Electrospinning versus knitting: two scaffolds for tissue engineering of the aortic valve

Electrospinning versus knitting: two scaffolds for tissue engineering of the aortic valve

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Introduction

State-of-the-art tissue engineered aortic valves are not strong enough to withstand aortic blood pressure levels. We hypothesize that current scaffolds do not have enough mechanical integrity and that they degrade too fast.

Objectives

Design of a valvular scaffold needs to focus on strong commissures, since they are high-stress regions in a valve (Fig. 1). Scaffold material must degrade slowly, to enable the seeded cells to create their own strong matrix that eventually replaces the degrading scaffold.

Figure 1. *a) A natural valve leaflet. The load-bearing collagen fiber architecture is clearly visible. b) Maximal principal strain distribution over an aortic valve model leaflet in diastole, with strains increasing towards black (with permission from N. Driessen).*

Materials and Methods - scaffolds

Valvular scaffolds were fabricated by electrospinning or by knitting of polycaprolactone (Fig. 2). Strong commissures for the spun valves were realised by electrospinning a leaflet and a corresponding sinus out of one piece and for the knitted valves by knitting the leaflets to the scaffold wall.

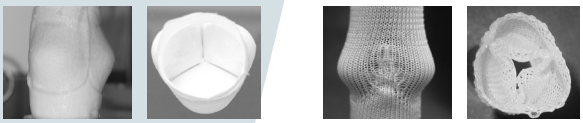

Figure 2. *a) an electrospun scaffold, seen from the side, b) seen from the bottom, c) a knitted scaffold pulled over a mould and d) released from the mould, covered with fibrin.*

The scaffolds were placed inside a physiologic flow simulator with an inserted scope, to study the opening and closing (Fig. 3).

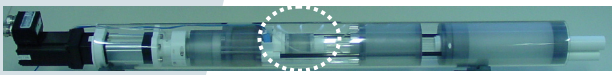

Figure 3. *The valve exerciser (1:5), simulating physiological flow, with a valve in the middle.*

Materials and Methods - valve culture

Figure 4. *The bioreactor; in the back six culture chambers with valves and in the front three medium vessels.*

Human Vena Saphena (HVS) myofibroblasts were enclosed in fibrin gel and cultured on the electrospun or knitted scaffold in a bioreactor that provided continuous medium perfusion (Fig. 4).

Results - scaffolds

The electrospun scaffold tore within six hours, whereas the knitted scaffold remained intact (Fig. 5).

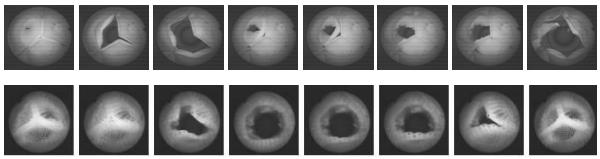

Figure 5. *The scaffolds inside the physiologic flow simulator over the course of 6 hours. Top) spun scaffold, bottom) knitted scaffold.*

Results - valve culture

Because of small pores in the spun scaffold, the majority of the cells remained on top of the scaffold. In the knitted scaffold cells penetrated well, as can be seen in Fig. 6.

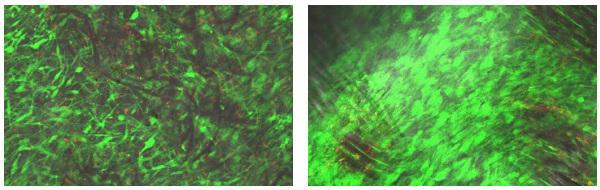

Figure 6. *Confocal laser scanning microscope images of a) cells on an electrospun leaflet and b) cells on a knitted leaflet.*

Cells that had been seeded on the spun scaffold had made less glycosaminoglycans and less collagen, as can be seen in Figure 7.

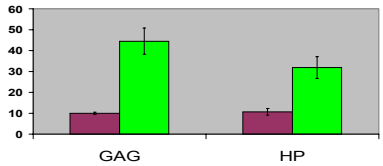

Figure 7. *Glycosaminoglycan and hydroxyproline production of the cells in a spun (purple) and a knitted (green) scaffold, in µg/mg tissue without scaffold ± standard error of the mean.*

Discussion

The knitted scaffold has strong commissures and allows good cell penetration. The spun scaffold is not very strong, which does not have to be a problem if seeded cells make enough extracellular matrix. In that case however, the spun scaffold must be adapted to enable proper cell penetration.

References

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2. Eur J Cardiothorac Surg 19 (4) (2001), 424-30
3. J Biomed Mater Res 60 (4) (2002), 607-12

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