Advanced Resistive Exercise Device

A number of different exercises can be performed on one machine.

Lyndon B. Johnson Space Center, Houston, Texas

The advanced resistive exercise device (ARED), now at the prototype stage of development, is a versatile machine that can be used to perform different customized exercises for which, heretofore, it has been necessary to use different machines. Conceived as a means of helping astronauts and others to maintain muscle and bone strength and endurance in low-gravity environments, the ARED could also prove advantageous in terrestrial settings (e.g., health clubs and military training facilities) in which many users are exercising simultaneously and there is heavy demand for use of exercise machines.

The ARED is a fairly simple, robust machine. It is designed to enable the user to perform the three primary resistive exercises, for stimulating bone regeneration and exercising the major muscle groups. It also has the ability to perform 15 other exercises for secondary muscle groups. For the original low-gravity application, it is required to simulate the lifting of weights in normal Earth gravitation, and to have an operational life of 15 years. The major subsystems of the ARED are a pair of vacuum cylinders, a frame-and-platform assembly, an arm base assembly, a wishbone arm/lift bar, a cable-and-pulley mechanism, and a flywheel mechanism:

- The frame-and-platform assembly serves as a backbone that supports all other subsystems and components.
- The vacuum cylinders provide constant resistance for exercise. These are commercial off-the-shelf pneumatic cylinders of 8 in. (≈20 cm) inside diameter. If necessary, the cylinders can be recharged by use of a vacuum source. The vacuum cylinders are connected to the frame-and-platform assembly and the arm base assembly.
- The arm base assembly serves as a load-adjustment mechanism and is a part of the overall load path.
- The wishbone arm/lift bar serves as the bar exercise interface for the user, enabling the user to perform the squat, dead lift, heel raise, and many other exercises. The wishbone arm is also in the direct load path from the arm base assembly to the user.
- The cable-and-pulley mechanism is connected to the arm base assembly. It is designed primarily to enable the user to perform long-stroke, low-load exercises. Examples of cable-and-pulley exercises are arm flies and hip abductions.
- The flywheel mechanism provides the equivalent of the inertial component of free-weight exercise. This mechanism includes a gear rack that is attached to a piston shaft and meshes with a gear train connected to a flywheel. When this mechanism is in use, movement of the lift bar causes rotation of the flywheel.

This work was done by Jasen Raboin, Jason Niebuhr, Santana Cruz, and Chris Lamoreaux of Johnson Space Center. For further information, contact the Johnson Innovative Partnerships Office at (281) 483-3809.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-23805.

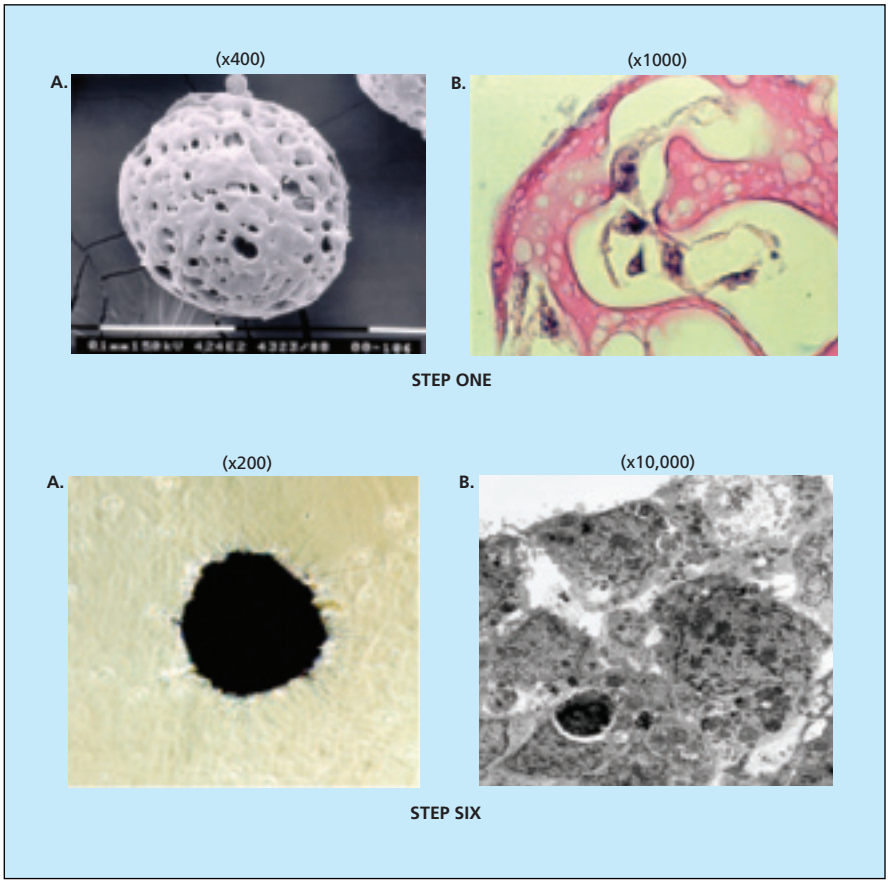
Rapid Engineering of Three-Dimensional, Multicellular Tissues With Polymeric Scaffolds

Engineered tissues could be grown in weeks or days instead of months.

Lyndon B. Johnson Space Center, Houston, Texas

A process has been developed for the rapid tissue engineering of multicellular-tissue-equivalent assemblies by the controlled enzymatic degradation of polymeric beads in a low-fluid-shear bioreactor. In this process, the porous polymeric beads serve as temporary scaffolds to support the assemblies of cells in a tissuelike 3D configuration during the critical initial growth phases of attachment of anchorage-dependent cells, aggregation of the cells, and formation of a 3D extracellular matrix. Once the cells are assembled into a 3D array and enmeshed in a structural supportive 3D extracellular matrix (ECM), the polymeric scaffolds can be degraded in the low-fluid-shear environment of the NASA-designed bioreactor. The natural 3D tissuelike assembly, devoid of any artificial support structure, is maintained in the low-shear bioreactor environment by the newly formed natural cellular/ECM. The elimination of the artificial scaffold allows normal tissue structure and function.

The advantages afforded by the enzymatic-digestion method, relative to the prior method, arise in connection with much greater speed of digestion. The biodegradable polymers commonly used heretofore as scaffolding materials have been poly(lactic acid), poly(glycolic acid), and copolymers of lactic and glycolic acids. The time needed for complete degradation of scaffolding made from these polymers typically ranges from 10 to 52 weeks, the exact time depending on the chemical composition of the polymer. Such long degradation times are problematic, especially when 3D tissue assemblies without artificial materials are needed in much shorter times (for example, for growth of autologous tissue to be im-



Twelve Porous Beads were used as scaffolds to grow multicellular spheroids, which, when enzymatically digested in a low-shear bioreactor, resulted in 3D tissuelike assemblies.

planted to replace damaged or diseased tissue). In contrast, the enzymatic-degradation method enables complete digestion of polymeric scaffolding within days.

For a tissue-engineering process that incorporates this enzymatic-digestion process, one must select a scaffolding material amenable to enzymatic degradation. For an experiment in which such a process was demonstrated, dextran-based beads were selected as the scaffolding and dispase (a neutral protease) was selected as an enzyme that could digest the beads without damaging cell membranes or disrupting the 3D tissuelike infrastructure. The beads were initially incubated with rat fibroblasts for four days on a rotary shaker, then the fibroblast-coated beads (see upper part of figure) were inoculated into a nutrient fluid in a horizontal-axis rotating-vessel (HARV) bioreactor, which provided a low-shear flow environment. After one day of incubation in the HARV, human epithelial cells were inoculated and cultured for three days to allow the formation of a natural structural infrastrucure comprising fibroblast-epithelial cell layers and a prominent ECM. Next, dispase was introduced into the culture medium to digest the beads and incubation was continued for another week. Microscopic examination of spheroids showed (see lower part of figure) that the controlled enzymatic degradation of an artificial matrix in the low shear environment of the NASA-designed bioreactor could rapidly produce 3D tissuelike spheroids free of any artificial infrastructure.

This work was done by Steve R. Gonda of Johnson Space Center, Jacqueline Jordan of Universities Space Research Association, and Denise N. Fraga of Enterprise Advisory Service, Inc. For further information, contact the Johnson Innovative Partnerships Office at (281) 483-3809.
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