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Commentary

Advances in Microfluidics for Orthopedic Applications

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DESCRIPTION

The bone serves as the body's most prevalent hard tissue and is responsible for movement and support. It's remodeling, growth, and development are all closely correlated with the mechanical stimulation. Studies on the relationship between force and bone tissue behavior have largely relied on clinical observations rather than experimental research. The bone tissue interacts with many different organs in the human body because it is a form of tissue with a complicated three-dimensional (3D) structure and a variety of cell types. The traditional study frameworks, which have mainly focused on static anatomy and cultures, are unable to accurately portray the true interior environment, leading to varying degrees of inaccurate or inconsistent experimental findings.

Many devices have been created to replicate these intricate microenvironments for orthopedic research to current technological breakthroughs. Microfluidic devices in particular have received a lot of attention. The use of microfluidic devices is expanding into industries like chemistry, chemical engineering, and healthcare. Due to the features of microfluidic devices, microchannel platforms can effectively manage small fluids as well as fine 3D structures. This new interdisciplinary field includes the study of biology, biomedical engineering, microelectronics, fluid physics, chemistry, and novel materials. Microfluidic devices are frequently referred to as "microfluidic chips," also called "Lab on a Chip" or "micro complete analysis systems," because of their integration and miniaturization. The first microfluidic devices were gas chromatographs, which were created in the 1970s using lithography and silicon wafers. These devices then evolved into microfluidic capillary electrophoresis and micro reactors. The distinctive fluid properties of microfluidics, such as laminar flow and droplets, in microscale environments, are among their key characteristics. Microfluidics can do micromachining and micromanipulation, which are challenging to carry out with a variety of conventional techniques.

The human body is made up of numerous carefully planned, regionally unique microenvironments, each with its own set of pipes and cavities. The body is made up of a variety of organs. A microfluidic device connects numerous units to mimic the collaboration of various organs by integrating various exact structures created by microfabrication to represent the micro-units of various organs. The microfluidic perfusion system can transform static cell culture into dynamic life culture by imitating the environment in the body. One of the key benefits of microfluidic devices for orthopedics is their capacity to mechanically stimulate fluid flow. The design of diverse fluid chamber types allows for fluid stimulation of the cells with control over variables including size, direction, and frequency. The formula allows for the explicit calculation of the stress distribution in the fluid chamber. This makes the analysis of bone tissue's biomechanics precise and manageable.

Tissue engineering grafts are in high demand in orthopedics. An emerging field called tissue engineering investigates biological replacements for restoring, preserving, and enhancing the functions and morphologies of different tissues or organs after damage using the ideas and methodologies of the living sciences and engineering. It must be founded on an accurate comprehension of the connections between the structural and functional characteristics of a healthy body and pathological states. The four main areas of tissue engineering research include seeded cells, biological materials, methodologies and techniques for creating tissues and organs, and tissue engineering clinical applications. In order to achieve tissue and even organ culture for bone tissue, a microfluidic device can integrate osteogenesis-related cells, scaffold materials, and various biological, physical, and chemical circumstances in a singular spatiotemporal mode. It can not only provide a more nutrient-rich, multidimensional culture environment compared to standard culture methods, but it can also create complex organizational structures and further develop on-chip bone tissue. Bone tissue engineering scaffolds like microspheres and microfibers can be created using the microfluidic device itself. High-precision construction of extracellular matrices, cells, biological components, etc. is made possible by this technology.

Hard connective tissue, such as bone tissue, is formed from the mesoderm. Congenital, traumatic, and inflammatory circumstances can cause several forms of tumors to develop in bone tissue, some of which can leave relevant distinctive components in tissues like blood. Several additional tissue-

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derived cancers frequently develop concurrently with bone tissue invasion and propagate along the tissue. The microfluidic device is effective and affordable since it can detect numerous samples in a tiny volume. On the one hand, the microfluidic device can offer new detection approaches that enable multi-marker detection with fewer samples, which is cost-effective and efficient. These days, microfluidic devices can combine these to provide simultaneous detection and real-time intervention. For high-throughput drug therapy screening, it is also possible to create an *in vitro* simulation of a diseased model. More crucially, it is feasible to create an *in vitro* pathological and physiological model using materials and micro-manufacturing technologies, which has great potential for use in diagnosis and treatment.

The advancement of engineering technology has increased the feasibility of exploring and using medicine. In recent years, a hot topic has been the fusion of industrial and medical research. The ability to investigate, diagnose, and cure orthopedic disease has significantly improved to a dynamic learning environment, exquisite design and architecture, fine manufacturing ability, and precise detection ability.