Title: A Mixed-Methods Analysis of a Novel Low-Cost Simulation Eye for Retinal Laser Training and Assessment

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Retinal Laser Training:

Different retinal lasers (will be explained with the aid of an image)

- Pan-retinal photocoagulation (PRP) – e.g., for diabetic retinopathy – area covered is outside the macula and optic nerve
- Sector-RP – one sector of the retina but outside the macula and optic nerve
- Retinopexy – Two or three confluent rings or laser
- Focal laser – for focal oedema/exudation. Targeting the microaneurysms – avoiding the foveal avascular zone ($500\mu m$ centre of the macula)
- Grid laser – For diffuse oedema. Diffuse laser of the macular but avoiding the foveal avascular zone ($500\mu m$ centre of the macula)

Laser safety and preparation:

- Laser safety:
    - Is aware of the local laser safety protocols
    - Turns the laser light for the room
    - Knows the correct goggles to use for observers
- Consent
    - Understands the risks and benefits of the laser
- Confirm site
    - Asks patient
    - Examines both eyes to confirm the indication for treatment
- Anaesthesia
    - Uses topical anaesthesia liberally – other options (local)
- Lens choice
    - Selects the correct lens
    - Knows the magnification factor of the lens used
    - Cleans the lens
    - Changes the lens if needed

Laser procedure:

- Use of coupling agent and applying the lens on the cornea
    - Ensure no bubbles – Not applicable to our SIM eye
- Accuracy – can the trainee place the laser application where they intend the burns to be
- Burn intensity – grey/white burn 1 second after application for PRP with very minimal visible reaction for macular laser
    - Spot size – $200 - 500\mu m$ diameter for PRP/pexy and $50\mu m$ for macular
    - Power – Start $100 - 200mW$ for PRP and grid but $50 - 75mW$ for focal – Always start low and titrate up to get the appropriate reaction – High power can cause break through the Bruch's membrane
    - Exposure - $20 - 100ms$ – Increased exposure will cause more pain.
    - Fluence - this is the amount of energy given over an area so depends on the spot size, power and exposure. To keep fluence constant, if exposure is reduced, the power needs to be increased.
- Burn spacing – PRP (1-0.5 spot size apart), retinopexy (Confluent), macular (1-2 spot size apart)

- Coverage
    - PRP – for a spot size of $200\mu m$ diameter **ON THE MACHINE**. E.g., the VOLK Super Quad lens has an image magnification factor of $\times 0.5$ and a laser spot magnification of × 2.0. Therefore, a spot size of $200\mu m$ set on the machine would translate into $400\mu m$ **ON THE RETINA**. Hence, the number of spots required to cover the $236 - 314mm^2$area of the retina (as recommended by ETDRS), one will need $Number\ of\ spots = \frac{Area\ needs\ covered}{area\ of\ individual\ spots\ (\pi r^2)} = \frac{236}{\pi 0.2^2} = 1878$ to $\frac{314}{\pi 0.2^2} = 2498$ spots using the Super Quad 165 lens with $200\mu m$ **MACHINE SPOT SIZE**. One will need even a larger number on the counter as some spots won't cause any burn due to defocusing, misalignment etc.
    - Inferior retina first (vitreous haemorrhage could obscure it if done later)
    - PRP – Staying one to two DD away from the optic nerve
    - PRP – Staying two to three DD away from the fovea temporally – consider two rows of barrier laser to demarcate this boundary at the start
    - Pexy – confluent 3 rings of laser application
    - Avoiding the long ciliary nerves at 3 and 9 o'clock positions
- ALWAYS knows where they are relative to the fovea
- No laser on the area of tractional detachment or fibrosis
- No laser on the major blood vessels
- Efficiency and overall fluidity
    - Time taken do carry out the treatment
    - Keeps patient comfortable (chin and neck position)
    - Keeps themselves comfortable (Arm, neck and leg position)
    - If patient in pain
        - Empathise and persevere
        - Pre-analgesia
        - Break
        - Arrange another session
        - Laser under local anaesthetics
    - Smooth adjustment of the lens to laser more peripheral area
    - Adjusts fluence as needed to obtain even grey/white burns – e.g., lower fluence is needed at the peripheral retina
    - Asking the patient to change direction of gaze to cover the largest area possible
    - Responding to the patient's pain – changing the area, reducing exposure etc.
    - If no response
        - Do you still have coupling agent under the lens?
        - Are you focused well enough?
        - Are you aligned as perpendicular as possible to the retina for the maximum efficiency?
        - Are you going to through an opaque area of lens? – change fluence
        - Is there corneal oedema (in case of a prolonged session or use of excessive amounts of anaesthetics)?
        - Consider changing the fluence

After laser:

- Cleans the lens
- Checks for corneal abrasion

Risks of laser:

- Intraprocedural:
    - Pain
    - Vitreous haemorrhage due to breaking Bruch's membrane
    - Lasering the fovea or the optic nerve
    - Damage to lens – cataract
    - Corneal abrasion
- Post procedural:
    - Corneal oedema
    - Corneal abrasion
    - Macular oedema
    - Tractional retinal detachment from contracting neovascular membrane
    - Vitreous haemorrhage from contracting neovascular membrane
    - Choroidal effusion
        - Acute angle closure
    - Poor night vision
    - Loss of field of vision
    - Driving licence loss
    - Laser scar creep
    - Laser scar related choroidal neovascularisation
    - Laser scar related Rhegmatogenous retinal detachment (very, very rare)
    - Laser related proliferative vitroretinopathy