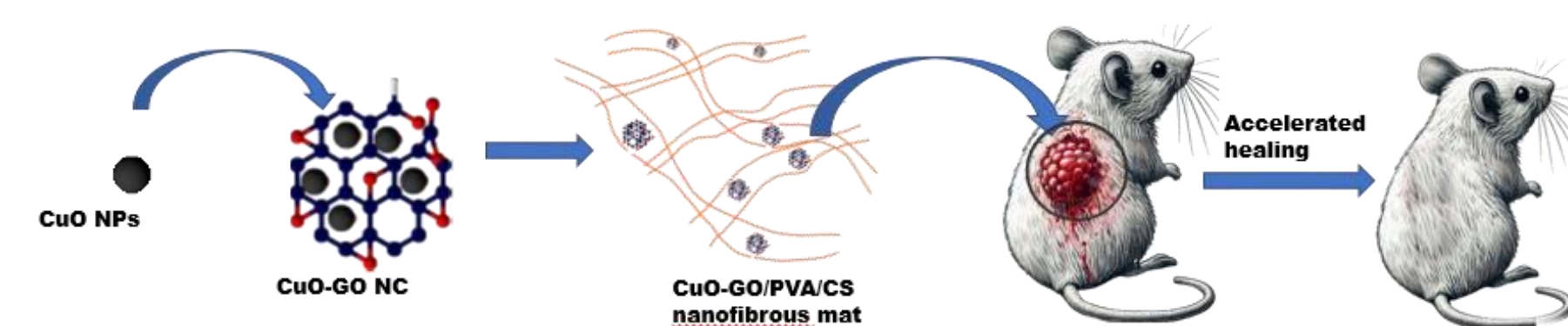


Abstract

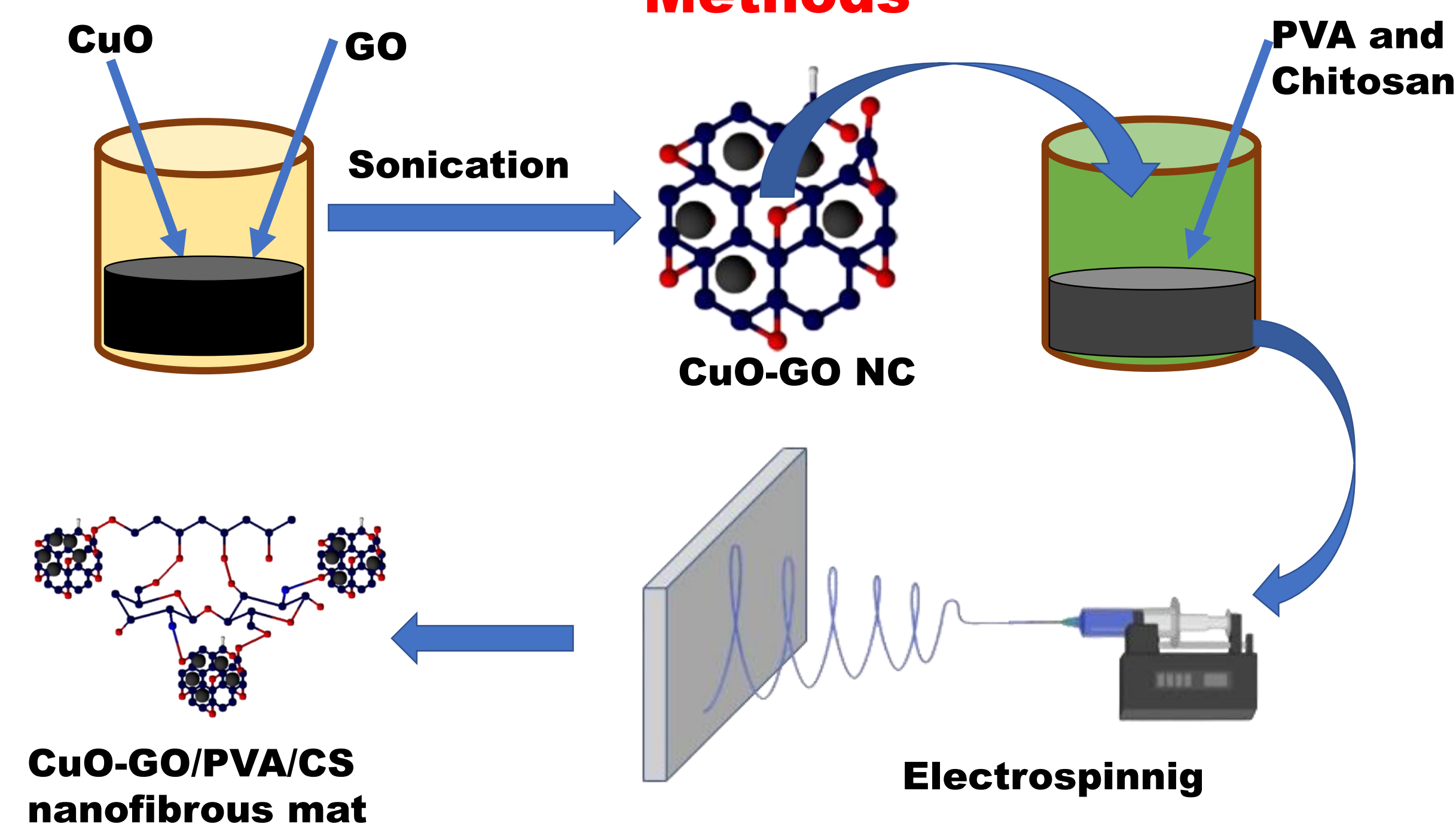
Conventional wound dressings mainly absorb exudates and shield wounds but lack therapeutic activity. To enhance functionality, we developed a biodegradable PVA/chitosan (CS) nanofibrous mat via electrospinning, incorporating a CuO-graphene oxide (CuO-GO) nanocomposite. GO was prepared by a modified Hummers' method, and CuO nanoparticles were biosynthesized using chitosan as stabilizer. The CuO-GO nanocomposite was prepared via ex-situ ultrasonic mixing and characterized using XRD, FTIR, SEM, and TEM. TEM revealed ~49 nm CuO nanoparticles uniformly distributed on GO sheets. The CuO-GO-loaded PVA/CS nanofibrous mat was thermally crosslinked at 120 °C for 80 min. Characterization confirmed proper integration, with UV-Vis peaks at 275 and 365 nm and fiber diameters ranging from 116–290 nm. CuO-GO enhanced tensile strength but reduced ductility, decreased hydrophilicity, and accelerated degradation. In vivo studies showed >95% wound closure within 14 days using mats with 2 wt% CuO-GO, indicating strong potential for wound healing applications.



Introduction

Wound healing is a complex, multi-phase process often impaired by microbial infections and poor tissue regeneration [1]. Traditional dressings such as gauze or cotton offer basic protection but lack active therapeutic functions. Recent advances in biomaterials have highlighted the potential of electrospun nanofibers for wound care, owing to their high surface area, porosity, and ability to mimic the extracellular matrix [2]. Biopolymers like chitosan (CS) and polyvinyl alcohol (PVA) are widely used due to their biocompatibility, biodegradability, and film-forming capabilities [3]. Additionally, metal oxide nanoparticles, particularly copper oxide (CuO), exhibit pro-angiogenic, pro-collagenic, and cell proliferative properties, which accelerate tissue regeneration. CuO enhances the expression of vascular endothelial growth factor (VEGF), supports fibroblast proliferation, and stimulates extracellular matrix remodeling, all of which are essential for effective wound repair [4]. Graphene oxide (GO) further complements the wound healing process through its unique surface chemistry. The oxygen-containing functional groups on GO enable it to adsorb serum proteins, including extracellular matrix (ECM) proteins, via hydrophobic interactions, electrostatic forces, and hydrogen bonding. This adsorption promotes cell adhesion, proliferation, and migration, key steps in tissue regeneration [5]. By facilitating ECM protein binding, GO helps maintain essential cell-matrix interactions, even in damaged tissue environments. Together, copper and GO create a synergistic platform that accelerates wound healing by enhancing angiogenesis, supporting collagen maturation, and improving cell attachment and tissue integration.

Methods



Results

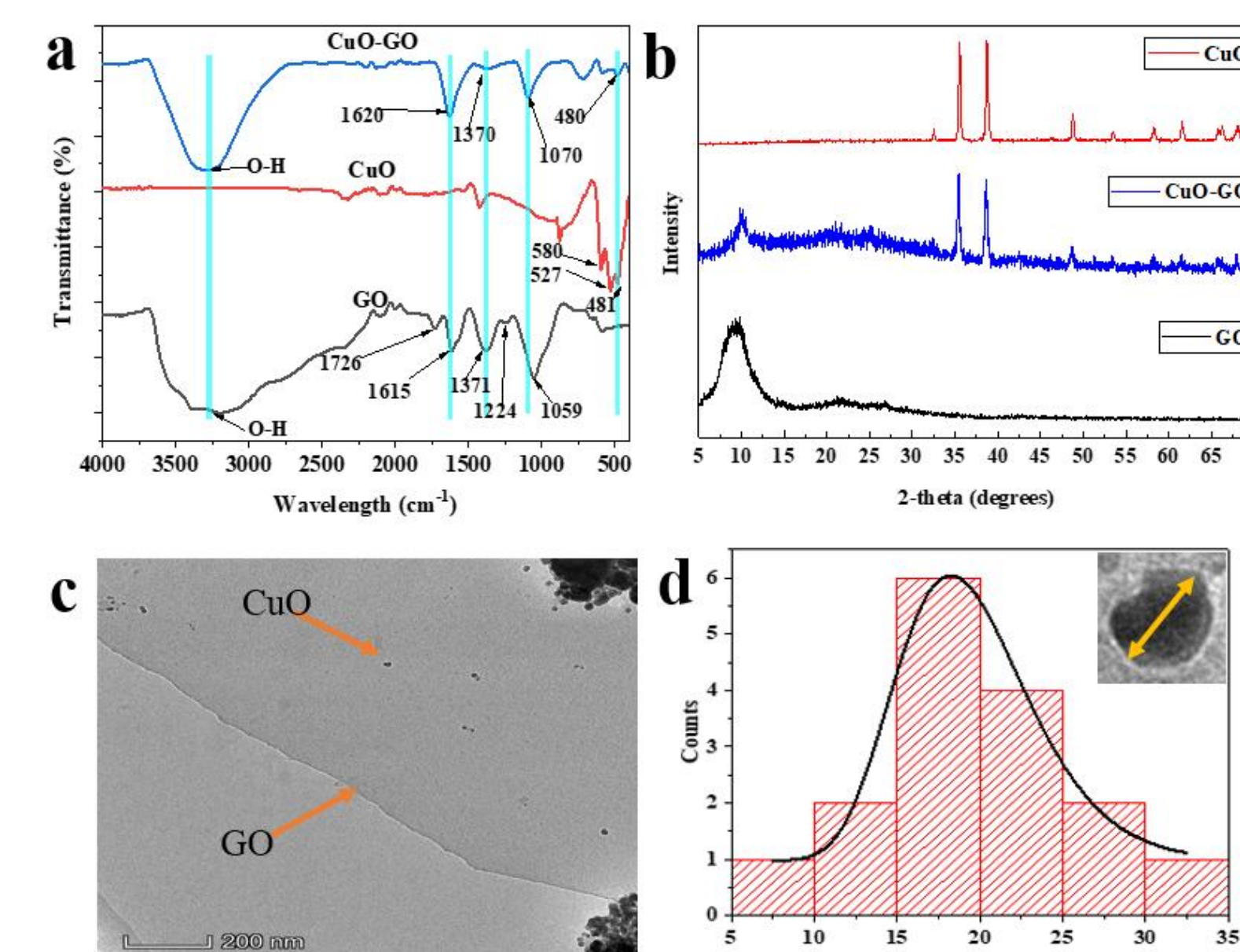


Fig. 1. Successful synthesis of the CuO, GO and CuO-GO NC was confirmed by the (a) FTIR (b) XRD and (c) TEM image. (d) Shows the nanosize distribution of CuO NPs.

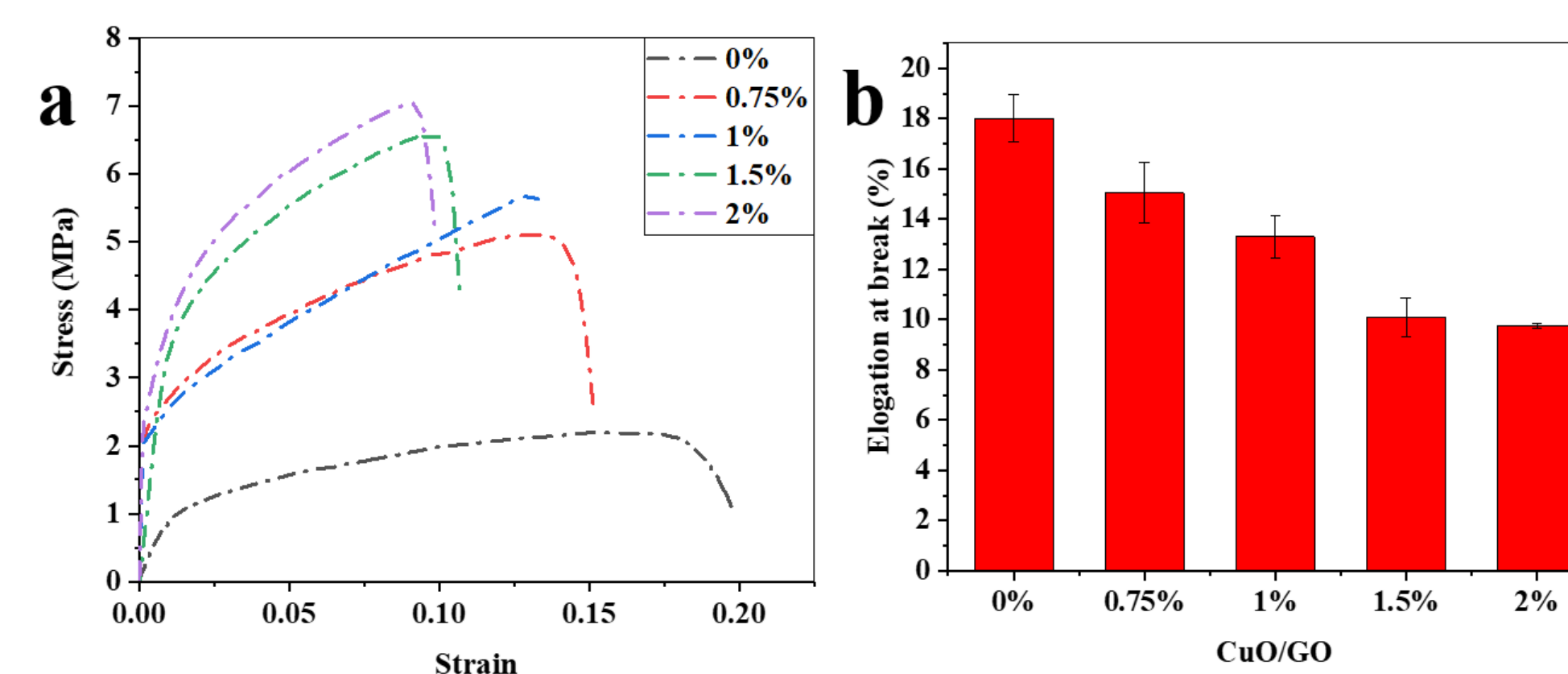


Fig. 3. Mechanical properties of the CuO-GO/PVA/CS nanofibrous mat matches those of human skin (a) stress-strain curve and (b) Elongation at break

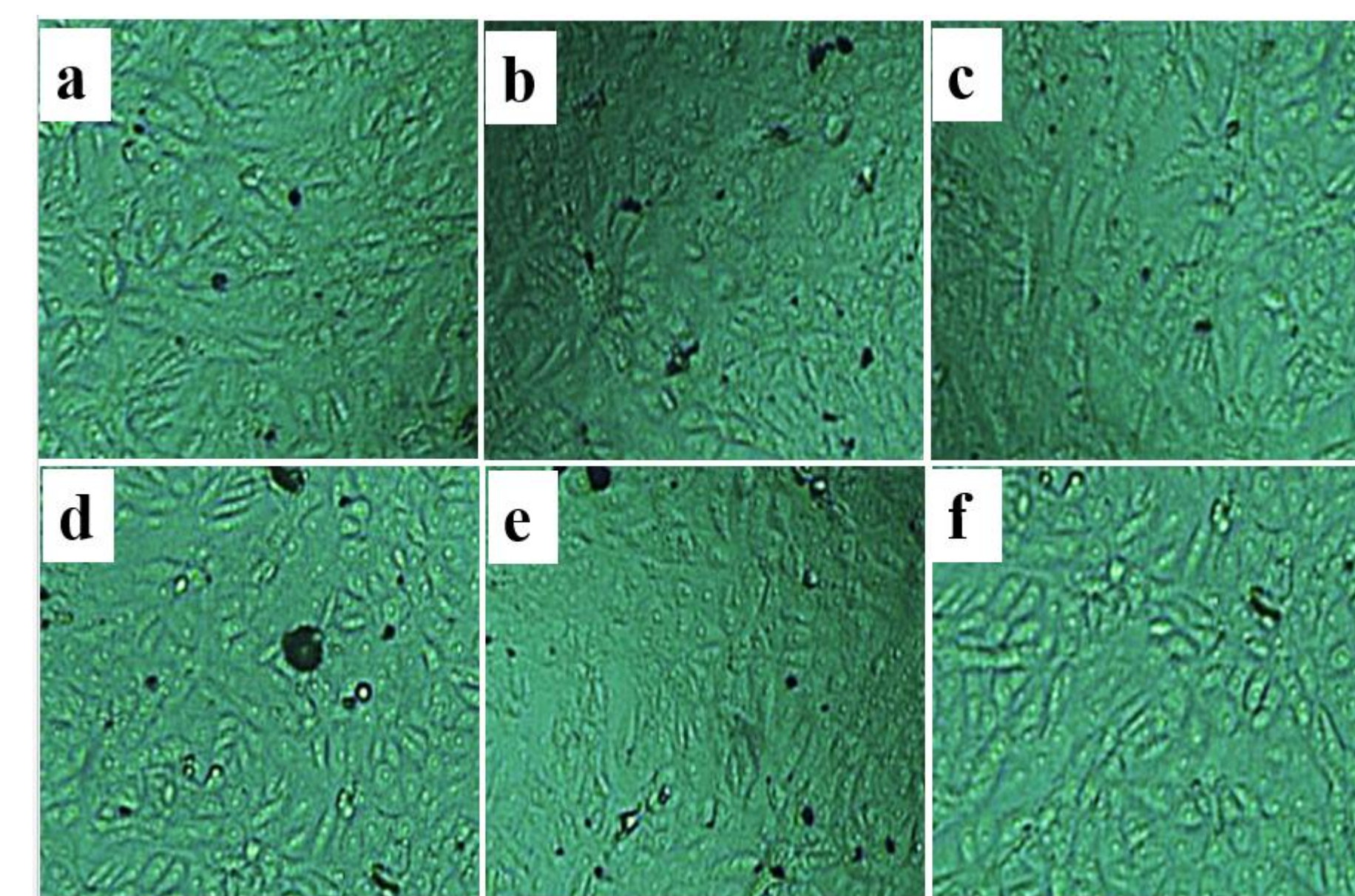


Fig. 5. Cell cytotoxicity analysis showing above 95% cell survival in (a to d) 0.75% -2.0% CuO-GO/PVA/CS nanofibrous mat respectively and (e-f) positive and negative controls respectively.

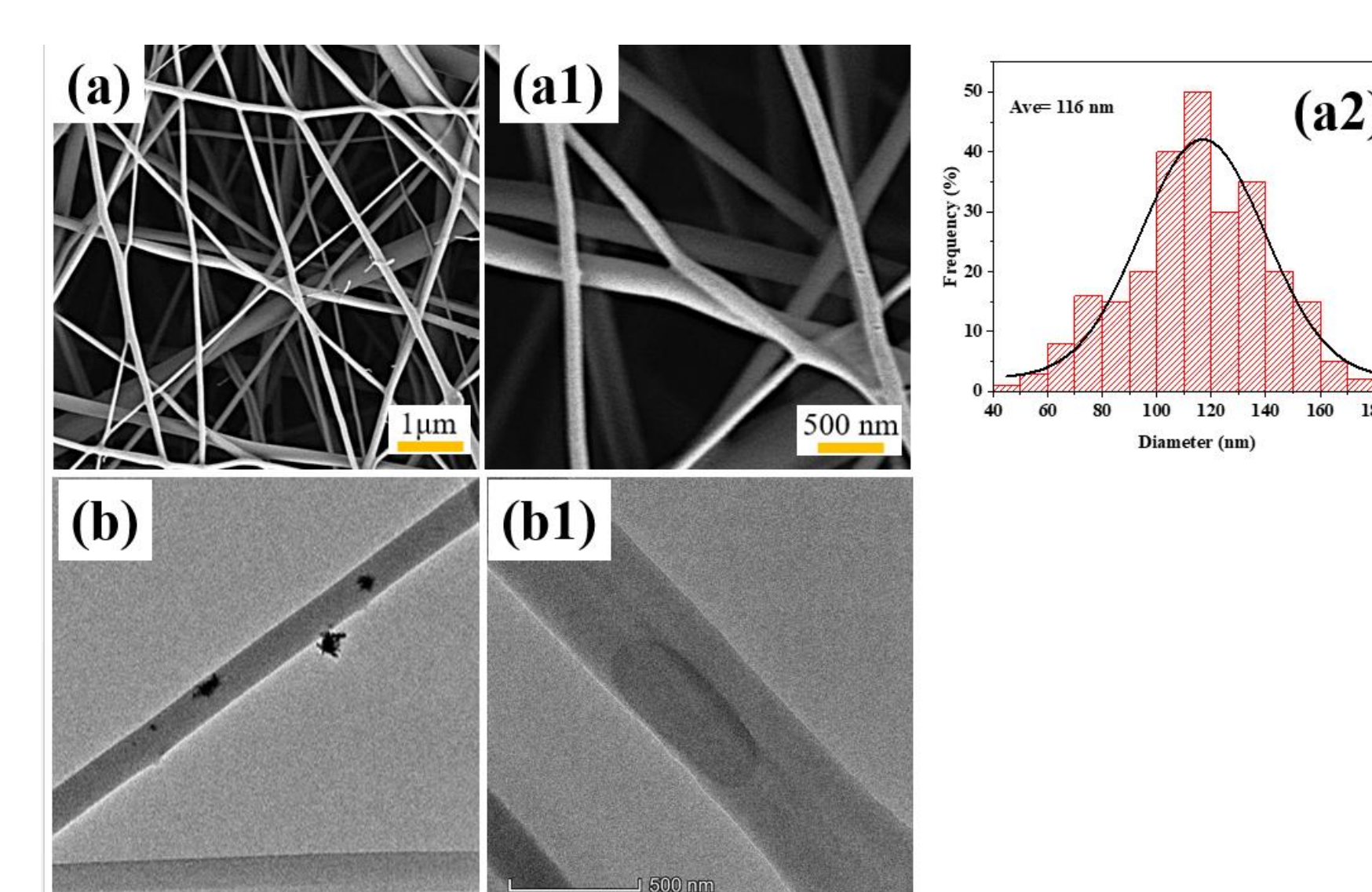


Fig. 2. Morphological analysis of CuO-GO/PVA/CS nanofibers (a and a1) SEM images (b1 and b2) TEM images and (a2) fiber diameter distribution. The CuO-GO was lodged inside the PVA/CS fibers as seen from the TEM

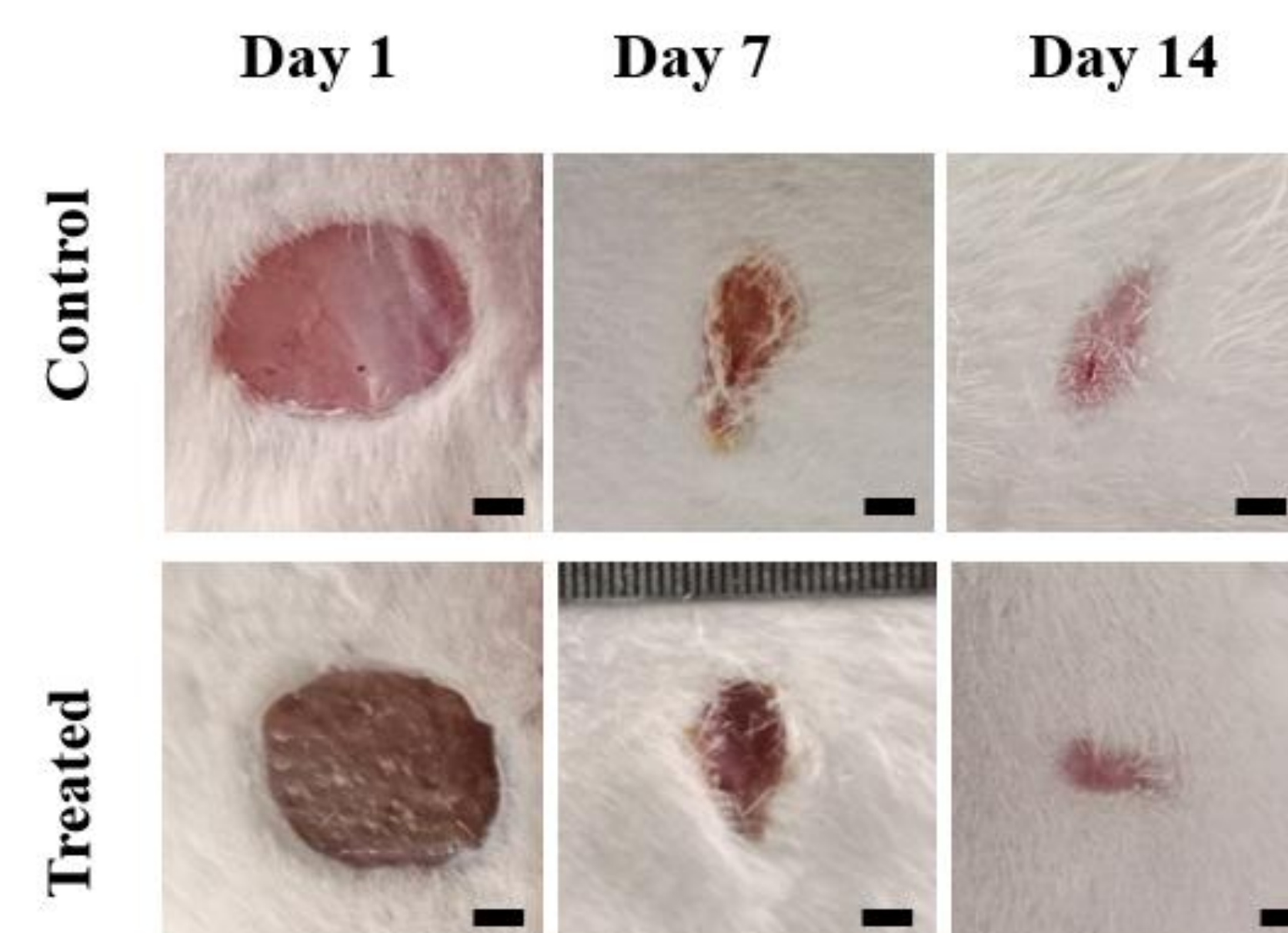


Fig. 4. Optical images of the wound size reduction over 14 days showing a progressive wound closure with signs of healthy healing

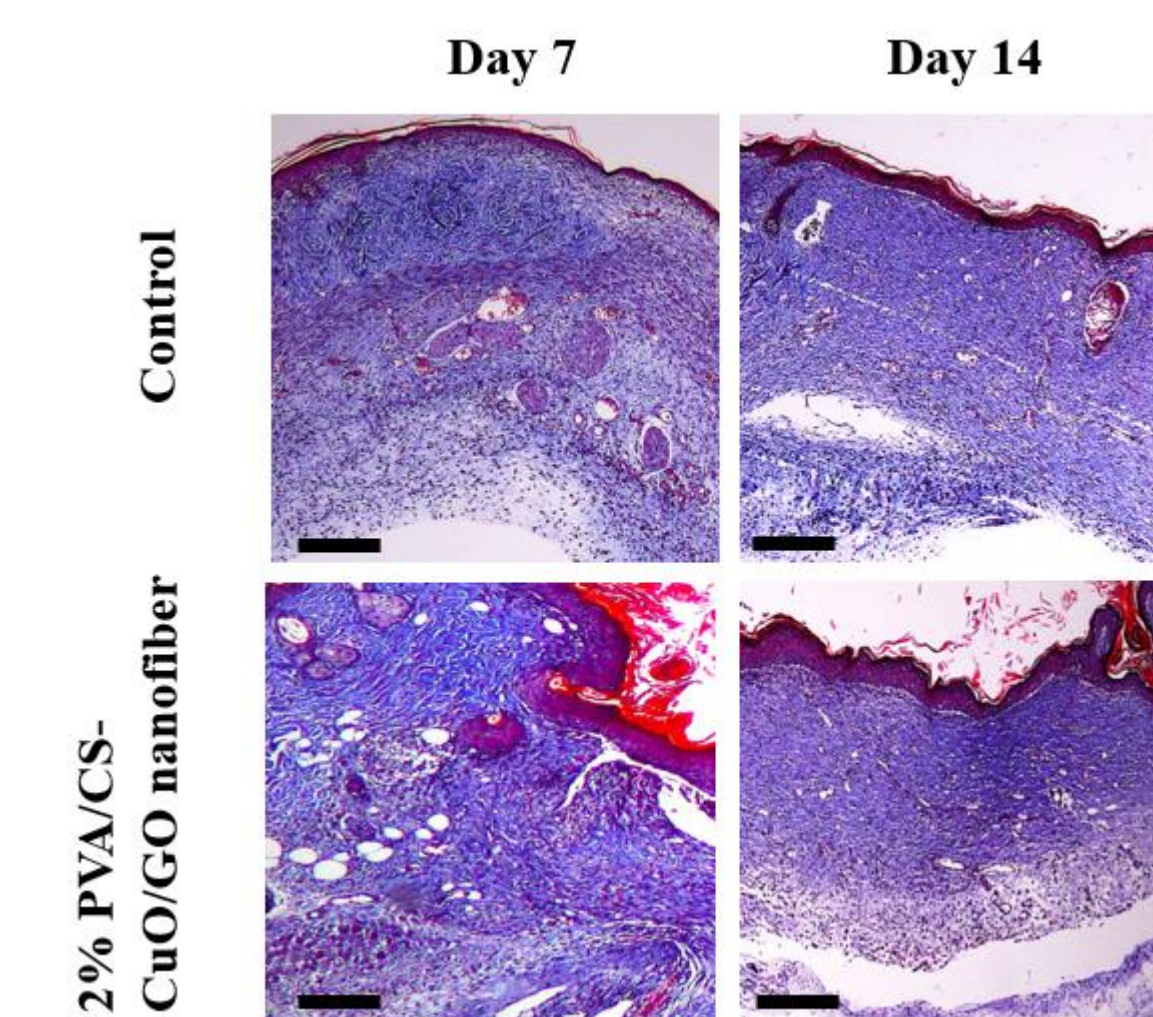


Fig. 6. MT staining of tissues from the wound site on days 7 and 14 confirming the rapid ECM deposition and tissue regeneration.

Conclusion

Chitosan-stabilized CuO nanoparticles were synthesized via a green chemistry approach and combined with graphene oxide (GO) through ultrasonication to form a CuO-GO nanocomposite. This was incorporated at varying weight percentages into PVA/CS nanofibrous mats fabricated by electrospinning. SEM analysis confirmed uniform, bead-free fibers with reduced diameters at higher CuO-GO loading. Thermal crosslinking improved structural integrity and enabled controlled swelling and degradation-key for wound exudate management. The mats exhibited excellent thermal stability, cytocompatibility, and retained properties after autoclave sterilization. In vivo studies demonstrated accelerated healing and minimal scarring, highlighting their potential as scalable, biocompatible alternatives to conventional dressings.

References

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Recommendations

Future studies should focus on:

- (1) incorporating bioactive molecules such as growth factors or anti-inflammatory agents into the nanofibrous mat to provide targeted and sustained therapeutic effects.
- (2) evaluating the performance of the CuO-GO-loaded PVA/CS nanofiber in complex wound models like diabetic or immunocompromised conditions to validate its effectiveness in delayed healing scenarios.
- (3) developing smart, stimuli-responsive versions of the dressing that can adapt to changes in the wound microenvironment, such as pH or infection, for enhanced real-time wound management.

Acknowledgement

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