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Nano-porous Aerogel Granulometry for Enhancing Efficiency of Hemostatic Devices

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Extended Abstract

Hemorrhagic trauma remains a global cause of preventable death, especially in prehospital settings. This study explores the use of nano-porous silica-based aerogels integrated into traditional gauze to enhance hemostatic performance. Aerogels' high surface area, porosity, fluid absorption capacity, and thermal regulation properties have demonstrated exceptional promise in accelerating clotting, promoting healing, and offering antimicrobial action [1]–[3], [10]. Leveraging these features, the proposed aerogel-infused gauze is evaluated for its efficacy under both venous (gravitational) and arterial (vacuum-driven) hemorrhage simulations.

The experimental design compared standard medical gauze against aerogel-infused gauze using synthetic blood and porcine blood samples. Samples were tested under gravity and vacuum pressure, replicating real-world bleeding dynamics. Gauze samples were infused with 4.9 mL of silica aerogel and tested under controlled environmental conditions following ASTM biosafety protocols. Under gravity-driven flow, aerogel-infused gauze demonstrated near-total cessation of blood flow; under pressure, it achieved >90% reduction compared to controls. Statistical analysis using a two-sample t-test ($df = 40$) yielded $p < 0.005$, and a Cohen's d of 4.62, underscoring both statistical and practical significance.

These findings align with recent studies reporting that aerogels, especially in hybrid or nanofiber matrix form, can improve coagulation kinetics, reduce rebleeding, and enable thermal regulation [3], [4], [6], [9]. Moreover, engineered formulations—such as hydrophobic aerogels, super-elastic mushroom-based composites, and graphene oxide-polymer hybrids—have been shown to enhance blood absorption, tissue integration, and in vivo clot stability [3], [6], [8]. Bagchee's related work supports the synergistic role of nanoporous structures and silver nanoparticles in optimizing both infection control and blood flow management in diabetic wounds and prosthetics [2], [7].

Beyond basic integration, this study proposes wound-geometry-specific aerogel layouts, such as concentric, peripheral, or grid distributions, to tailor fluid flow management in complex trauma scenarios. This modular approach supports application in both superficial and deep wounds, including surgical incisions, abrasions, puncture wounds, and contusions. These customizable patterns enhance absorption efficiency and clot localization, reflecting the adaptive design principles found in other recent works on 3D-printed and cross-linked aerogel-based devices [5], [6], [11].

In sum, this study demonstrates that aerogel-infused gauze significantly improves hemostatic response and introduces a scalable, low-cost pathway to next-generation trauma care tools. Future work includes biocompatibility testing, improved integration methods, durability assessments, and clinical trials. The versatility of aerogels in biomedical design offers significant promise for global deployment in emergency medicine, especially where cost, accessibility, and efficacy intersect.

References

[1] Mecwan, M., Li, J., Falcone, N., Ermis, M., Torres, E., Morales, R., Hassani, A., Haghniaz, R., Mandal, K., Sharma, S., Maity, S., Zehtabi, F., Zamanian, B., Herculano, R., Akbari, M., John, J. V., Khademhosseini, A., Recent advances in biopolymer-based hemostatic materials, *Regenerative Biomaterials*, Volume 9, 2022.

[2] Bagchee, M., Application of nano-porous aerogel granulometry for enhanced hemostasis and infection control in diabetic foot infections. American Limb Preservation Society, DFCon 2024, Nov. 2024

[3] Yang, G., Huang, Z., McCarthy, A., Huang, Y., Pan, J., Chen, S., Wan, W., Super-Elastic Carbonized Mushroom Aerogel for Management of Uncontrolled Hemorrhage. Adv. Sci. 2023, 10, 2207347. https://doi.org/10.1002/advs.202207347 (https://doi.org/10.1002/advs.202207347).

[4] Meador, Mary & Malow, Ericka & Silva, Rebecca & Wright, Sarah & Quade, Derek & Vivod, Stephanie & Guo, Haiquan & Guo, Jiao & Cakmak, Miko. (2012). Mechanically Strong, Flexible Polyimide Aerogels Cross-Linked with Aromatic Triamine. ACS applied materials & interfaces. 4. 536-44.
[5] Shixuan Chen, Mark A. Carlson, Yu Shrike Zhang, Yong Hu, Jingwei Xie, Fabrication of injectable and superelastic nanofiber rectangle matrices ("peanuts") and their potential applications in hemostasis, Biomaterials, Volume 179, 2018, pp 46-59,2023-2024 Seminole Regional Science & Engineering Fair Research Plan Page | 10
[6] Yang, X., Shi, N., Liu, J., Cheng, Q., Li, G., Lyu, J., Ma, F., Zhang, X., 3D Printed Hybrid Aerogel Gauzes Enable Highly Efficient Hemostasis. Adv. Healthcare Mater. 2022, 12,2201591. https://doi.org/10.1002/adhm.202201591 (https://doi.org/10.1002/adhm.202201591)
[7] Bagchee, M., Silver Nanoparticles with Nanoporous Aerogel in Designing Antimicrobial Medical Casts and Prosthetics, Presented at BMES 2024, Baltimore MD, 2024 (2024 BMES Annual Meeting)
[8] Borges-Vilches, J., Figueroa, T., Guajardo, S., Carmona, S., Mellado, C., Meléndrez, M., Aguayo, C., Fernández, K., Novel and effective hemostats based on graphene oxide-polymer aerogels: In vitro and in vivo evaluation, Biomaterials Advances, Volume 139, 2022.
[9] Xiaoli Jia, Chao Hua, Fengbo Yang, Xiaoxiao Li, Peng Zhao, Feifan Zhou, Yichi Lu, Hao Liang, Malcolm Xing, Guozhong Lyu, Hydrophobic aerogel-modified hemostatic gauze with thermal management performance, Bioactive Materials, Volume 26, 2023, Pages 142-158.
[10] Karamikamkar S, Yalcintas EP, Haghniaz R, de Barros NR, Mecwan M, Nasiri R, Davoodi E, Nasrollahi F, Erdem A, Kang H, Lee J, Zhu Y, Ahadian S, Jucaud V, Maleki H, Dokmeci MR, Kim HJ, Khademhosseini A. Aerogel-Based Biomaterials for Biomedical Applications: From Fabrication Methods to Disease-Targeting Applications. Adv Sci (Weinh). 2023 Aug;10(23)
[11] Liu, H., Xing, F., Yu, P., Zhe, M., Shakya, S., Liu, M., Xiang, Z., Duan, X., & Ritz, U. (2024). Multifunctional aerogel: A unique and advanced biomaterial for tissue regeneration and repair. Materials & Design, 243, 113091–113091. https://doi.org/10.1016/j.matdes.2024.113091