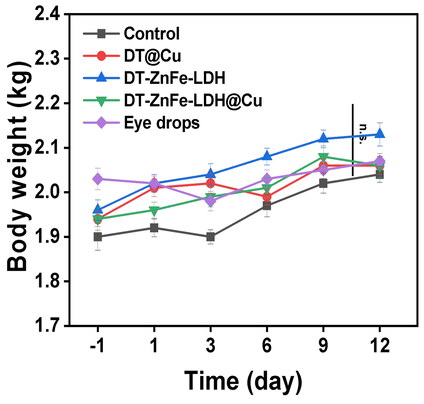


Fig.11 Changes in the body weight of rabbits during different treatments.

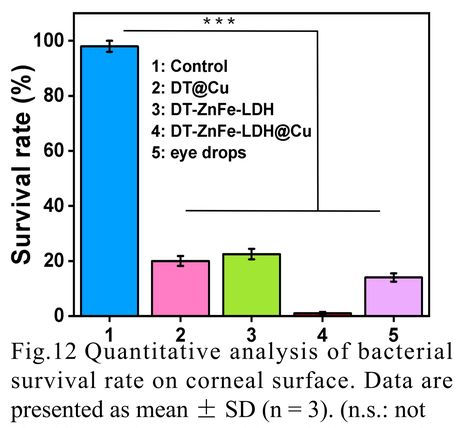


Fig.12 Quantitative analysis of bacterial survival rate on corneal surface. Data are presented as mean ± SD (n = 3). (n.s.: not significant, *p < 0.05, **p < 0.01, and ***p < 0.001).

Conclusions

- ✓ The unique triple enzyme-like catalytic activities of the DT-ZnFeLDH@Cu was enabled by the loading of Cu-SAzymes and Dex-NH_2 onto ZnFe-LDH to penetrate bacterial biofilms and adhered the biofilm via electrostatic interactions.
- ✓ Under acidic conditions, the POD-like and OXD-like activities of DT-ZnFe-LDH@Cu catalyzed the conversion of H_2O_2 to ·OH, $O_2^{\bullet-}$, and $^1O_2$, thereby killing the bacteria. Simultaneously, the CAT-like activity enabled the nanozyme to convert excess ROS into O_2, thereby regulating inflammatory responses.
- ✓ DT-ZnFe-LDH@Cu demonstrated superior therapeutic potential in treating bacterial infections in the corneas of a BK rabbit model compared to commercially available tobramycin eye drops..

Acknowledgements

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Communication

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