Architected and Translatable Biomaterial Platforms for Regenerative Medicine and Dynamic Biomedical Implants

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The successful clinical translation of biomaterials depends on the ability to balance mechanical performance, biological compatibility, scalability, and predictable in vivo behavior. This work presents complementary biomaterial platforms that address these challenges through structural and architectural design strategies rather than reliance on complex material chemistries, targeting applications in bone regeneration and dynamically loaded biomedical implants.

The first platform focuses on resorbable implantable materials and injectable hydrogels designed for regenerative medicine. These systems are engineered to degrade into benign by-products, elicit minimal inflammatory responses, and support host-driven tissue regeneration. Extensive preclinical evaluation across small and large animal models demonstrated favorable biocompatibility, host cell infiltration, and neovascularization, leading to enhanced regeneration of both soft and hard tissues. Importantly, the injectable hydrogel platform exhibited strong translational potential, enabling minimally invasive delivery, effective stabilization of healing sites, and sustained delivery of a wide range of bioactive compounds. The safety and regenerative efficacy of this approach were further validated in an early-stage clinical study, underscoring its relevance for real-world therapeutic applications.

The second platform addresses durability limitations of elastomeric materials used in medical devices subjected to repetitive mechanical loading, such as cardiovascular implants. By employing architected reinforcement strategies, including multilayered designs and spatially programmed internal architectures, mechanical performance was significantly enhanced without compromising elasticity. These structurally heterogeneous designs enabled efficient stress redistribution, improved energy dissipation, and effective suppression of crack initiation and propagation, resulting in substantial gains in toughness and fatigue resistance. Crucially, these reinforcement strategies were achieved using scalable manufacturing approaches compatible with complex device geometries.

Together, these biomaterial platforms highlight a unifying design paradigm in which architectural control and intentional mechanical heterogeneity enable predictable biological performance, enhanced mechanical durability, and clinical translatability. The results establish a versatile foundation for next-generation regenerative therapies and resilient biomedical implants operating in demanding physiological environments.