Supplemental material

Dimensional analysis of porous PGS-M scaffolds

Scaffold shrinkage was examined by measuring the diameter of porous disk-shaped scaffolds (n=6) produced from Mixed sucrose particles combined with 30%, 50% and 80% DM PGS-M, at the optimum ratio of 3.8:1. Scaffold diameters were measured, at six circumferential locations using digital callipers, immediately following photocuring, after leaching of the sucrose porogens, and after freeze-drying (Figure S1). Compared to the dimensions of the scaffolds following photocuring, the 30% DM PGS-M scaffolds appeared to shrink slightly after sucrose leaching. Further shrinkage of the 30% DM PGS-M scaffolds (~16%) occurred following freeze-drying, compared with their dimensions following photocuring ($P<0.01$). This was not observed in the 50% or 80% DM PGS-M scaffolds. It is possible that the water retained inside the scaffolds following sucrose leaching may have both slightly swelled the PGS-M and also provided some mechanical support. Indeed, PGS has been noted to swell ~2% in water.[1] Removal of the water during freeze-drying therefore resulted in a removal of this swelling and a loss of mechanical support, leading to scaffold shrinkage. This was most pronounced in the 30% DM PGS-M scaffolds as this material had the lowest stiffness compared to the 50% and 80% DM PGS-M.[2] Additionally, the freeze-dried 30%, 50% and 80% DM PGS-M scaffolds were also swelled by immersing them in methanol. Interestingly, there was no significant difference between the sizes of the different scaffold types following methanol treatment. When compared to their freeze-dried sizes, the 30% and 50% DM PGS-M scaffolds experienced significant swelling as a result of the methanol treatment ($P<0.001$).

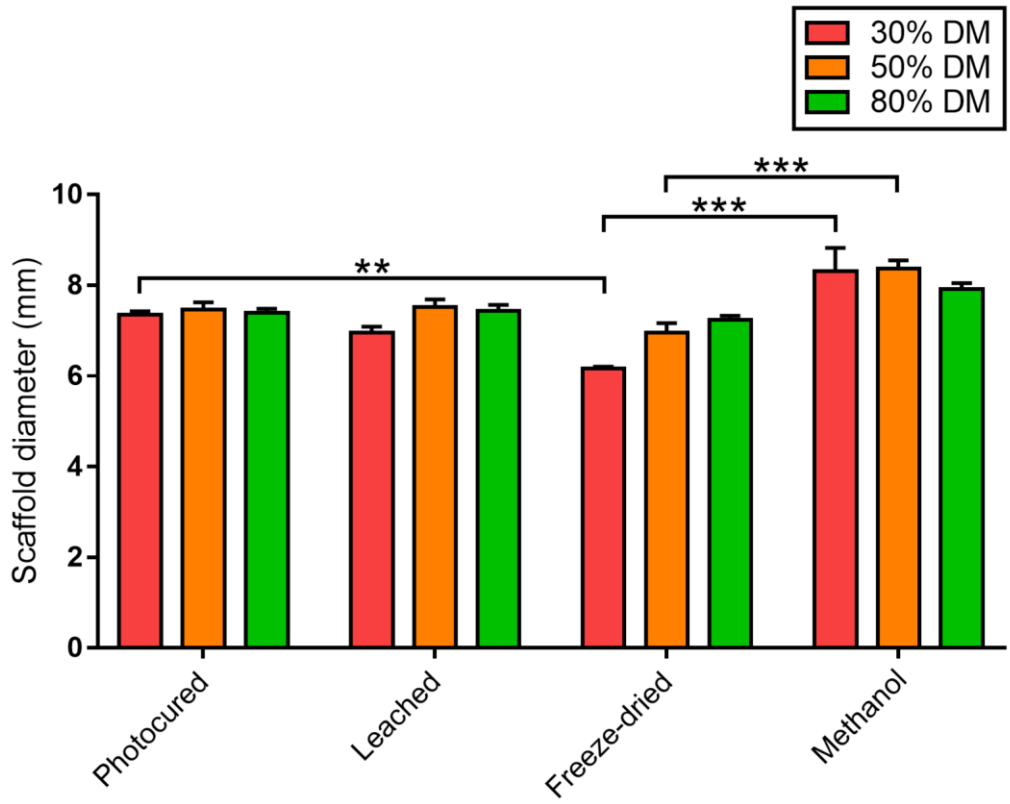

Figure S1. Dimensional analysis of porous disk-shaped PGS-M scaffolds produced from 30%, 50% and 80% DM PGS-M. Scaffold diameters were measured after photocuring, sucrose leaching, freeze-drying, and immersion in methanol. Significant shrinkage of the 30% DM PGS-M scaffolds occurred following freeze-drying, compared to their photocured dimensions ($P<0.01$). Additionally, freeze-dried 30% and 50% DM PGS-M scaffolds experienced significant swelling when immersed in methanol ($P<0.001$).

Manufacture of porous tubular PGS-M scaffolds

Porous tubular PGS-M scaffolds were produced using Mixed sucrose particles combined 3.8:1 (w/w) with 30% DM PGS-M prepolymer and photoinitiator, as described above. 1 ml polypropylene syringes (Terumo), modified by removing their ends, were used as moulds. Five different manufacturing methods were explored (Figure S2): (Method i) The lumen of the tubular scaffold was created by assembling the PGS-M and sucrose mixture around a 3 mm diameter stainless steel rod, concentrically held inside a syringe mould. This construct was then photocured, as described above, and extruded from the mould. (Method ii) PGS-M and sucrose mixture was assembled around a 3 mm diameter polyvinyl alcohol (PVA) rod, concentrically held inside a syringe mould. This construct was extruded from the mould and then photocured. (Method iii) A syringe mould was filled with PGS-M and sucrose mixture and a 3 mm diameter core then cut out of the mixture, using a stainless steel die. The construct was extruded from the mould and then photocured. (Method iv) A syringe mould was filled with PGS-M and sucrose mixture and the core removed, as in Method iii. However, the construct was photocured prior to being extruded from the mould. (Method v) A syringe mould was filled with PGS-M and sucrose mixture and the core removed, as in Method iii. However, the core space was then filled with sucrose particles and the construct extruded from the mould and photocured.

Following photocuring, the constructs were washed in dH_2O and methanol, as described above, to remove the sucrose, soluble PGS-M prepolymer and photoinitiator. In Method ii, constructs containing PVA rods were initially washed in dH_2O at 80°C to dissolve this material. The resulting porous tubular scaffolds were bisected along their length, freeze-dried and imaged using SEM, as described above, to examine their structure.

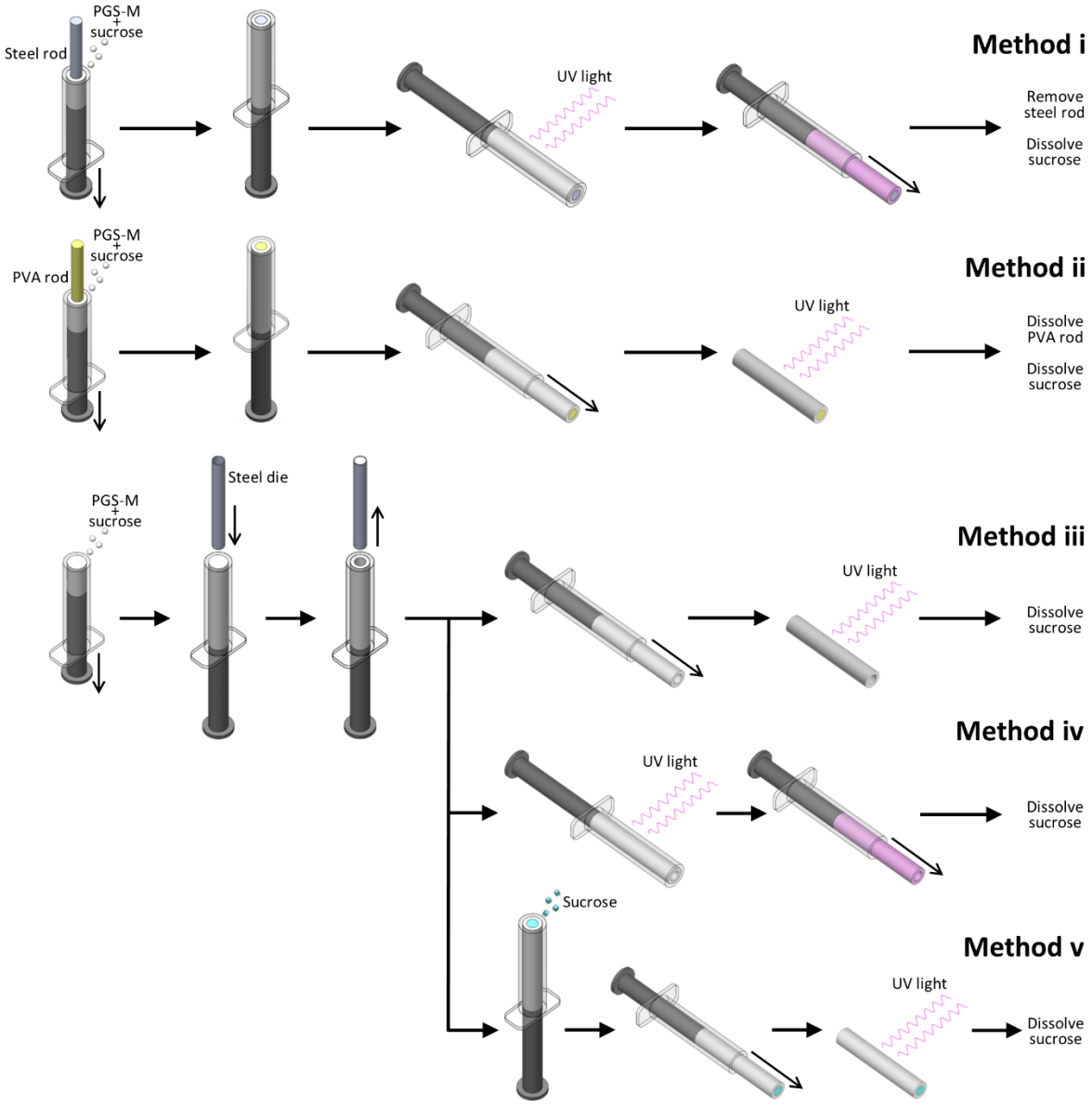

Figure S2. Manufacturing methods for producing porous tubular PGS-M scaffolds. (Method i) PGS-M and sucrose mixture compacted in a mould around a stainless steel rod, then photocured and extruded from the mould. (Method ii) PGS-M and sucrose mixture compacted in a mould around a PVA rod, then extruded from the mould and photocured. (Method iii) PGS-M and sucrose mixture compacted in a mould and a core removed using a die, then extruded from the mould and photocured. (Method iv) PGS-M and sucrose mixture compacted in a mould and a core removed using a die, then photocured and extruded from the mould. (Method v) PGS-M and sucrose mixture compacted in a mould and a core removed using a die before being refilled with sucrose, then extruded from the mould and photocured. Sucrose porogens were subsequently leached from all of the constructs by washing in dH_2O.

The structure and surface features of the tubular scaffolds were examined using SEM (Figure S3). The results are summarised in Table S1. All of the methods produced macroscopically tubular scaffolds that were self-supporting following the leaching of the sucrose porogens.

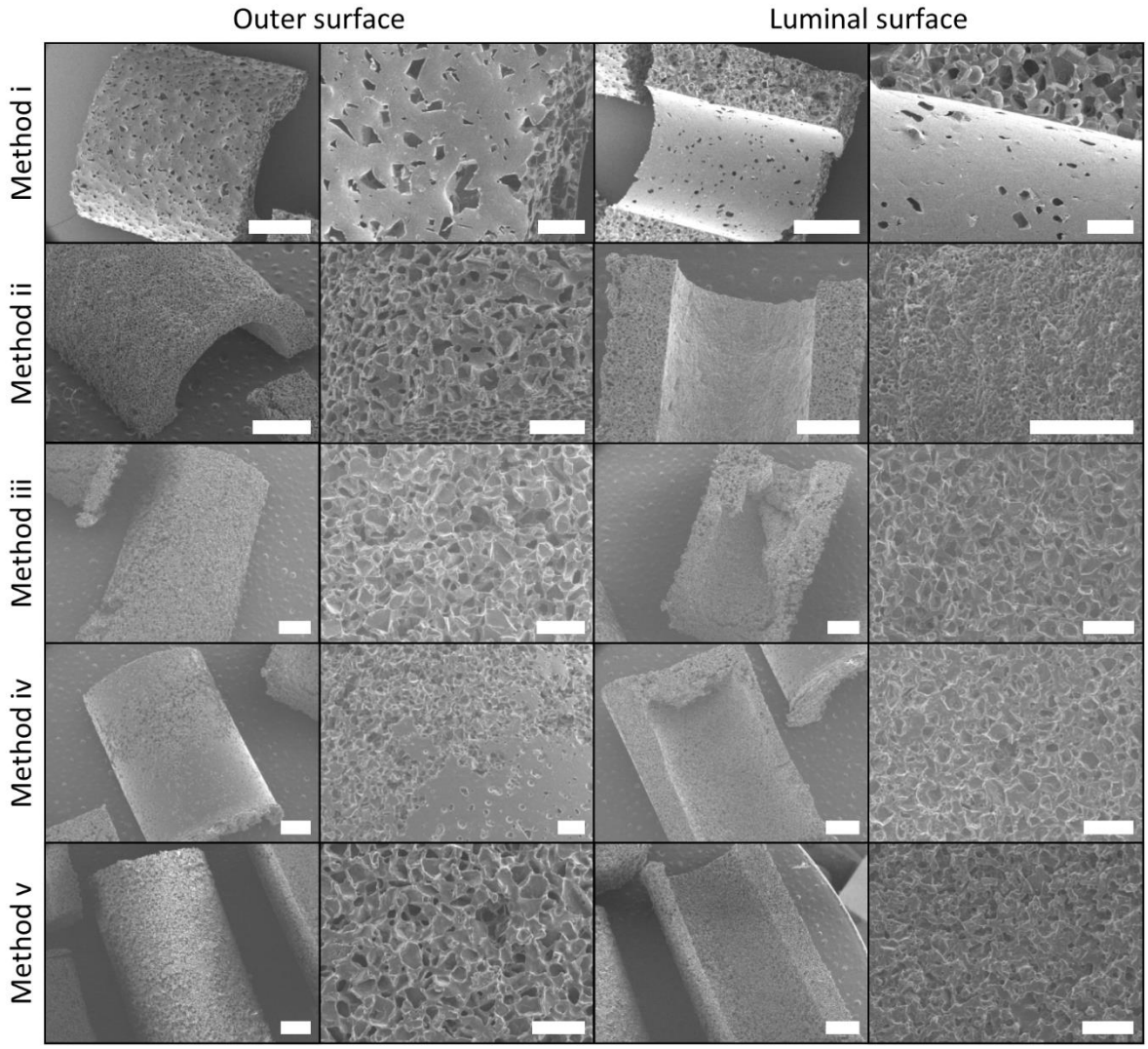

Figure S3. SEM of porous tubular PGS-M scaffolds manufactured using various methods. Method iii and Method v produced scaffolds with porous interiors and outer and luminal surfaces; however, only Method v was able to retain the scaffold's tubular design. Scale bars for the lower and higher magnification images are 1 mm and 200 µm, respectively.

Table S1. Summary of the structures of the tubular PGS-M scaffolds produced using Methods i-v.

Tubular scaffold fabrication method	**Outer surface**	**Interior**	**Luminal surface**	**Additional comments**
Method i	Skin layer present	Porous	Skin layer present	
Method ii	Porous	Porous	Skin layer present	Additional processing steps were required to remove the PVA rod
Method iii	Porous	Porous	Porous	Scaffolds deformed due to collapse of the compact during extrusion from the syringes
Method iv	Skin layer present	Porous	Porous	
Method v	Porous	Porous	Porous	

In Method i, a stainless steel rod was held concentrically in a cylindrical mould with PGS-M and sucrose compacted around it to form a tube. Following photocuring and extrusion from the mould, the steel rod was removed, leaving a luminal space. SEM revealed that the resulting scaffolds possessed uniform wall thickness along their length. Although the scaffold interiors appeared highly porous, both the outer and luminal surfaces were partially covered by a "skin" of PGS-M, limiting their porosity.

Method ii replaced the stainless steel rod of Method i with a PVA rod and extruded the PGS-M and sucrose compact from the mould prior to photocuring. The PVA rod was dissolved away using heated dH_2O to produce the scaffold lumen. These scaffolds possessed porous interiors and outer surfaces, however, their luminal surfaces were again covered by a skin layer of PGS-M.

Method iii used a die to remove the central portion from the compacted PGS-M and sucrose, shaped in a cylindrical mould, to produce a tube. This method appeared to produce scaffolds with porous outer and luminal surfaces, as well as interiors. However, the tubular geometry of the scaffolds appeared to be deformed. This was due to buckling of the tubular PGS-M and sucrose compacts when they were extruded from the syringes, prior to photocuring.

Method iv was similar to Method iii, but the compact was photocured inside the mould to help resist collapse on extrusion. The scaffolds produced possessed uniform tubular geometries and retained the porous luminal surfaces seen in Method iii. However, their outer surfaces showed large regions of skin formation which appeared to greatly reduce their porosity.

Method v was again similar to Method iii, except the central cavity of the cored PGS-M and sucrose compact was filled with sucrose particles to prevent collapse on extrusion out of the mould. These scaffolds were similar to those produced in Method iii, but without the observed deformation. They also appeared to possess porous outer and luminal surfaces, along with porous interiors.

The results observed from using Methods i-v suggested that the contact between the compacted PGS-M and sucrose mixture and the mould surfaces during the photocuring process was a key factor in determining the surface porosity of the resulting tubular scaffolds. Using a solid cylindrical core to form the scaffold lumen and photocuring the PGS-M around this, as in Methods i and ii, resulted in a low porosity luminal surface. Photocuring the PGS-M while still contained within the scaffold mould, as in Methods i and iv, resulted in a low porosity outer surface. Only Methods iii and v produced scaffolds with porous interiors, and outer and luminal surfaces. In both of these methods, photocuring was conducted following extrusion from the mould. In Method iii the internal surface of the PGS-M and sucrose compact was only in contact with the atmosphere during photocuring and in Method v, the luminal space was filled with sucrose particles during photocuring.

References

1. Wang Y, Ameer GA, Sheppard BJ, et al. A tough biodegradable elastomer. *Nat Biotechnol* 2002; 20: 602–606.

2. Pashneh-Tala S, Owen R, Bahmaee H, et al. Synthesis, Characterization and 3D Micro-Structuring via 2-Photon Polymerization of Poly(glycerol sebacate)-Methacrylate–An Elastomeric Degradable Polymer. *Front Phys*; 6. Epub ahead of print 2018. DOI: 10.3389/fphy.2018.00041.