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A novel 3D printed eye flow resistance model for intraocular pressure after glaucoma surgery: *R1*, *R2* and *R3*

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Abstract

Purpose : Glaucoma surgery is performed to lower intraocular pressure (IOP) to reduce risk of vision loss. Recently, devices such as Xen, iStent and Cypass have been designed to lower IOP with minimally invasive glaucoma surgery (MIGS). There is a need to better understand IOP and flow resistance following glaucoma surgery for future device design. We developed a 3D-printed engineering eye model to study the effect of flow resistance on IOP following glaucoma surgery.

Methods : A 2 part eye model to study the effects of flow resistance on IOP following glaucoma surgery was 3D printed using the Form2 SLA (Formlabs, Somerville, USA). The first part (anterior segment) has an anterior chamber with a 0.5 mm thin silicone cornea connected to micro-channels and capillary tubes modelling the trabecular meshwork and uveo-scleral pathways (resistance *R3*). The second part has a MIGS device/capillary tube (resistance *R1*) attached to a 0.2 mm thin silicone bleb of varying sub-conjunctival resistance (resistance *R2*). The micro-channels and capillary tubes are 3D-printed. The flow rate was set to mimic aqueous humour production between 0.5 to 3.5 µl/min with IOP pre-glaucoma surgery from 20 to 50 mmHg. Photographic readings of the silicone cornea and bleb heights as well as pressure and flow rate measurements were recorded using a microfluidic set-up (Fluigent,Villejuif, France). Mathematical algorithm software was used to post-process the data and build the post-glaucoma surgery IOP model.

Results : The 3D-printed eye model demonstrates that post-glaucoma surgery IOP is related to the resistance of the device (*R1*), the sub-conjunctival resistance (*R2*), the conventional pathway resistance (*R3*), and the rate of aqueous humour production (*Q*) as follows: $IOP=Q/((1/R3)+(1/(R1+R2)))$.

Conclusions : IOP post-glaucoma surgery can be studied in detail using the 3D-printed eye model as the resistance of each aqueous outflow pathway can be adjusted individually. It was shown that increasing the sub-conjunctival resistance (*R2*), which could occur due to scarring, increases the intraocular pressure (Figure 1).

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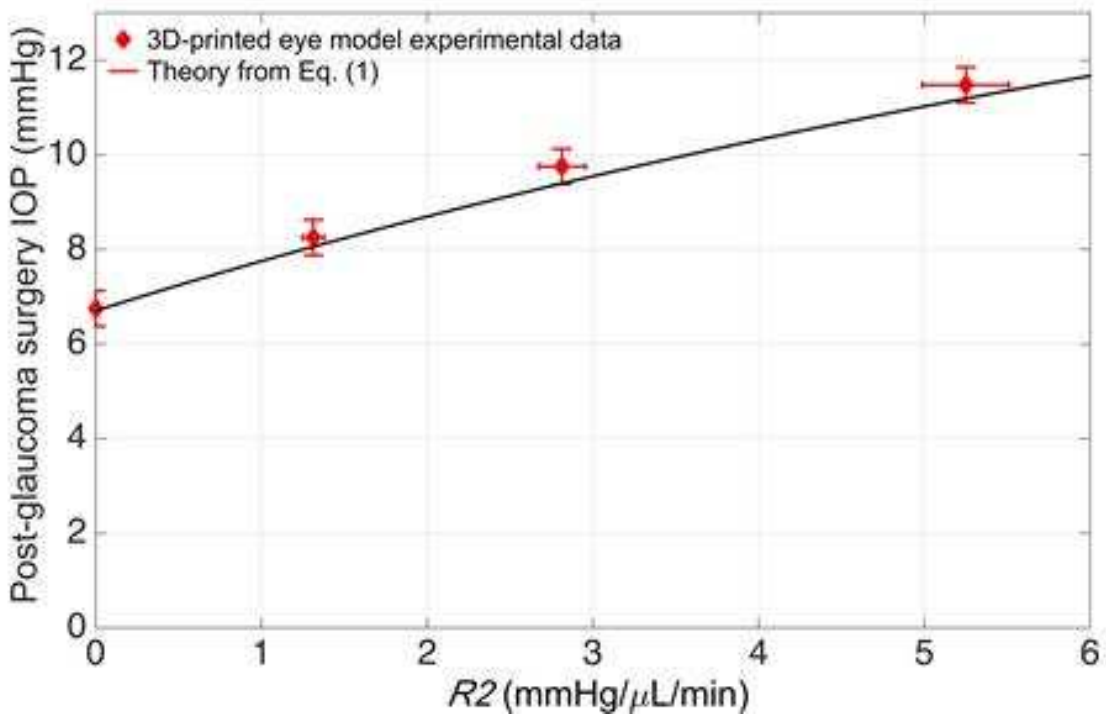

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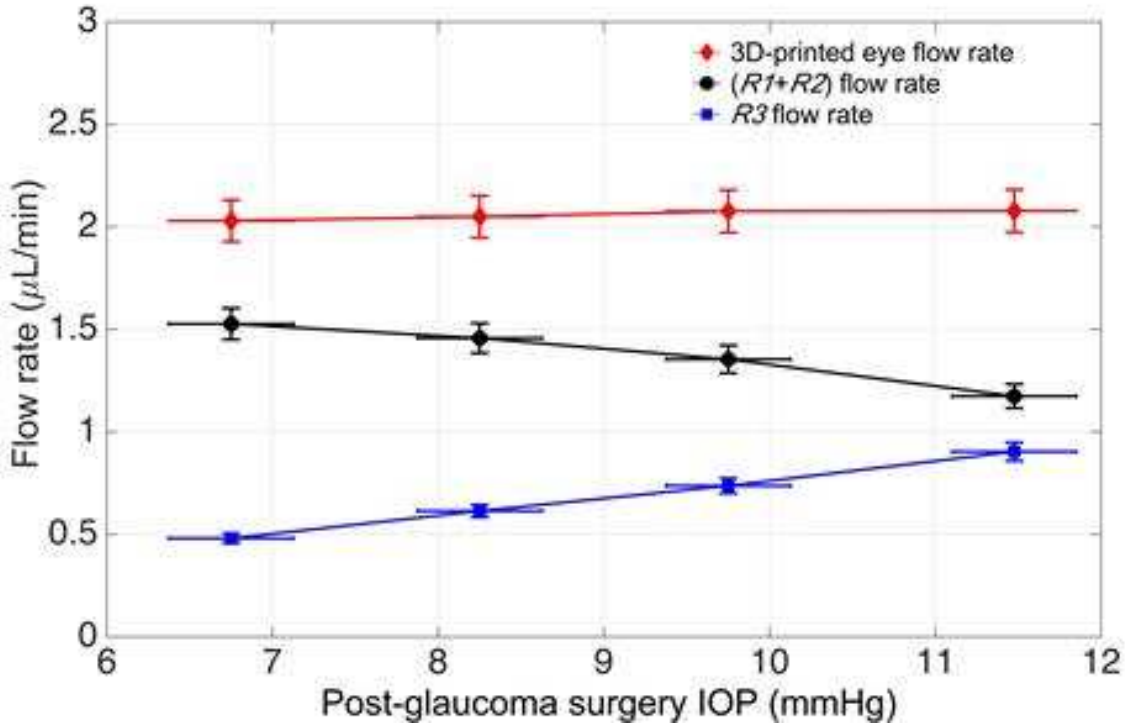
The post-glaucoma surgery IOP increases with sub-conjunctival resistance (*R2*) following Equation 1. The pre-surgery IOP of 26.2 mmHg was lowered to 6.7mmHg with a device with resistance *R1* of 4.5 mmHg/µl/min.



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Flow rates along each pathway of the 3D-printed eye model after the glaucoma surgery described in Figure 1.