

1 **Title: Frugal retinal laser training simulation eyes**

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13 the data, and drafted the manuscript. BS, JLU and ST gathered the data and helped
14 with the study design. JE and AB helped with simulation eye design and study
15 design. All authors critically appraised the manuscript for scientific content.

16 **Conflict of interest:** Andrew Blaikie is seconded to the University of St Andrews
17 from NHS Fife. The University owns a social enterprise subsidiary company, for
18 which Andrew Blaikie acts as an unpaid adviser. The social enterprise business sells
19 the Arclight devices to users in high resource countries with all profits being used to
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Simulation based training (SBT) is increasingly being integrated into medical apprenticeships (1). This process has been accelerated by the COVID-19 pandemic. The advantages of being able to progressively train and assess competency on potentially hazardous procedures in a safe and controlled environment as well as reduce face to face contact is of clear benefit to patients, trainees and trainers alike. Retinal lasering has been identified as a procedure that would particularly benefit from SBT (2). Most simulation tools are however expensive and impractically so for those training in low and middle income settings where the need is greatest to deal with the emerging epidemics of blindness from diabetes and premature birth (3). Here we describe a recently developed simulation eye adapted for retinal laser training and assessment (Figure 1) (4). We have included a video of the simulation eye being 'treated' with laser on PASCAL 532nm laser (Video 1).

There are a number of features of this simulation eye that contribute to its high fidelity as well as potential for wider adoption and implementation. The optics is based on a 'reduced' model eye. Despite having a radius 1.76 times larger (Figure 1b) than an emmetropic eye, the field of view, magnification and relative position of anatomical landmarks are identical to the examination of a real eye. This is independent of the device (slit lamp biomicroscope or direct and indirect ophthalmoscope) or lens design and power being used. The three dimensional fundi (Figure 1a) are created from traditional wide-field flat images using a reverse sinusoidal map projection approach which are then printed with a domestic colour printer on a matte photographic paper. This approach, despite being inexpensive, creates high resolution anatomically accurate ora to ora fundi. Importantly when lasered they respond similarly in appearance (Figure 1d) to that of a real retina. At lower fluence faint blanching develops but as power increases white marks are seen

49 progressing to 'pigmented' burns with suprathreshold fluences. In addition the
50 fluence values required to create appropriate laser burns are similar to therapeutic
51 settings. Mounting a pair of eyes in a typical anatomical position to a laser slit lamp
52 (Figure 1c) is also simple and quick using an ultra-low cost pre-formed foam
53 template.

54 The simulation eye has been assessed by our local NHS laser protection advisor
55 and has been approved to be safe for use as a training and assessment tool for
56 retinal laser.

57 In conclusion the attributes of this simulation eye offer the opportunity to widen
58 access to risk free teaching and objective competency assessment of a range of
59 retinal lasering skills. These include panretinal photocoagulation, retinopexy, macular
60 focal and grid laser as well as binocular indirect laser for the treatment of retinopathy
61 of prematurity. The frugal design approach reduces costs (4GBP per eye) and
62 consequently, for the first time, a high fidelity yet affordable simulation tool suitable
63 for the COVID-19 era is available to allow safe acquisition and assessment of laser
64 competency even in lower resource settings where the need is greatest (5).

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95 **Figure title and legend:**

96 Figure 1 Title: Frugal Retinal Laser Simulation Eye

97 Figure 1 Legend: a) Three-dimensional fundus. b) Simulation eye elements c)

98 Mounted on slit lamp. d) Appearance of the simulation eye during treatment

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100 **Video title and legend:**

101 Video 1 Title: Frugal Retinal Laser Simulation Eye

102 Video 1 Legend: Design features and construction of the retinal laser simulation eye.

103 The 'retina' in the simulation eye being 'treated' with 532nm PASCAL laser.

