Appendix A

Porous elastic material

In this appendix we show the finite element model used to approach the properties of the porous-elastic material. We perform two concentric cylinders (Figure A.1). The exterior cylinder with the properties of CDM matrix and the inside cylinder with elastic properties of fibroblast taken from Efremov et al. [17] and other case with porous-elastic properties (Table A.1).

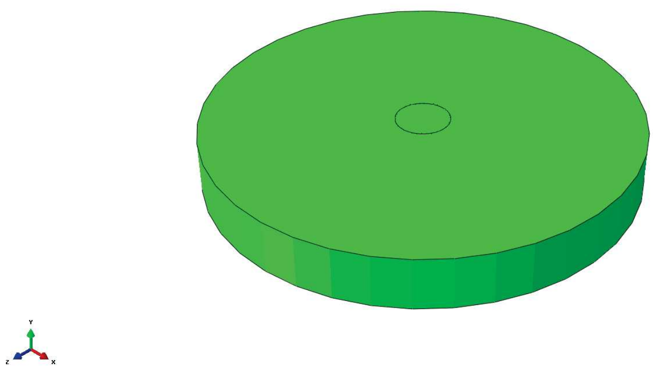

Figure A.1: Model used to approach porous-elastic properties.

We fix all movements on the bottom surface and we apply a negative displacement of 2 μm on the top surface of the inside cylinder. Thus, to compare the different materials we analyse the reaction force on the top surface (Figure A.2) and compute the total reaction force (Tabla A.2).

Material	Young's modulus (Pa)	Poisson's ratio	Permeability $\frac{m^4}{N \cdot s}$
Elastic	1500	0.3	-
Porous-elastic	1500	0.3	$4 \cdot 10^{-20}$
Porous-elastic	500	0.3	$4 \cdot 10^{-20}$
Porous-elastic	3000	0.3	$4 \cdot 10^{-20}$

Table A.1: Summary of inside cylinder properties.

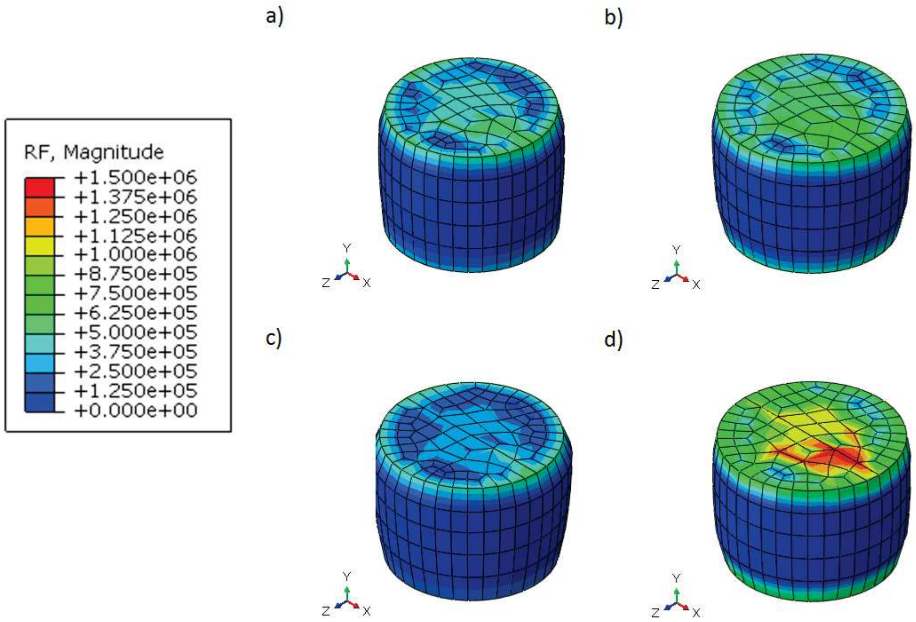

Figure A.2: Reaction force obtained. a) Elastic material with properties according to Efremov et al. [17]; b)porous-elastic material with solid phase equal to elastic properties model; c) porous-elastic material with lower Young's modulus for the solid phase; d) porous-elastic material with higher Young's modulus for solid phase.

As we can see in Table A.2, the value for an equal reaction force is between 500 and 1500 Pa. However, due to the viscoelastic behaviour of the material, this model only is valid as a approximation. The velocity of the displacement applied change the properties of the solid phase to obtain the same reaction force results. Nevertheless, we conclude that the equivalent elastic modulus of a porous-elastic material is lower than a elastic material.

Material	Reaction force (μN)
Elastic	46.05
Porous-elastic	58.85
Porous-elastic	37.73
Porous-elastic	139.911

Table A.2: Total reaction forces obtained.

Appendix B

Computational model of rheometer

In this appendix we show the finite element model used to simulate the rheometer test used to characterize the collagen hydrogels. The operation of the rheometer consists on introducing a sample of matrix between a fixed plate and a movable plate. This movement produces shear stress in the sample which is used to characterize the mechanical properties of the material (Figure B.1a).

To model the test, we perform a cube (Figure B.2). The base of the cube is fixed while the upper face was cyclically displaced reproducing the experimental oscillatory test. After that, we assign the hyperelastic constitutive model to the cube. Figures B.1b and B.2 show the cube configuration before and after the test.

To obtain the results, we compute the shear stress of the cube in the XY plane and the strains (which are known because we are applying displacements). The final results obtained are showed in Figures B.3 and B.4 for 2 and 4 mg/ml collagen hydrogels respectively.

Furthermore, we carry out the same test to obtain the shear behaviour for the elastic collagen matrix showed in Figure 2.4b.

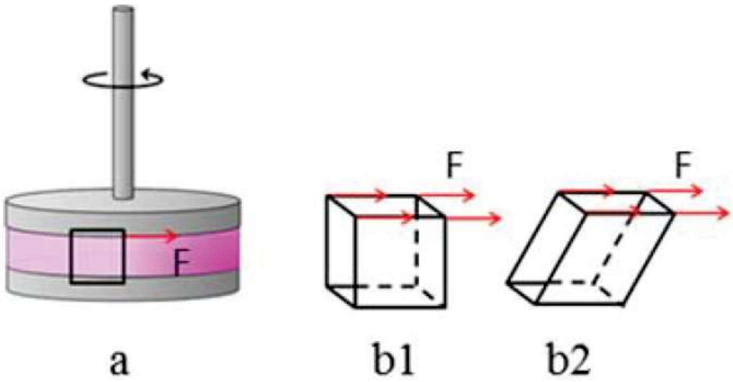

Figure B.1: a) Scheme of the hydrogel in the rheometer. b) Equivalent geometry used in the computational simulations in the undeformed state(b1) and after loading(b2). [11]

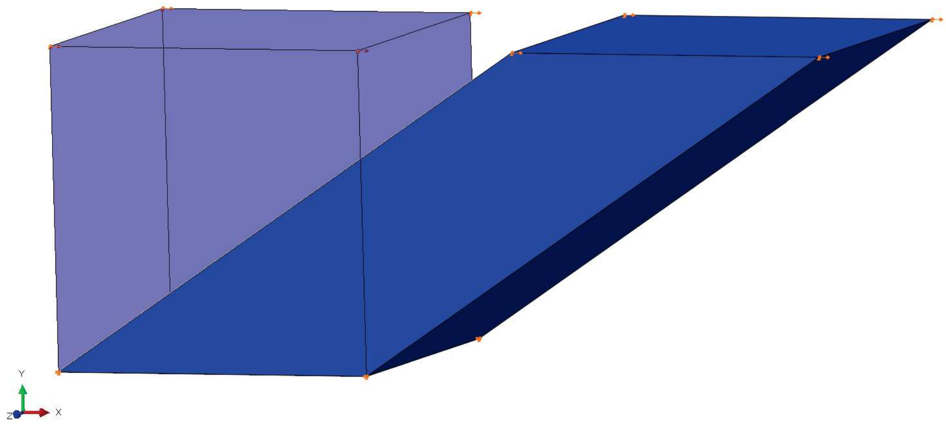

Figure B.2: Model used to approach collagen hydrogels to a hyperelastic material with fibers.

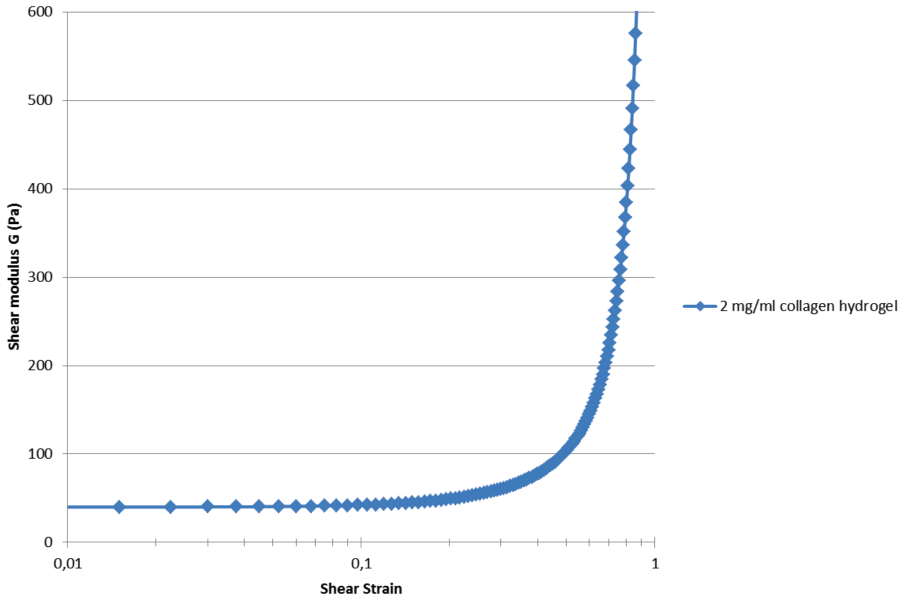

Figure B.3: Shear modulus versus shear strain obtained with the hyperelastic material whit fibers for a 2 mg/ml collagen hydrogel.

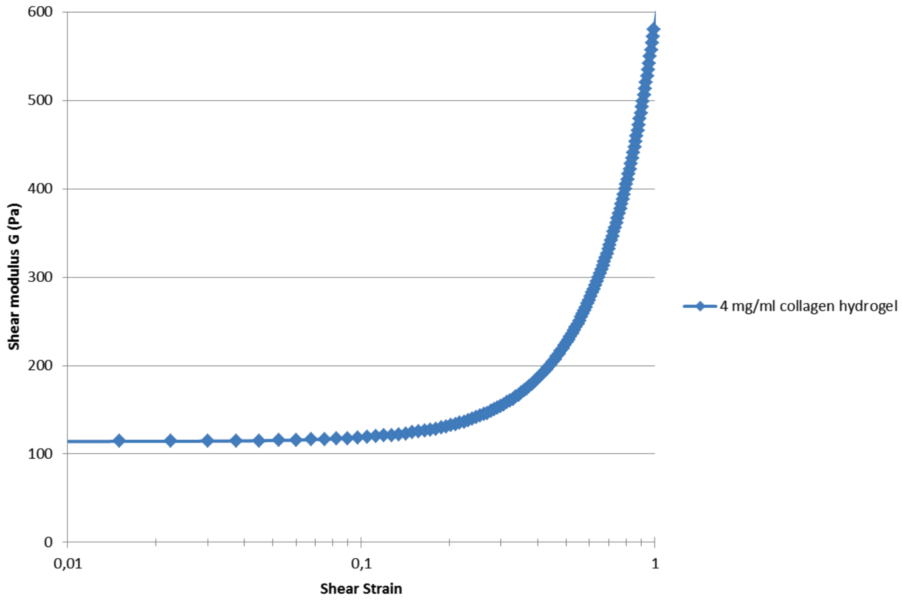

Figure B.4: Shear modulus versus shear strain obtained with the hyperelastic material whit fibers for a 4 mg/ml collagen hydrogel.