Better seal to better heal

Bench-to-bedside translation of bioadhesive innovation

By **Hyunwoo Yuk, Ph.D.**

Bedside is not only the ultimate destination for translation of biomedical innovations but also a starting point. 12 years ago, my brother was injured near death in a traumatic accident. I stayed at his bedside throughout his 1.5 years of hospitalization journey – starting from the emergency care to ICU to a rehabilitation hospital. Bleeding, broken body, injured organs, and series of high-stake surgeries are unforgettable as they are, but they imprint to one's memory if it is for your loved one holding your hands. It taught me numerous unmet needs in treating and healing various injuries in the body in painful yet most vivid way. Painstaking experience that I observed in the front seat – sprawling scars form sutured incisions and tissues all over the body; countless hours of nerve-wracking waiting outside of the OR room due to delays by hemostasis during surgeries; paralysis in limbs due to unsuccessful healing of peripheral nerves from trauma – have shaped my mission: *We need better solutions to repair and heal injuries, and those solutions should reach the bedsides of patients beyond academic research.*

Despite being the cornerstone of surgeries and the first line of clinical treatment, the standard-of-care for repairing and sealing injured tissues has not been changed much throughout the history of medicine. Sutures, one of the oldest medica devices in human history with an early record of use back to Ancient Egypt, is still the primary method for the closure of injured tissues and fixation of implantable devices. Control of bleeding from injuries still largely relies on the body's native mechanism of hemostasis by forming blood clots around the injury. While these solutions have saved countless lives, their longstanding legacy and limitations leave outstanding challenges to overcome. In some sense, my experience is just another testimonial that highlights these challenges and the critical need for disruptive innovations.

Trained as a material scientist and mechanical engineer, repairing and sealing damaged structures was not a new thing to me. Various adhesives are routinely used to repair broken parts or seal leaking pipes quickly and robustly. High-performance adhesive tapes like duct tapes have been a staple in engineers' toolbox owing to their user-friendly preparation-free use, near-instant adhesion, robustness, and applicability to diverse engineering surfaces.

When I started my study at MIT, I began to investigate how these adhesives found their use in clinical applications. To my surprise, medical adhesives comparable to duct tape were only used in a limited manner for carefully cleaned and dried skin, largely absent in other clinical applications. As an aspiring graduate student, the lack of such solution for repairing and healing injured tissues confused me considering their advantages in engineering applications would also be obviously favorable for clinical applications. At the same time, it also shined a hint for innovation.

I initially focused on basic research of understanding the science of adhesion and how to realize duct tape-like near-instant and robust adhesion on wet and bleeding tissues. Unlike engineering solids, biological tissues' inherent wetness, often with various body fluids like blood, introduce the interfacial fluid layer between the adhesive and tissue surface, acting as a physical barrier that hinders adhesion formation. Building upon this finding, I invented the mechanism and a unique class of tissue adhesive biomaterials that can form instant and robust adhesion to wet and bleeding tissue in less than 5 seconds [*Nature* **575**, 169-174 (2019)] – a functionality that was previously considered not possible for biological tissues.

With the new powerful bioadhesive technology in hand, I began collaborating with clinical experts at Mayo Clinic and Harvard Medical School to apply our bioadhesives in diverse translational applications, including bleeding control [*Nature Biomedical Engineering* **5**, 1131-1142 (2021)], tissue repair [*Science Translational Medicine* **14**, eabh2857 (2022)], wound healing [*Nature Biomedical Engineering* **6**, 1118-1133 (2022)], cardiac rhythm management [*Science Translational Medicine* **16**, eado9003 (2024)], and anti-fibrotic interfaces for implants [*Nature* **630**, 360-367 (2024)]. Despite prolific academic achievements, our

team faced limitations in further pursuing clinical translation of our bioadhesive technology in an academic setting, which led to the birth of SanaHeal, Inc., the startup I co-founded with my Ph.D. advisor, Dr. Zhao, and clinical collaborator, Dr. Nabzdyk, for the commercialization of our breakthrough bioadhesive technology.

Along with continued scientific effort to push the bleeding edge of innovation, my entrepreneurial endeavor has shown encouraging early promises. Since its incorporation in late 2021, SanaHeal has raised $12 million in dilutive investment, been awarded $5 million in non-dilutive grants from the NIH and secured over $4 million in non-dilutive funds through co-development agreements with commercial partners, including large publicly traded medical device companies under my leadership. In addition to the Spinoff Prize, our bioadhesive technology and commercialization efforts have earned recognitions, including the Execution Award from MedTech Innovator and the Sloan Healthcare Innovation Prize from MIT Sloan. Our first product for trauma bleeding control with our commercial partner has been field-tested in Ukraine and is approved for 510(k) clearance by the FDA (K250319). Other products in the pipeline are undergoing co-development and commercialization with commercial partners in a wide range of indications, from gastrointestinal and surgical bleeding control to bioadhesive surgical meshes and peripheral nerve repair.

The past 12 years have been an intense yet fulfilling journey as a scientist, engineer, inventor, and entrepreneur, continuously evolving to explore my way to understand, develop, and translate better solutions for repairing and healing injuries. While this venture is still ongoing and not easy, I will always be guided and motivated by my experience as it might be shared by many other patients, their family members, and clinical caregivers. It is my and our mission to learn from the bedside and bring better solutions back to the bedside, and I believe that we are going to achieve it.