Biomechatronics in burn trauma: Pioneering solutions and uncharted challenges

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To the Editor

Burn trauma is a serious health issue affecting millions each year, with long-lasting physical and emotional effects. Traditional burn treatment typically includes wound care, grafting, pain management, and rehabilitation, but recovery remains a challenging, often drawn-out journey. However, recent advancements in biomechatronics—a field that blends biology, mechanics, and electronics—are showing great promise in transforming burn care. This innovative technology has the potential to significantly accelerate healing, enhance recovery, and improve the quality of life for burn survivors. By using advanced prosthetics, sensors, and biomaterials, biomechatronics may help restore functions lost due to burn injuries. This letter provides a closer examination of how biomechatronics is revolutionizing burn care and the challenges that still lie ahead [1,2].

One of the most exciting applications of biomechatronics for burn survivors is the development of prosthetics and exoskeletons. For those dealing with severe tissue loss or functional impairment, biomechatronic prosthetics provide a solution that traditional ones often cannot. While regular prosthetics usually lack the adaptability required for burn victims, who typically experience skin loss and scarring, biomechatronic prosthetics integrate with the body's electrical and mechanical systems, providing a more natural range of motion and enhanced control. Exoskeletons, wearable devices that improve human movement, are also being developed to aid burn patients during rehabilitation. These devices help regain lost mobility and strength, reducing the need for manual assistance and promoting greater independence. With the potential to accelerate rehabilitation, enhance its effectiveness, and tailor it to each patient's needs, biomechatronic exoskeletons could significantly improve burn recovery [3,4].

Another promising innovation is smart bandages, which are embedded with sensors to track conditions like temperature, moisture, and infection. These sensors send real-time data to healthcare providers, enabling them to make precise adjustments in care. Additionally, bioelectric dressings, which utilize electrical pulses to stimulate tissue regeneration, may accelerate wound healing and enhance skin grafting outcomes. These advances help reduce complications, infection risks, and recovery time while improving the effectiveness of skin grafts and lowering the chance of rejection [5,6].

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Burn injuries often cause nerve damage, leading to chronic pain or numbness. Neuroprosthetics could offer relief by integrating electronics with the nervous system to alleviate pain and restore sensations like touch and movement. Devices like transcutaneous electrical nerve stimulation (TENS) units use electrical pulses to stimulate nerves, easing pain without relying on medication. Moreover, prosthetics with sensory feedback could help burn survivors experience the sensation of touch, temperature, and pressure, making artificial limbs feel more natural [7].

Rehabilitation after severe burns typically requires extensive physical therapy, which is vital for regaining movement and strength. Robotic rehabilitation devices, which include biomechatronic systems, help burn survivors perform specific exercises to restore their function. These systems can also track progress, providing valuable data for healthcare professionals to adjust treatment plans as needed. Additionally, integrating virtual reality (VR) interfaces with these biomechatronic systems creates a more interactive rehabilitation experience, improving motivation and results [8,9].

Despite the impressive potential, integrating biomechatronic devices into burn care presents several challenges. One of the biggest obstacles is personalizing these technologies. Every burn injury is unique, requiring a customized treatment approach. For these devices to be truly effective, they must be adaptable to each individual's needs. Furthermore, integrating these devices with existing medical care systems, including burn protocols and rehabilitation frameworks, will require collaboration between engineers, doctors, and regulatory bodies. Another primary concern is biocompatibility. Biomechatronic devices must be made from materials that are safe for human skin and tissue, especially for burn patients whose skin and immune systems are often compromised. The long-term effects of these devices, including their durability, safety, and maintenance, require thorough investigation for smart bandages and neuroprosthetics [8,10].

Cost is yet another barrier to the widespread adoption of biomechatronics in burn trauma care. The advanced technology behind these devices is expensive, which could limit access for many burn victims, especially in low-income or rural areas. Making these technologies more affordable will be essential for ensuring broader access to treatment. Biomechatronics provides innovative solutions for burn trauma care, enhancing rehabilitation, wound healing, and pain management. The development of prosthetics, smart bandages, neuroprosthetics, and robotic rehabilitation tools presents an exciting future for burn victims. However, challenges such as device personalization, integration with healthcare systems, safety, and high costs must be addressed.

The success of biomechatronics in burn care will depend on ongoing technological advancements, collaboration across disciplines, and making these solutions accessible to all patients. With continued research and development, biomechatronics could reshape burn trauma treatment, enabling quicker, less painful recoveries and better long-term outcomes for survivors.

Authors' contributions

S YK: Conceptualization, Project administration, Supervision, Writing original draft, and editing. A F: Data collection, writing original draft, and editing. L K and S KM: Validation, writing original draft, and editing. All authors read and approved the final version of the manuscript.

Conflict of interest

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