Supplementary Table S4. Review of Collagen Hydrogel Mechanical Characterization

Deformation mode	*Time scale of deformation*	*Strain scale of deformation*	*Parameters varied*	*Highlights of study*	*Reference*
Single-mode studies					
Tension	0.067%/s	30–50%	Collagen concentration, polymerization pH	Fiber structure imaging (confocal reflectance) during strain application; longer, thinner fibers correlate with higher strain	60
	0.07%/s	0–10%	Addition of polymers (including collagen) to PLGA hydrogels	Collagen strengthens PLGA hydrogels	18
	0.67%/s	8–18% (break)	Addition of GAGs and fibroblasts to collagen hydrogels	GAGs increase tensile modulus; fibroblasts reduce modulus	28
	0.8%/s	17–56% (break)	Addition of various crosslinkers to collagen hydrogels	Crosslinkers increase tensile strength but reduce extensibility	15
	1.67%/s	Not stated	Collagen concentration	Studied EC traction in constrained or floating hydrogels; found larger capillary structures in constrained gels	77
	5%/s (step) followed by relaxation	5–20%	Addition of agarose (varying concentration) to collagen hydrogels	Agarose slows hydrogel relaxation and reduces hydrogel compressibility	55
Compression (unconfined)	0.167%/s	2–5%	Addition of GAGs	GAGs increase compression modulus	85
Compression (confined)	0.1%/s	0–10%	None	Anisotropy measurement during strain application; find that interstitial flow and fiber bending regulate stress response	65
	1%/s	5–15%	pH	Compression modulus increases with pH; ECs grown on rigid hydrogels migrate less but form deeper networks	13
	Step (rate unspecified) followed by relaxation	3–20%	Collagen concentration	Compression modulus increases with collagen concentration	44
Shear (oscillatory)	0.016–16 Hz	2%	Addition of protein supplements	Collagen breaks down under shear with oscillation frequency above 3 Hz	54
	0.1 Hz	0.5%	Collagen concentration, addition of GA	G′ increases with concentration but pore size decreases; decoupled pore size and shear modulus and found cell spreading and migration depend primarily on pore size	41
	0.1–1 Hz	Not stated	Addition of protein supplements	Fibronectin or laminin supplements at high concentration reduce G′ and G″ of hydrogels	72
	0.1–100 Hz	5%	Temperature, addition of GA	G′ and G″ are frequency independent at 5% strain; shear moduli increase with temperature and addition of GA	26

(*continued*)

Supplementary Table S4. (Continued)

Deformation mode	*Time scale of deformation*	*Strain scale of deformation*	*Parameters varied*	*Highlights of study*	*Reference*
Shear (oscillatory) (continued)	0.4 Hz	5%	Addition of agarose	Agarose increases G′ but leaves gross fiber structure unchanged	16
	0.5–1 Hz	5%	Collagen vs. fibrin	Fibrin stiffer than collagen at same concentration	59
	1 Hz	0.8%	Polymerization temperature	Modified temperature and measured shear moduli throughout polymerization; final G′ and G″ decrease slightly at higher temperatures	47
	1.6 Hz	5%	Polymerization pH	G′ and G″ are frequency independent at 5% strain; shear moduli increase with pH	34
	0.1–10 Hz	n/a (0.5 Pa)	Addition of GAGs	Chondroitin sulfate increases ECM void fraction, decreasing shear modulus; dextran does not affect mechanical properties	21
Shear (creep)	n/a	n/a (9.5 Pa)	Addition of GA	GA increases shear modulus; Voigt–Kelvin model describes creep test well	30
Multimode studies					
Tension Compression (unconfined)	0.03–0.04%/s 3.6%/s	0–40% 15–30%	Polymerization temperature, pH, ionic strength	Tensile and compression moduli increase with pH; fabrication at physiological temperature and pH does not result in physiological strength	35
Tension Compression (unconfined) Shear (oscillatory)	0.6%/s 2.76%/s 1 Hz	20–80% 15–60% 1%	Collagen source, concentration	High oligomer content may be linked to increased hydrogel strength	12
Compression (unconfined) Shear (oscillatory)	2.76%/s 1 Hz	10–30% 1%	Collagen concentration, molecular weight	Compression and shear moduli are positively correlated with oligomer content (molecular weight); effect is stronger than that of concentration	76
Compression (confined) Shear (oscillatory)	0.08%/s for ramp tests 0.016–16 Hz	0–10% 1%	None	Creep, ramp, and sinusoidal compression as well as oscillatory shear. Found that collagen hydrogels exhibit Maxwell behavior in both shear and compression with similar timescales; shear modulus is larger than compression modulus	53

EC, endothelial cell; GA, glutaraldehyde; GAG, glycosaminoglycan; PLGA, poly (lactic-co-glycolic) acid.