Scaffolding structures for tissues including skin

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Summary

Scaffolding structures are used in manifold medical applications. The spectrum of the materials varies from organic to inorganic up to composite materials. Depending on the application the implant structures can replace the defect or support the regeneration of the injured tissue. By using different manufacturing technologies and materials the scaffolding structures can be adapted to individual applications or specific defects. The article gives an overview about manufacturing technologies and materials based on selected application examples.

Introduction

The application range of scaffolding structures in the field of medicine and medical technology is manifold. The spectrum of the materials varies from organic materials such as collagen, hyaluronic acid, lactic acid, xenogenic and autologous tissues to inorganic materials such as metals, metal alloys and ceramics up to organic-inorganic composite materials for hybrid implants. The range of use ranges from textile structures for tissue engineering or artificial vessels [3] to metallic fixation systems for stabilization and fixation for orthopaedic applications.

Depending on the therapeutic indication the materials has to fulfil individual requirements. These demands include apart from the biocompatibility the mechanical properties or biological functions like the stiffness or the pore size. In addition to the actual implant function the surface modification by patterning or coating is getting more important. Besides purely bio-tolerant and bioinert surfaces bioactive implant surfaces can also be realized e. g. for supporting an active ingrowth of bone tissue [5].

The huge number of currently applied implants offers different options for classification. Classifications e. g. according to the duration of application, such as short-term or long-term, according to the function, such as fixation of tissue, shape of the body surface, movement support, and according to structuring and scaffolding function are possible.

The following paragraph gives a short overview about different used manufacturing technologies and materials.

Materials and Manufacturing Technologies

Textile structures already used to stabilize and replace various hard and soft tissues. Textiles are utilized in many application e. g. as sutures, surgical mesh structures, ligament or vascular grafts. So it is possible to vary the surface texture, porosity, degradation and the mechanical properties by using the available textile technological processes and the selection of the biocompatible thread materials. Textile implant structures can be implemented according to disease or defect by almost all known technologies such as weaving, knitting, warp-knitting, braiding, embroidery and non-woven technologies [3], [11]. These properties are very interesting for tissue-engineering applications, where textiles used as defect coverage (patch graft) or as tissue replacement (scaffold). Beside their mechanical behaviour they have to support the cell adhesion.

The embroidery technology for example allows a function and power flow optimized construction and a defect specific individual and localized design of pore size and shape relating to the structural compatibility. Textile structures, which remain permanently in the human body or be degraded in the use of absorbable materials, can be manufactured by the specific selection of the materials [4], [9].

Figure 1 shows an embroidered scaffold structure for tissue-engineering applications and a result of a cell colonization test with mouse fibroblasts.

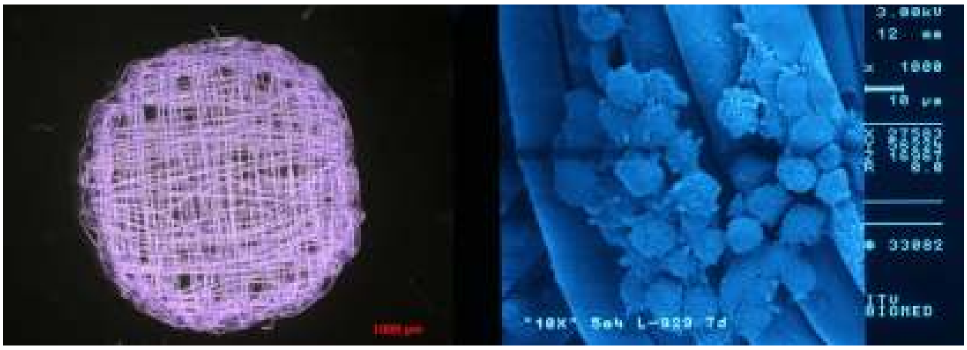

Figure 1: left: embroidered multilayer scaffold structure with absorbable thread material, right: adhesion and proliferation of mouse fibroblasts (L 929) after 7 days on the embroidered scaffold structure (Source: TITV Greiz - Textile Research Institute Thuringia-Vogtland, Greiz, Germany)

Metals and metal alloys are for example used in the field of orthopaedics as scaffolding and supporting structures and implants. These implants range from joint replacement for hip and knee and complex modular systems for osteosynthesis applications to intervertebral disc prosthesis made of composites (PE / Ti material).
Another major field in the area of orthopaedics are the fixators. These medical products can for example be used subcutaneously for the vertebral stabilization or externally / transcutaneously to stabilize fractures of the limbs [2]. Possible application areas are complicated trauma or bone extensions e. g. leg length discrepancies.
In addition to the traditional production methods, such as primary shaping, forming, machining, the generative processes like selective laser melting offer new possibilities for the technical realization of patient-specific scaffolding structures being based on biocompatible titanium and cobalt-chromium alloys or ceramics. By the layered manufacturing of the implants individual graded structures and porosities can be adapted relating to the load optimization or the ingrowth behaviour [6]. Besides applications in the field of joint arthroplasty, where for example structured surfaces improve the ingrowth and so enable an increased stability, the possibility of production of free-form surfaces particularly in the skull and jaw allows a specific implant design e. g. in the reconstruction of damaged skull bone areas (see Figure 2).

Figure 2: Patient-specific cranial-implant (Source: Fraunhofer Institute for Machine Tools and Forming Technology IWU, Chemnitz/Dresden)

Biocompatible polymers are increasingly used to avoid explantation and to support the tissue and bone regeneration by using fixation systems. For example in the field of hand and facial surgery screw systems based on poly lactid acid are used. These screws combine a moderate mechanical strength, with the advantage of biodegradability [8]. An appropriate choice of material allows a time-assessable degradation. Due to that the regenerated tissue can gradually take over its original function during the healing process. Such implants can be manufactured for example by injection moulding process.

New developments also allow using *absorbable magnesium-based metal implants*. These materials offer significantly higher strengths compared to the polymers associated with an adjustable degradation time. They are used as foam or sponge structures for the treatment of bone defects or as a net or lattice structure for example in cardiovascular surgery [1], [10]. By the combination of magnesium with titanium or absorbable polymer coatings the mechanical properties can be adapted for example to the natural bone structure [7].

Conclusion

Currently many research activities can be identify in the field of scaffolding structures for different tissues types. The requirements and applications are manifold. The spectrum of the materials varies from flexible or elastic materials for soft tissue replacement or support up to rigid materials for bone defects. Mostly the targets are mechanical properties, which are designed to the natural tissue and a biocompatible surface, which allows a controlled ingrowth of human cells. To reach these targets different manufacturing and coating technologies can be used.

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