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Rheology of Vitreous Humour and pharmacological substitutes used in eye surgery

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The Vitreous Humour (VH) is a transparent gel that fills the vitreous cavity in the Human eye. VH is mainly composed of water (99%) and includes a network of protein fibrils (collagen) and hyaluronan (1%). It is known that VH becomes progressively liquefied with age, or as a consequence of some diseases, and consequently the rheological, biomechanical and structural properties of the fluid also change. For the normal operation of the eye, when vitreoretinal pathologies appear, effective treatments must be performed. A common treatment for these diseases is the injection of a VH substitute in the vitreous cavity. The major vitreous substitutes commercially available are silicone oils and perfluorocarbon liquids, but currently there is little information about their rheological properties, which are known to be intimately linked to their functionality.

The aim of this work is to measure the rheological properties of the VH and five commercial vitreous substitutes currently used in vitreoretinal surgeries. Six fluids were analysed: VH collected from rabbit eyes, two silicone oils (RS-Oil1000 and RS-Oil5000, Alchimia), two perfluorocarbon liquids (HPF8 and HPF10, Alchimia) and a mixture of silicone oil with perfluorocarbon (Densiron68, Fluoron). The rheological characterization of the fluids was done using a shear rheometer (DHR-2, TA Instruments) to perform steady shear, small amplitude oscillatory shear (SAOS) and creep measurements. Extensional measurements using the Slow Retraction Method were performed with a capillary break-up extensional rheometer (Haake CaBER1, ThermoElectron) and an in-house extensional rheometer.

Our results show that VH separates into two different phases (gel and liquid) and both phases exhibit viscoelastic behaviour. The liquid phase rheology is independent of time but the gel properties are time dependent, with the VH gel phase exhibiting storage (G') and loss (G'') moduli that increase with time after dissection (e.g. the maximum value of G' and G'' increase from 3.2 Pa and 0.9 Pa right after dissection to 11.4 Pa and 2.3 Pa a few hours after dissection). Despite being used for the same purpose, the pharmacological fluids show significantly different rheological properties between them and when compared with the VH. All pharmacological fluids tested display a Newtonian behaviour in steady shear flow and their viscosities vary from 0.49 mPa s to 4.57 Pa s, at 37°C.

Keywords: Vitreous Humour, VH substitutes, Rheology, Biorheology.

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