Reply to Letter to Editor

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Many thanks for your interest in the 'tube-in-tube' technique that we have described for aqueous shunt extensions.[1] We greatly appreciate your time in trying out the technique and the suggestions you have made in refining the 'tube-in-tube' technique. Essentially, both the Tennant tying forceps or Kelman-McPherson forceps can be used, with the predominant requirement being that the forceps needs to have a fine and smooth tip and the ability to allow working space for the surgeon to complete the 'tube-in-tube' complex. We have also used a cross action forceps like the Watzke which allows for a single handed opening of the "outer tube". Regardless of the forceps used, the built-in spring may not be strong enough to stretch open the tube alone and we have used several manoeuvres including inserting another object such as another forceps or the handle of an ophthalmic spear into the forceps to aid its ability to stretch open the tubing. Although ideally performed with a skilled assistant, the technique can be performed by a single surgeon. In this situation, it is usually technically easier to have the existing tube as the 'outer' tube, but great care needs to be taken to avoid overstretching and damaging the tube. We therefore agree fully that the extension should become the 'outer' tube whenever possible.

High resolution photographs of the forceps stretching the 'outer' tube are shown in Figure 1. When the tip of the Kelman-Mc Pherson forceps was inserted by a distance of approximately of 3 mm and opened using the ophthalmic spear, the 'outer' tube was overly stretched and micro-tears appear on the tube as shown in Figure 1a. In that case, placement of the inner tube proximal to the tears could result in leakage from the tube. However, for a distance of insertion of 2 mm or below, the tube was simply stretched but not overstretched and no micro-tears was apparent under high magnification as shown in Figure 1b.

Thank you for quantifying the ideal overlap required (2mm) for strength of the 'tube-in-tube' complex as well as confirming the appropriate intraluminal stent suture size in case of over-drainage. We also found that along the 'tube-in-tube' complex the width of the 'inner tube' is reduced reaching a maximum of 50% reduction at the end of the 'inner' tube where the 'inner' tube resistance to deformation is the smallest. Side views examples of the ‘tube-in-tube’ complex are shown at the location where the ‘outer’ tube ends in Figure 2a and where the ‘inner’ tube ends in Figure 2b. Further quantification of the ‘inner’ tube internal diameter deformation can be obtained by photographing cross-sections of the tube alone as shown in Figure 3a and in the ‘tube-in tube’ complex as shown in Figure 3b. it can be noticed that the ‘inner’ tube lumen reduces from a circular shape with a diameter of 0.325 mm (Figure 3a) to an oval shape of approximately 0.2 by 0.26 mm (Figure 3b) when part of a ‘tube-in-tube’ complex. This reduction of the ‘inner’ tube size permits as you mentioned 4/0 (0.2 mm internal diameter) to be thread in but not necessarily 3/0 suture (0.3 mm internal diameter).

Your wet-lab work does confirm that the tube-in-tube complex should have flow similar to an original non-extended tube. We have also found important to avoid having a long bevel when trying to establish an even and straight ‘tube-in-tube’ complex and have occasionally needed to trim the original tube end. The force required to dislodge the ‘tube-in-tube’ complex was measured using the force gauge PCE-DFG 500 and a minimum of 3 repeats were done for each overlap length. For 1mm and 2mm overlaps, the forces were measured to be 0.47 ± 0.13 N and 0.99±0.17 N, respectively. When 3mm overlap was tested, the ‘inner’ tube would break at 1.07±0.14 N before the ‘tube-in-tube’ complex could be dislodged. According to American National Standard guidelines, the junction of any component of an implantable glaucoma device should withstand an axial pull force of 0.5N without breaking or leaking[2]. The 2mm and 3mm complex meets this criterion. In line with your wet-lab work, we did not notice any flow leakage when the ‘tube-in-tube’ complex with respectively 1, 2 and 3 mm overlap was sealed and connected to a microfluidic set-up delivering a flow pressure of 45 mmHg.

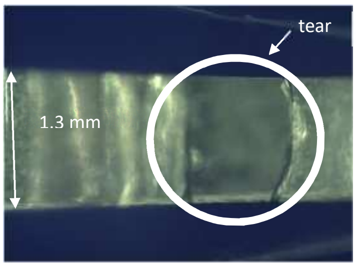
The use of a small amount of viscoelastic is a welcome addition to the technique we have described to facilitate lubrication between the tubes. When a small amount of viscoelastic is used the average axial pull force to dislodge the ‘tube-in-tube’ complex is reduced by a few percent but can reach as low as 0.3 N for a 2 mm overlap if an excessive viscoelastic amount is used. One could compress the 'tube-in-tube' complex gently to remove the excess of viscoelastic if necessary.

We agree this technique lends itself to being a good wet-lab model procedure and look forward to improvement of the technique and hopefully the availability of tubing parts to minimise costs.

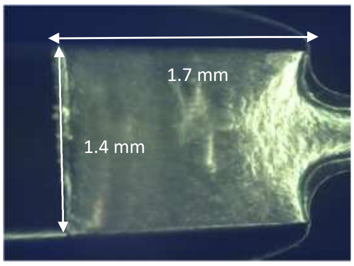
REFERENCES

1. Chiang MY, Camuglia JE, Khaw PT. A Novel Method of Extending Glaucoma Drainage Tube: "Tube-in-Tube" Technique. *J Glaucoma* 2017;26:93-95.

2. American National Standard for Ophthalmics - Implantable Glaucoma Devices,. ANSI Z80.27-2014



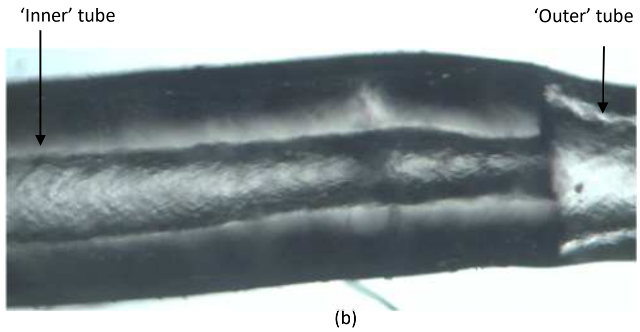
(a)



(b)

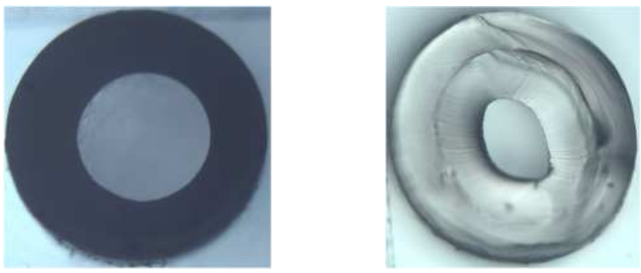
Figure 1: High resolution photographs of the ‘outer’ tube stretched using the tips of Kelman-McPherson forceps opened with the handle of an ophthalmic spear and inserted into the ‘outer’ tube by a distance of (a): 3mm and (b): 1.7 mm.

(a)



(b)

Figure 2: High resolution photographs of 'tube-in-tube' complex side views shown at the (a): 'outer' tube end and (b): 'inner' tube end.



'Outer' tube
'Inner' tube

(a) (b)

Figure 3: High resolution cross-section photographs of (a): the tube alone and (b): the 'tube-in-tube' complex.