

Fig. 2 Patient 1's right eye post insertion of the pericardium graft superotemporally for reinforcement of sclera prior to Baerveldt (Advanced Medical Optics, Santa Ana, California, USA) tube implantation (black arrow)

transit of the tear film to the lower lid, which increases pooling of commensal organisms near the inferior tube.

Despite a recent survey highlighting glaucoma surgeons preferring trabeculectomies over GDD in advanced glaucoma, they remain contraindicated in scleromalacia patients due to the risk of perforation [5]. The concept of a two-step GDD procedure allowed a safe and effective outcome for recalcitrant glaucoma patients with scleral thinning.

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Intraoperative real-time image-guided ab externo canaloplasty

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Introduction

Real-time image-guided surgery is spreading in different surgical fields for its potential to improve surgical outcome

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Compliance with ethical standards

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and numerous types of imaging devices are available today [1–5]. The purpose of this study is to evaluate the role of intraoperative ultrasound biomicroscopy (iUBM) and optical coherence tomography (iOCT) for monitoring morphological changes of anterior chamber (AC) structures during ab externo canaloplasty for treating open angle glaucoma (OAG).

Material and methods

Consecutive patients affected by OAG refractory to topical therapy were enrolled and underwent ab externo

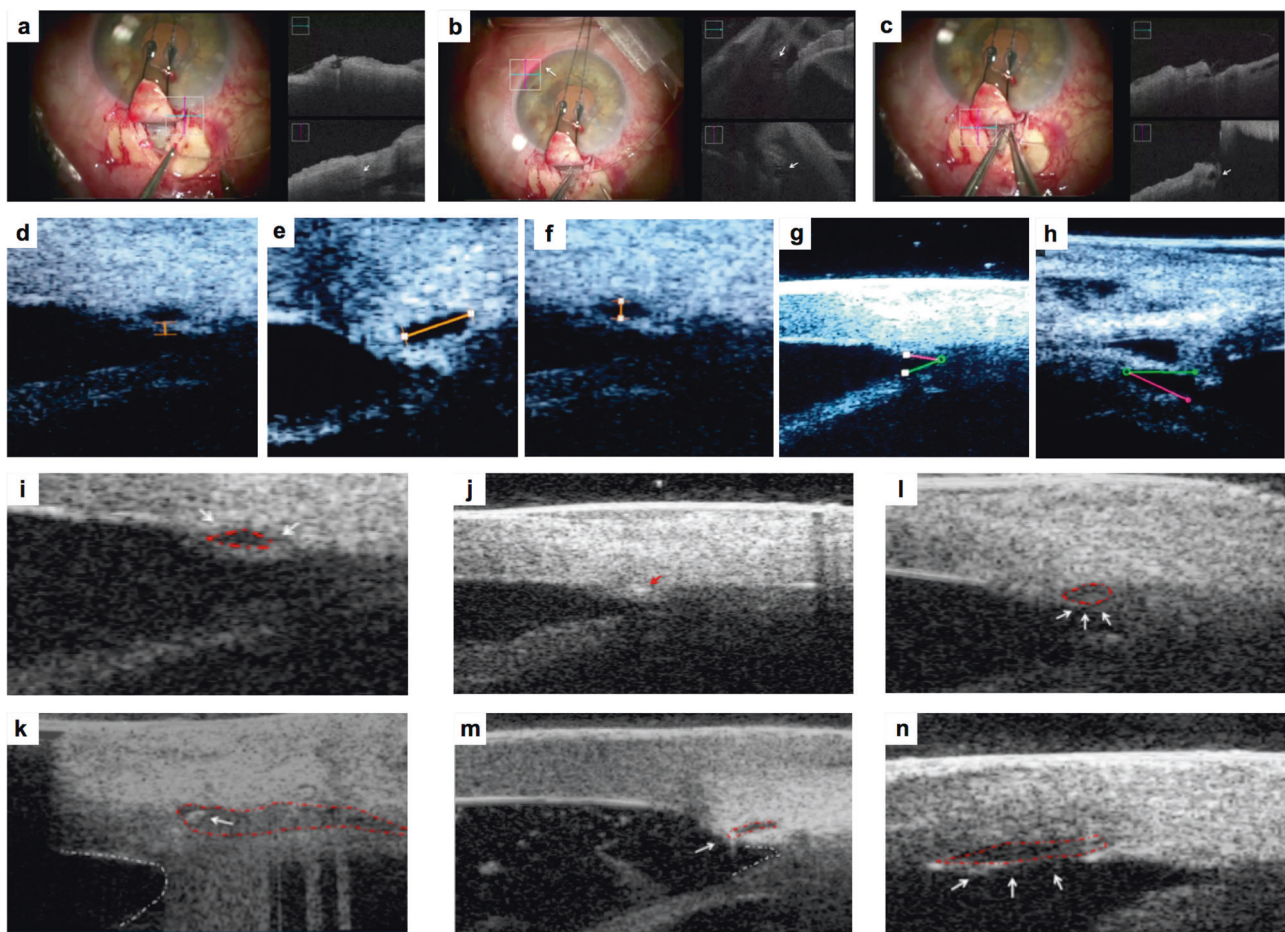


Fig. 1 Picture **a** Microscope image (left picture) shows trabeculo-descemet window after dissection of the deep scleral flap. iOCT image (right picture) shows SC before dilating the ostium of SC using the iTrack microcatheter (white arrow). Picture **b** Microscope image (left picture) shows the progress of microcatheter into SC. Red light indicates the position of the microcatheter tip in the SC. iOCT image (right picture) shows the microcatheter in the SC (white arrows) Picture **c** Microscope imaging shows the final step of retraction of the microcatheter with simultaneous injection of Healon GV into the SC. iOCT image (right picture) shows the enlarged SC (white arrow) Picture **d** Intraoperative UBM image: TM thickness measurement after SC viscodilation. Picture **e, f** Intraoperative UBM image: horizontal and vertical diameter of SC after viscodilation. Picture **g, h** Intraoperative UBM image: AC angle before (**g**) and

after surgery (**h**) Picture **i** Preoperative iUBM shows SC that appears as an anechogenic oval-shaped space (red dashed line), and TM (white arrow) Picture **j** iUBM shows the microcatheter in the SC that appears hyperechogenic in comparison to the surrounding tissue (red arrow) Picture **l**: iUBM shows enlarged SC after viscodilation (white arrows, red dashed line) Picture **k**: iUBM shows SC with suture before tensioning suture (white arrow), deep scleral dissection and filtering window (red dashed line). AC angle appears with a concave and rounded profile (white dashed line) Picture **m** iUBM shows SC and suture after tensioning suture (white arrow). SC appears elongated (red dashed line) and AC angle becomes acute (white dashed line) Picture **n** iUBM shows Descemet's membrane detachment after viscodilation (white arrows and red dashed line)

Table 1 Demographic and clinical preoperative data of patients

No.	Age (years)	Gender male (m)/female (f)	IOP, mmHg	BCVA logMAR	lens status phakic (p)/pseudophakic (pp)	AL, mm	Glaucoma type
1	67	f	34	0.6	P	24.7	POAG
2	72	m	36	0.5	P	23.5	POAG
3	68	m	26	0.8	P	22.8	POAG
4	50	f	22	0	P	25.8	POAG
5	75	m	31	0.1	PP	24.9	POAG
6	61	m	29	0.1	P	24	POAG

Table 1 (continued)

No.	Age (years)	Gender male (m)/female (f)	IOP, mmHg	BCVA logMAR	lens status phakic (p)/pseudophakic (pp)	AL, mm	Glaucoma type
7	49	f	29	0	P	23.7	POAG
8	77	m	27	0	PP	22.9	POAG
9	69	f	30	0.6	P	23.4	POAG
10	45	m	24	0	P	24.2	POAG
11	71	f	26	0	PP	25.4	POAG
12	72	m	28	0.4	P	23.8	POAG
13	69	f	26	0.2	PP	22.5	POAG
14	49	f	24	0	P	22.9	POAG
15	42	m	31	0	P	24.2	POAG
16	51	f	28	0	P	25.1	PEX
17	47	m	26	0	P	25.7	PEX
18	58	f	24	0	P	22.8	PG
19	46	m	23	0	P	23.1	PG
20	33	f	21	0	P	24.6	UG
Total mean \pm (range) *% **	58.5 \pm 12.96 (33–77)	50%/50%	27.3 \pm 3.9 (21–36)	0.14 \pm 0.2 (0.8–0)	80%/20%	24 \pm 1.02 (22.5–25.8)	75%/10%/10%/5%

AL axial length, BCVA best-corrected visual acuity, IOP intraocular pressure, PEX pseudoespholative glaucoma, PG pigmentary, POAG primary open angle glaucomaglaucoma, UG uveitic glaucoma

*Mean \pm (range) for quantitative parameters

**Percentage for qualitative parameters

canaloplasty (iTrackTM, Ellex iScience, Inc., Fremont, CA, USA) between January and June 2017. The study was approved by hospital ethics committee and informed consent from all patients was obtained. Surgery was performed by one surgeon (R.F.). Demographic and preoperative parameters were as follows: age, gender, eye, glaucoma type, intraocular pressure (IOP), best-corrected visual acuity (BCVA), lens status, and axial length. IOP and BCVA were monitored at 1, 3 and 6 post-operative months. iOCT integrated on to a microscope (OPMI Lumera 700, RESCAN 700 spectral domain-OCT wavelength 840 nm, Carl Zeiss Meditec, Jena, Germany) and iUBM (iUltrasound iscience interventionalTM, Menlo Park CA, 80 megaHertz transducer frequency) were used for evaluating the morphological changes of AC structures and for measuring the diameters of Schlemm canal (SC), trabecular meshwork (TM) thickness and AC angle during the surgery.

Results

Twenty eyes (20 patients) were recruited (Table 1). IOP decreased significantly during follow-up (from 27.3 \pm 3.9 to 14.5 \pm 2.5 mmHg). BCVA improved only in patients who underwent cataract surgery (6 out of 20).

iOCT allowed the surgeon to monitor SC and AC angle changes during microcatheter passage and viscodilation. During viscodilation SC changed its profile from oval to round-shape with hyporeflexive content (Fig. 1a–c). The poor quality of iOCT imaging did not allow the observer to obtain accurate measurements.

TM thickness, SC diameters and AC angle were measured by iUBM. TM thickness mean was 92 \pm 20.6 μ m. Horizontal and vertical diameters mean of SC were, respectively, 410 \pm 56 and 110 \pm 23 μ m during viscodilation. AC angle mean was reduced from 25.8° \pm 11° to 24.5° \pm 14° after tensioning suture and its profile changed from concave to acute. SC appeared as an anechogenic oval-shaped space. Microcatheter into SC appeared hyperechogenic. In one case endothelial detachment was detected during viscodilation (Fig. 1d–n).

Discussion

iOCT allowed the surgeon to monitor morphological changes of AC structures during surgery but scanning acquisition was not immediate requiring continual adjustment of the focus and scanning point due to the eye movements during surgery that changed the depth of the plan of visualization. The limit of iOCT was the short penetration depth, responsible for

shadowing of scleral tissue and of overlapping and inverted images. Anyhow, iOCT was the best option to obtain a high resolution for imaging superficial areas. Instead iUBM was useful in detecting deeper structures, giving sharper images to measure morphological changes of AC structures. However, the image acquisition required interrupting surgery and the contact of the probe with the eye.

Intraoperative real-time image-guided surgery represents the future even if it still requires further efforts to make the instrumentation functional and simple to use.

Compliance with ethical standards

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Comment on: Pressure and velocity in intraocular and subarachnoid space fluid chambers: an inseparable couple

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To the Editor,

I thank Killer et al. for their interesting article regarding the relationship between pressure and velocity, and its implications on aqueous humour turnover [1]. The authors use a combination of the Bernoulli and the Navier-Stokes equations to demonstrate that flow rate of a fluid is a function of both its pressure and velocity. The authors conclude that a high pressure, IOP, results in a lower aqueous velocity. They go onto hypothesise that a low aqueous velocity leads to a reduced turnover of toxic substances in the anterior chamber which likely plays an important role in the pathogenesis of glaucoma. The assumption in their

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conclusion is that aqueous flow remains constant. If, however, flow were to increase as a function of IOP then velocity may remain constant, or may even increase, thus breaking the inseparable coupling of pressure and velocity alluded to in the authors' title.

The Goldman equation demonstrates that in fact aqueous flow does vary with IOP:

$$C = F / (IOP - P_e)$$

Rearranged:

$$F = C \times (IOP - P_e)$$

where C is outflow facility, F is outflow rate and P_e is episcleral venous pressure.

Therefore, as IOP increases, so does the outflow rate. A number of experiments have demonstrated this to be true, and that aqueous flow does not remain constant as the authors have assumed (Fig. 1) [2].

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