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PRESSURES GENERATED DURING CORNEAL WOUND HYDRATION

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Stromal hydration of clear corneal incision has become widely adopted by ophthalmologists to improve wound integrity. However, the evidence supporting wound hydration is limited. Furthermore, there have been numerous reports of associated complications, including Descemet's membrane detachment and cannula ejection resulting in serious ocular injury.[1,2] To the best of our knowledge, the the pressure generated during wound hydration has not been previously investigated.

Six freshly enucleated eyes were obtained from a local slaughterhouse and used within 4 hours post-mortem. We created four wounds using a 3mm keratome (Alcon Laboratories, Fort Worth, Texas) at 12, 3, 6, and 9 o'clock, and used Healon GV (Abbott Medical Optics, Illinois, USA) to maintain the anterior chamber. We used a LabJack U12 Legacy USB Data Acquisition device (LabJack Corporation, Lakewood, Colorado) calibrated to measure 2mV per milibar, corresponding to a full-scale output of 10V (145 psi). Disposable Transpac pressure transducers (ICU Medical, San Clemente, CA) were attached to the LabJack U12 input with a 3-way 2ml BD Luer-lock syringe (Becton, Dickinson and Company, Franklin Lakes, NJ) containing balanced salt solution with a standard 30G anterior chamber Rycroft cannula (Designs for Vision, Camperdown, Australia). All wounds were hydrated by a single experienced operator (WOC) and pressure required was measured using the apparatus described above. The pressures generated with forced maximal corneal hydration were also measured and photographs of the corneal appearance were taken for comparison. Finally, we measured the pressure required to expel a loose Luer-lock cannula and attempted to expel a tight Luer-lock cannula and compared this with Terumo slip-on cannulas (Terumo Corp. Somerset, NJ) applied loosely and tightly.

We found that over 24 initial corneal hydration measurements, the mean maximal pressure generated was 24.95 psi (range 16.1-41.84psi, SD9.72psi). Figure 1 demonstrates a typical pressure tracing of a standard hydration. When maximal force was applied to wound hydration, the pressure generated exceeded the maximal range measurable, with resultant corneal oedema and linear stromal splits (Figure 2a). When the Luer-lock cannula was applied loosely, the pressure required to dislodge the cannula exceeded the maximum measurable pressure of 140psi. In contrast, we found that ejection of a loose slip-on cannula occurred at pressures of 37.71-140 psi. We were unable to dislodge either cannula when tightly attached, even with maximal force beyond the measurement range, as demonstrated by deformation of the syringe's plunger with the cannula still attached (Figure 2b).

Our findings highlight the importance of taking due care when performing wound hydration, especially with respect to cannula attachment, given a loose slip-on cannula could be expelled using pressures generated during standard wound hydration. In a large series of 10,230 cases of anterior segment surgery, Rumelt and colleagues reported the incidence of cannula ejection being 0.88 per 1000 procedures per year, with resultant intraocular injuries including iris damage, posterior capsular rupture, hyphema, vitreous haemorrhage, and retinal breaks.[2] Reassuringly, we were unable to eject a tightly applied cannula regardless of type, even with forces capable of deforming the syringe which were beyond the maximum measurement limit.

Descemet's membrane detachment has also been described in the past as a complication of cataract surgery and wound hydration.[1] Calladine and colleagues found that wound hydration was more likely to cause a localised Descemet's membrane detachment compared to wounds without hydration (65% vs 25%).[3] When we hydrated the cornea as forcefully as possible, we found that severe cornea deformation and splitting occurred (Figure 2A). This pressure was beyond 140psi (our instrument's maximal range) and far exceeds the pressure required to hydrate the stroma. We did this to simulate possible pressures if hydration was performed without due care or by an inexperienced operator.

We chose porcine cornea, because while thicker (666 ± 68nm), it has similar swelling pressure and hydration behaviour to the human cornea.[4] We also ensured that the experiments were conducted as early as possible to minimise any post-mortem corneal oedema. Thus we would expect the pressures generated from this study to be similar when applied to clinical practice in humans. However anecdotally, during the experiments, we felt the overall pressure required to hydrate the porcine cornea was more than that for human cornea. Further studies utilising human subjects are required to confirm this.

In summary, we have demonstrated that the average maximal pressure applied during stromal wound hydration in a porcine model ranged between 16.1 and 41.84 psi, with the lowest pressure required to eject a loose slip-on cannula well within this range.

FIGURE LEGENDS:

Figure 1: A graph demonstrating the pressures generated during a standard corneal stromal wound hydration for a 3mm clear corneal incision. The plateau is where hydration pressure was estimated; it ranged between 16.1 to 41.95psi.

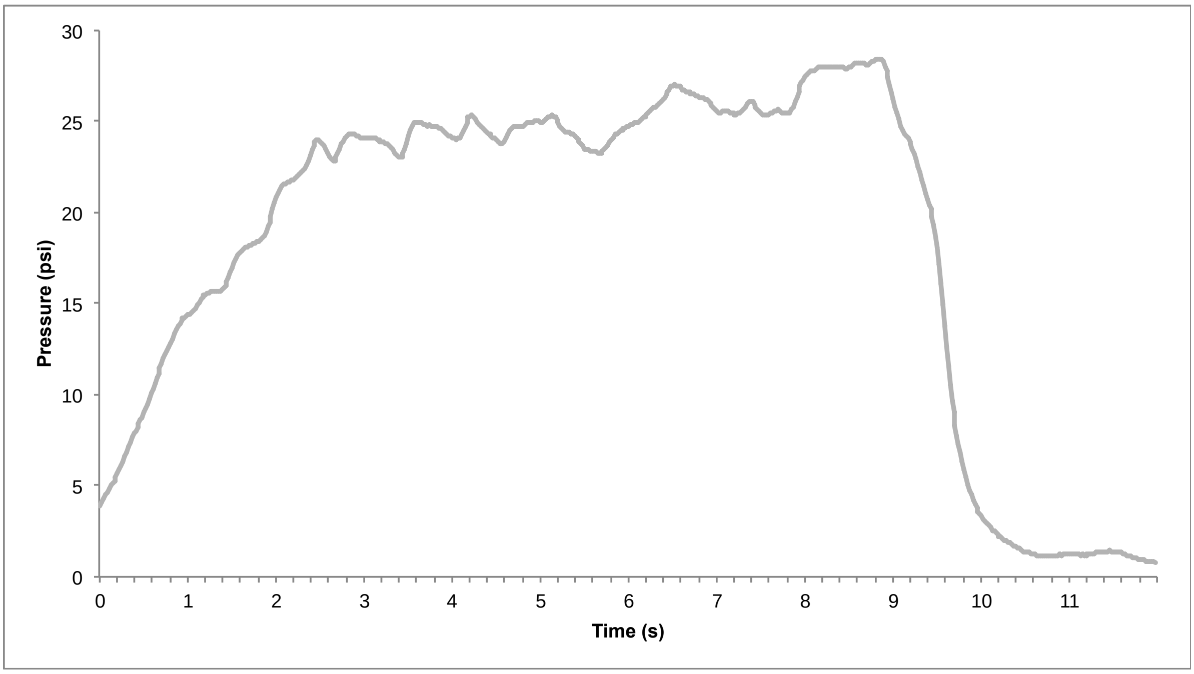

Figure 2A and 2B: Clinical photographs demonstrating corneal oedema and linear stromal splits when maximal pressures of >140 psi are generated (left) and deformed syringe plunger when attempting to dislodge a tightly applied cannula (right)

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