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Improving Outcomes In Breast Reconstruction: From Implant-Based Techniques Towards Tissue Regeneration

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Abstract

Patients undergoing mastectomy for breast cancer have nowadays many options for breast reconstruction, that will help in re-establishing patient's self confidence in her own body image.
Implant-based reconstruction remains the most common form of post-mastectomy reconstruction, but it could also present some complications, the most common being capsular contracture.
Accordingly, a novel breast mound may be perfectly designed using the reverse engineering approach and additive manufacturing methods combined with autologous fat grafting. A 3D hierarchical structure with autologous adipose-derived stem cells may be used as a construct for tissue regeneration.
The 3D morphologically controlled scaffold may be placed in the subcutaneous position at the level of the conservative mastectomy side. The scaffold will be colonized with autologous fat tissue in some sessions. The biodegradable customized structure will help to maintain the breast shape and the natural consistency may be obtained with the fat grafting, also considering adequate enhancement techniques (Stromal Vascular Fraction derived growth factors).
The principles of regenerative medicine may be combined and integrated with those of reverse engineering (3D image capture, 3D modelling and rapid prototyping) to design custom-made and high functional hierarchical structures with tailored properties and 3D complex geometry.
The current study will focus on the basic principles and strategies in designing 3D advanced and complex structures for breast repair and regeneration.

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Keywords: Breast reconstruction; Tissue Regeneration; Fat Grafting; Reverse Engineering; Additive Manufacturing.

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1. Introduction

An increasing number of women are diagnosed with breast cancer each year, with estimates of the lifetime risk in western society being 1 in 8 [1].
Thanks to screening regimes, there has been an increase in the number of patients undergoing surgery for early stage breast cancers. Moreover with the emergence of oncoplastic techniques, more patients now have the choice of cancer excision while preserving the breast shape, thus avoiding mastectomy.
However, many patients with early breast cancer undergo mastectomy either because of an unfavorable location of the tumor or because the patient prefers this option to breast conservation [2].
During the last decade, skin and nipple-sparing mastectomies, the so-called conservative mastectomies [3], together with the skin-reducing mastectomy for large breasts [4], have gained widespread acceptance and are currently considered standard treatment for early stage breast cancer [5]. The preservation of all or most of the breast envelope has allowed surgeons to reduce the disfiguring impact associated with mastectomies.
Patients undergoing mastectomy have nowadays many options for breast reconstruction, that will help in re-establishing patient's self confidence in her own body image .
The goal of breast reconstructive surgery is to achieve a breast mound that has an aesthetically pleasing surface, shape and volume.
Reconstructive techniques available today cannot reconstitute the physiological function of the mammary gland, but the restoration of body image that is lost after mastectomy is paramount in helping restore a woman's self-esteem.
Reconstructive techniques used in breast surgery following mastectomy can be broadly divided into those that use alloplastic materials (i.e., breast implants) and those that use autologous tissues (i.e., the patient's own tissues). There are also techniques that combine these two basic approaches.
Breast implants are either saline-filled or silicone-filled medical devices that are available in a variety of shapes and sizes to suit an individual patient [6]. The implants require adequate soft tissue coverage and therefore a sub-muscular pocket for the implant to be placed in must be prepared. Often the pocket is expanded to size using a temporary expander implant, which is then exchanged for a fixed-volume implant [7].
Autologous techniques include the use of pedicled and free flaps. The main advantage of autologous flaps is that they more closely resemble native tissue in their feel and consistency. Flaps also withstand the effects of radiotherapy better than implant-based techniques. However, autologous techniques are complex and time-consuming, with the possibility of donor-site morbidity and longer postoperative recovery.
Implant-based reconstruction remains the most common form of post-mastectomy reconstruction, but it could also present some complications, the most common being capsular contracture [8,9].
After the placement of a breast implant, the body will mount a tissue reaction to it, as it is a foreign object. This results in a thin layer of scar-like tissue forming around the prosthesis, known as a capsule. However in some patients the capsule thickens and contracts, resulting in worsening degrees of capsular contracture. Significantly increased capsular contracture rates are seen in patients receiving external beam radiotherapy. In such patients, it is often more appropriate to avoid an implant-based reconstruction and carry out an immediate reconstruction using autologous flap.
In order to reduce implant-related complications and improve womens' quality of life and satisfaction level following breast reconstruction after mastectomy for breast cancer, a further strategy may involve tissue repair and regeneration supported by 3D morphologically controlled scaffolds obtained through additive manufacturing methods.
Accordingly, the current study will focus on the basic principles and strategies in designing 3D advanced and complex structures for breast repair/reconstruction and regeneration.

2. Basic principles and strategies in designing 3D hierarchical structures for breast repair and regeneration

The current gel-filled breast implants are characterized by a shell made of an elastomeric material (i.e., polydimethylsiloxane, PDMS) and a gel-like core consisting of a PDMS which has a lower cross-linking degree.
For this reason, the complex viscoelastic performances as well as the nonlinear and large-deformation behaviour (Fig. 1) may be clearly reproduced to design advanced breast devices, also benefiting from the knowledge of the structure-property relationship of the materials and from the integration of different technologies.

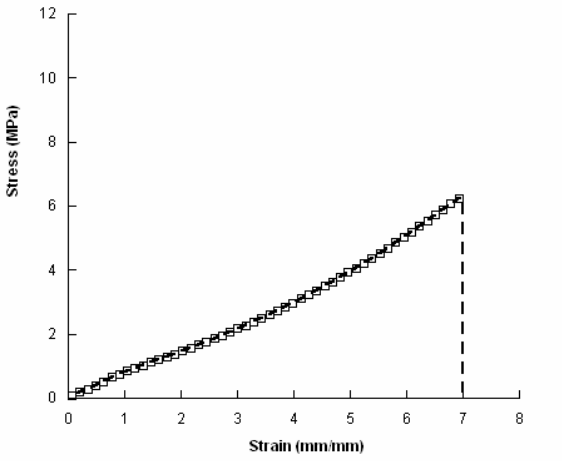

Fig. 1. Typical tensile stress-strain curve for shell specimens from current gel-filled breast implants.

Two different approaches may be adopted for breast tissue repair/reconstruction and regeneration.