Eye (2006) 20, 32–37

www.nature.com/eye

CLINICAL STUDY

Pig eye trabeculectomy—a wet-lab teaching model

GA Lee[1,2], MY-M Chiang[2] and P Shah[3]

[1]City Eye Centre, Brisbane, Australia

[2]University of Queensland, Brisbane, Australia

[3]Birmingham and Midland Eye Centre, Birmingham, UK

Correspondence: GA Lee
City Eye Centre, 10/135
Wickham Tce, Brisbane QLD
4000, Australia
Tel: 61738316888;
Fax: 61738316883.
E-mail: eye@cityeye.com.qu

Received: 10 August 2004
Accepted: 21 October 2004
Published online: 28 January 2005

The authors have no financial or propriety interest in any material or method mentioned

Presented in part at the European Glaucoma Society Meeting in Florence, Italy, 2004

Abstract

Purpose **A teaching model for trabeculectomy is described using pig eyes prepared in formalin.**

Method **The model enables trainee surgeons to practice various aspects of tissue handling required for successful trabeculectomy including the construction of a fornix-based conjunctival flap, scleral flap with buried releasable sutures, and water-tight conjunctival closure.**

Results **Exposure to the necessary skills required to perform trabeculectomy surgery can be improved by the use of wet laboratory practice.**

Conclusions **Trabeculectomy surgery experience is becoming more limited as fewer procedures are being performed due to the efficacy of recent medications. Wet laboratories will become an increasingly important aspect of a comprehensive ophthalmology training programme.**

Eye (2006) **20,** 32–37. doi:10.1038/sj.eye.6701784; published online 28 January 2005

Keywords: glaucoma surgery; trabeculectomy; resident training

Introduction

Trabeculectomy surgery, as described by Cairns,[1] is considered to be the gold standard in treating medically refractory glaucoma. Standard trabeculectomy is associated with potentially serious complications including postoperative hypotony, failure, blebitis, and endophthalmitis. Numerous modifications of the original technique have been made to improve patient outcomes. This modern-style trabeculectomy incorporates safety features such as a fornix-based conjunctival flap, buried releasable sutures to the scleral flap and water-tight conjunctival closure. These techniques are technically more demanding and require extensive surgical experience to be mastered. In order to achieve optimal patient outcomes, a formalin-prepared pig eye model for trabeculectomy teaching has been developed for ophthalmology trainees. The use of this model allows surgeons to practice the required surgical skills in a supervised controlled environment, prior to live patient surgery.

Method

A microsurgical laboratory consisting of dissecting microscopes and microsurgical instruments was set up (Figure 1). Freshly exenterated pig eyes were arranged through a butcher, but can also be sourced via an abattoir or piggery.

The pig eye is prepared by soaking in 10% formaldehyde solution for 5–12 h. This step is essential for firming of the pig eye tissues, in order to simulate human tissue consistency. The eye is removed from the formalin, rinsed, and reinflated with normal saline via the optic nerve until firm. Excess adnexal tissue can be removed with large scissors, but with care not to damage the superior conjunctival tissues. The pig eye is then mounted on a dummy head or fixed to a foam block with short 25 G needles. Good fixation is essential as many of the surgical manoeuvres require countertraction. To improve corneal transparency, the epithelium can be scraped away and viscoelastic applied to the surface if available. The instruments required for this teaching model include

1. blunt-ended Westcott scissors,
2. Pierce-Hoskins notched or plain forceps,
3. fine needle holder,
4. crescent blade,
5. 30° blade or diamond knife,
6. tying forceps,
7. Vannas scissors,
8. 7-0 silk or vicryl for the corneal traction suture,

Figure 1 Dissecting microscope with pig eye mounted on foam block and instruments.

9. 10-0 nylon suture—for example Ethilon 3/8 circle spatula point (9000 G).

Fornix-based conjunctival flap

The 7-0 silk or vicryl corneal traction suture is passed through the mid-peripheral superior cornea at 50% depth with care not to perforate. The pig peripheral cornea is much thicker than the live human eye; however, the principles are similar, for example the needle must be held flat with the tip parallel to the endothelium and passed in a long pass corneal track. The conjunctival flap is fashioned with a fornix-based peritomy, using a blunt-ended Westcott scissors and notched or plain forceps (Figure 2). Compared to the human eye, the limbal tissue in the pig eye is quite adherent to the underlying sclera. The conjunctiva is then opened in front of and along either side of the superior rectus. Care must be taken when handling the conjunctiva as it is thinner and more friable than live human conjunctiva. If the conjunctiva is very thin, the Tenon's tissue can be hydrated with normal saline for easier handling. This model also allows simulated application of mitomycin-C, where careful edge protection and insertion of multiple soaked pledgets over a wide area can be practiced.

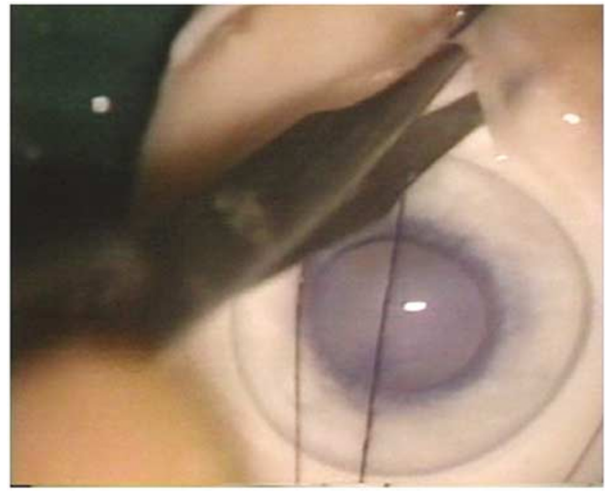

Figure 2 Creation of the superior conjunctival flap (fornix based) with Westcott scissors and forceps. The corneal traction suture is *in situ*.

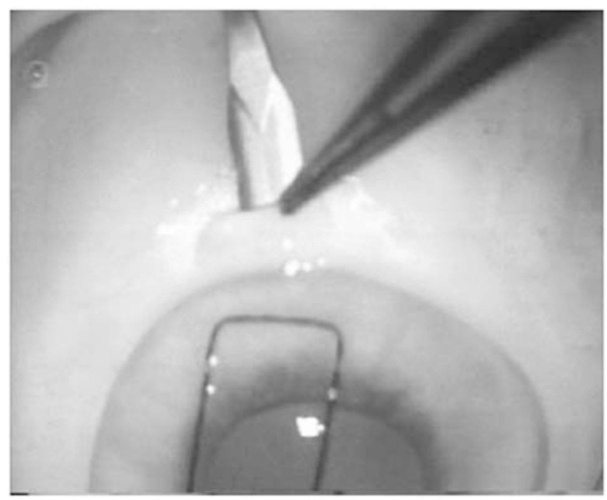

Figure 3 Fashioning of the scleral flap with the crescent blade.

Scleral flap

To prepare the scleral flap, the episcleral tissues are firmly scraped away with the tip of the crescent blade. A 50% thickness scleral flap approximately 3–4 mm posteriorly and 4–5 mm wide is fashioned with a 30° or diamond blade. The posterior lip and sides of the flap are cut to the same depth. A crescent blade is then used to dissect the scleral flap into clear cornea (Figure 3). Alternatively, the flap sides can be cut after the scleral pocket is dissected. In general, the sclera in the pig eye is thicker and tougher than the human eye.

Buried releasable sutures

Two reverse-step superficial corneal stromal troughs are cut at 90° to the sides of the scleral flap. A 10-0 nylon

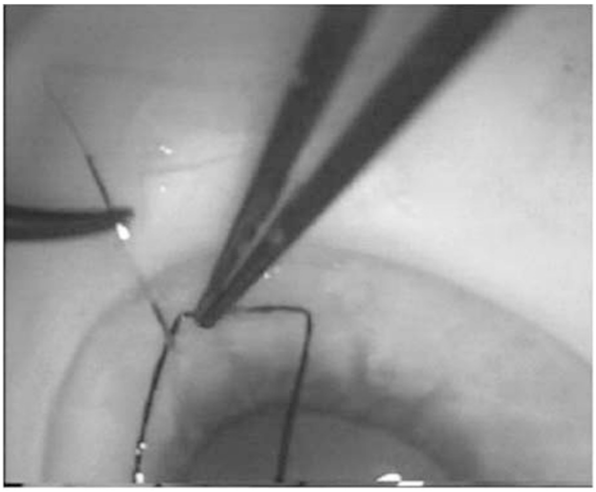

Figure 4 Passing of the needle through the limbal tissue into the precut corneal groove.

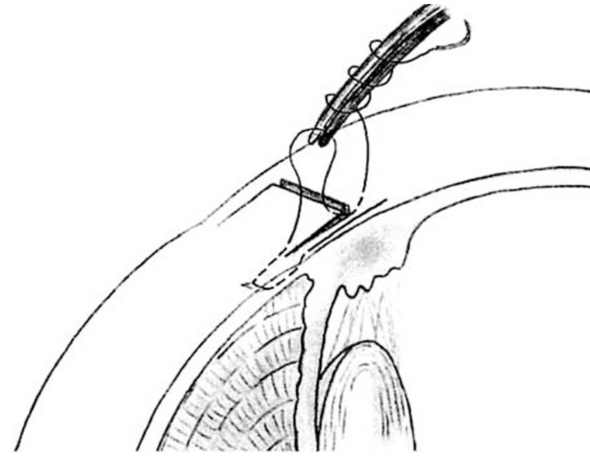

Figure 6 Diagram showing triple-throw loop tightening of the buried releasable suture on the scleral trapdoor.

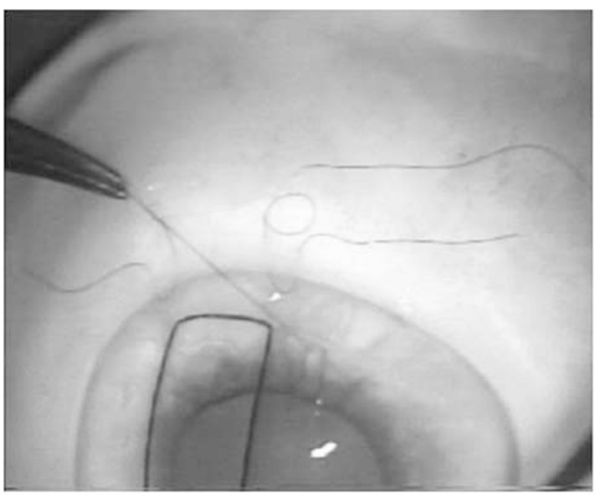

Figure 5 Buried releasable suture *in situ* (right suture) and tying of the knot with a triple throw loop.

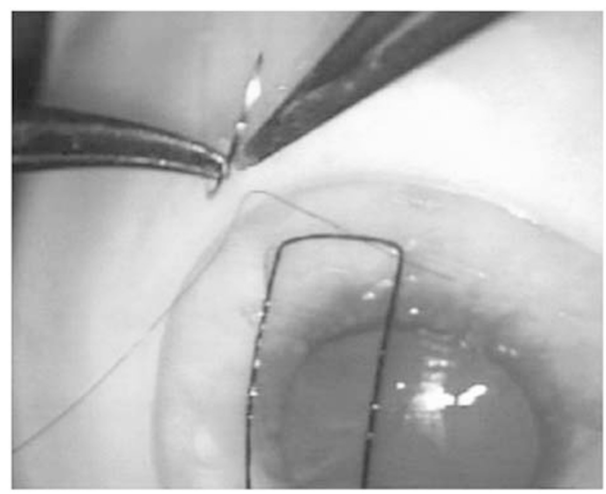

Figure 7 Purse-string style suture to close the two ends of the conjunctival flap.

suture is used for the releasable suture. The needle is passed from just behind the limbus beside the scleral trapdoor to emerge from the corneal trough (Figure 4). The needle is passed back into the corneal trough, through the partial-thickness scleral flap and emerges on the upper surface of the flap. The needle is then passed full-thickness through the tip of the scleral flap into the adjacent scleral bed. A loop is left for tying with a triple-throw loop (Figures 5 and 6). This suture is technically demanding and in this teaching model, can be repeated many times until proficiency is gained. The process of removing the suture also can be practiced by using a bent tip 25 G needle to hook the loop of suture out of the corneal trough. The free end can be pulled with fine plain forceps, thereby releasing the triple-throw loop and allowing removal of the suture.

Unfortunately, in the pig eye model it is not possible to perform sclerostomy with a punch or peripheral iridectomy due to the thick peripheral cornea. A fresh human cadaver eye would provide the best simulation of this important step.

Conjunctival and Tenon's closure with purse-string and mattress sutures

The conjunctiva and Tenon's are closed with two purse-string sutures and two central horizontal mattress sutures using a 10-0 nylon suture with the aim of minimal tension on the conjunctiva. For the purse-string suture, the needle is passed intracorneally behind the limbus to emerge in clear cornea. The suture is looped back through the undersurface of the cut edge of the

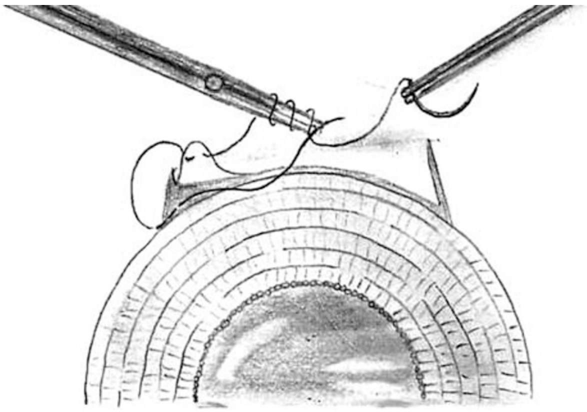

Figure 8 Diagram showing the purse-string closure of the superior conjunctival flap edge.

conjunctival flap (Figure 7). A purse-string style knot is created by two further passes through the conjunctival edge which draws the conjunctival edges together and then a 3-1-1 knot for locking (Figure 8). A buried knot should result if performed correctly. The conjunctival closure is completed with two buried central horizontal mattress sutures resulting in water-tight conjunctival closure. This can be tested by injecting saline subconjunctivally through the wound edge and seeing if a bleb forms.

Limitations of the teaching model

The simulation of all surgical conditions is not readily created such as poor surgical access, blood obscuring the operating field requiring cautery, and patient movement. The vital step of adjusting the suture tension on the scleral flap thereby limiting the aqueous flow through the sclerostomy and hence titrating the intraocular pressure also cannot be simulated. The aim of the model however, is to master all the other steps so that additional surgical challenges can be more easily overcome. Additional tuition on the intensive postoperative management and potential complications of trabeculectomy must also be part of the training programme.

Discussion

The training of ophthalmology residents has attracted much attention due to the extraordinary advances in the field of ophthalmology, especially in the last decade. Many resident training programmes have simply added this new information and recently developed skills to their existing clinical and surgical curriculum. The continuing expansion of the curriculum, confined by the unchanged duration of resident training, may lead to a more superficial understanding of key concepts as well as deficiencies in major topics.[2] Arguments have been made in the United States to increase the duration of the ophthalmology resident training programme from the traditional 3–4 years in order to provide a better comprehensive training. The Australian fellowship in 2004 has already been increased from 4 to 5 years. Also, questions have been raised as to whether postresidency fellowships should be made compulsory.[3,4]

Apart from the expanding curriculum, the available funding plays an extremely important part in the future of resident training programmes. Economic pressures have driven academic clinical practices to see more private patients to increase revenue, therefore steering many ophthalmologists away from teaching. Residents may also be required to provide more service-oriented activities at the expense of education.[2,5,6]

As an example of training standards, cataracts performed by ophthalmology residents have been surveyed both in the United States and the United Kingdom. The United States survey[7] revealed that the mean number of cataract procedures performed by residency completion was 113, with a small percentage performing less than 50. Of the residents, 40% gained experience as the primary surgeon during first year, 38% during second year, and 22% during third year. Of the residents, 68% spent time during their training at an outside or overseas facility to increase surgical volume. The United Kingdom survey[8] targeted ophthalmology senior house officers (SHOs) at all surgical training posts. Only 38% had completed a full phacoemulsification procedure and in less than 50%, a part procedure. Many SHOs expressed dissatisfaction with the training received. The issue of limited surgical opportunity needs to be improved in order to adequately train ophthalmology residents in surgery.

Morrell *et al*[9] in 1989 evaluated 97 eyes undergoing trabeculectomy either by consultants or surgeons in training (50 by consultants and 47 by trainees) and found no significant differences in terms of the success rate and complication rate. A more recent article also found junior doctor success rates similar to those of fully qualified surgeons.[10] Nonconsultant career grade clinicians in the same study achieved lower success rates. It was proposed that the difference was due to the junior doctors receiving better supervision and appropriately selected cases than the career grade doctors no longer regarded as trainees. With modern advances in the field of trabeculectomy surgery, including the augmentation with mitomycin-C, the operation is becoming more technically demanding and requiring advanced microsurgical skills. With the widespread replacement of extracapsular surgery with sutureless phacoemulsification surgery, many ophthalmologists in training have limited skills in the areas of tissue handling and suturing. An additional problem is that the incidence of trabeculectomy has declined steadily over recent years resulting in a reduction in the number of suitable cases for training purposes, partially attributable to newer and more effective antiglaucoma medications.[11] As patients are tending to undergo surgery at a later stage in the glaucomatous disease, achieving a low stable intraocular pressure has become critical to maintain visual field. It is the consultant's paramount responsibility that any surgery performed is carried out at the highest and safest level. This is only possible to achieve if the surgeon is experienced and regularly practises glaucoma surgery.

Many models previously described for ophthalmology resident training have concentrated on phacoemulsification. The models have involved the use of postmortem human eyes, postmortem animal eyes, synthetic eyes, and computer-simulated eye surgery. The use of postmortem human eyes is ideal because they most closely mimic live human eyes; however, their availability is often limited. Also, universal fluid precautions need to be taken during handling to prevent transmissible diseases. Poor visualisation of intraocular structures through an opaque cornea is the major problem when using human cadaver eyes. This may be improved by dehydration of the cornea by hyperosmotic agents,[12,13] sutured keratoprosthesis,[14] and the use of contact lenses.[15–18]

Animal models that have been used for skills development in ophthalmology include bovine,[19,20] porcine,[21–23] goat,[24–26] and rabbit eyes.[27] Freshly harvested animal eyes are preferable to avoid corneal oedema and opacification. In general, postmortem animal eyes are readily accessible and inexpensive. Disadvantages include different anatomy and consistency to human eye, a more elastic anterior capsule and soft nuclear material. The bovine eye is further limited by its larger size, making phacoemulsification and insertion of intraocular lenses less realistic.[20] The preparation of the eyes with formalin in this model makes the tissues handle more like human tissue. Without the formalin, the tissues are fragile and have a tendency to fragment. If formalinised, the tissues can be stored for longer periods; however, if kept too long the tissue can become too stiff to be manipulated.

Despite the number of models described for cataract surgical training, available trabeculectomy teaching models remain very limited. The human cadaver model using high-molecular weight osmotic material by Auffarth *et al*[12] has been used in trabeculectomy training. Yip *et al*[28] developed a globe-holding device for teaching cataract surgery and trabeculectomy on porcine eyes. However, details of both the human and porcine eye models were not described.

Trabeculectomy surgery is technically demanding. The majority of the surgery performed in the teaching hospitals is sutureless clear corneal phacoemulsification surgery. Suturing skills and delicate tissue handling thus are not adequately trained. A major challenge is that by the time the decision is made to proceed to trabeculectomy, often the glaucoma is advanced and hence long-term intraocular pressure control must be achieved. The first chance is often the best chance to establish a functioning bleb and hence good surgical experience is essential. In order to acquire skills, wet-lab training on artificial or animal eyes may become a mandatory part of the curriculum. Inadequate surgical exposure results in failure to obtain the necessary skills and unless the experience is obtained during training, then trabeculectomy will become the realm of subspecialists with glaucoma fellowship training.

Method of literature search

A search of full Medline database was conducted using keywords or combination of keywords: ophthalmology, ophthalmic, resident, teaching, training, technique, pig eye, porcine eye, bovine eye, model, eye surgery, ocular surgery, cataract, phacoemulsification, glaucoma surgery, and trabeculectomy. The articles were manually searched to include those of interest. The literature search was limited to the English language.

Acknowledgements

The authors would like to thank Professor Peng T Khaw for the concepts of modern-style trabeculectomy and Dr Adrian Rowley for illustrating Figures 6 and 8.

References

1 Cairns JE. Trabeculectomy. Preliminary report of a new method. *Am J Ophthalmol* 1968; **66**: 673–679.
2 Sadun AA. The challenge of teaching ophthalmology: a Residency Review Committee perspective. *Ophthalmology* 2000; **107**: 1971–1972.
3 Keltner JL. Four years of ophthalmology training. Has its time come? *Arch Ophthalmol* 1990; **108**: 35–37.
4 Parke II DW. Should postresidency fellowships be mandatory? *Arch Ophthalmol* 1990; **108**: 37–39.
5 Liesegang TJ, Hoskins Jr HD, Albert DM, O'Day DM, Spivey BE, Sadun AA *et al*. Ophthalmic education: where have we come from, and where are we going? *Am J Ophthalmol* 2003; **136**: 114–121.
6 Parrish II RK. The future of ophthalmology residency training programs. *Ophthalmic Surg* 1994; **25**: 500–503.
7 Rowden A, Krishna R. Resident cataract surgical training in United States residency programs. *J Cataract Refract Surg* 2002; **28**: 2202–2205.

8 Gibson A, Boulton M, Watson M, Fielder A. Surgical training in ophthalmology. *Lancet* 2002; **360**: 1702.
9 Morrell AJ, Searle AE, O'Neill EC. Trabeculectomy as an introduction to intraocular surgery in an ophthalmic training program. *Ophthalmic Surg* 1989; **20**: 557–560.
10 Edmunds B, Bunce CV, Thompson JR, Salmon JF, Wormald RP. Factors associated with success in first-time trabeculectomy for patients at low risk of failure with chronic open-angle glaucoma. *Ophthalmology* 2004; **111**: 97–103.
11 Paikal D, Yu F, Coleman AL. Trends in glaucoma surgery incidence and reimbursement for physician services in the Medicare population from 1995 to 1998. *Ophthalmology* 2002; **109**: 1372–1376.
12 Auffarth GU, Wesendahl TA, Solomon KD, Brown SJ, Apple DJ. A modified preparation technique for closed-system ocular surgery of human eyes obtained postmortem: an improved research and teaching tool. *Ophthalmology* 1996; **103**: 977–982.
13 Swinger CA, Kornmehl EW. Dehydration of post-mortem eyes for practice and experimental surgery. *Ophthalmic Surg* 1985; **16**: 182–183.
14 Borirak-chanyavat S, Lindquist TD, Kaplan HJ. A cadaveric eye model for practicing anterior and posterior segment surgeries. *Ophthalmology* 1995; **102**: 1932–1935.
15 Castellano D, Spraul J, Whitaker TE. A simple, cost-effective method for practicing phacoemulsification in the cadaveric eye. *Ophthalmic Surg Lasers* 1998; **29**: 253–256.
16 Lenart TD, McCannel CA, Baratz KH, Robertson DM. A contact lens as an artificial cornea for improved visualization during practice surgery on cadaver eyes. *Arch Ophthalmol* 2003; **121**: 16–19.
17 Oram O, Gross RL, Severin TD, Feldman RM, Orengo-Nania S. A human cadaver eye model for anterior and posterior segment laser applications. *Ophthalmic Surg* 1994; **25**: 449–451.
18 Rootman DS, Marcovich A. Utilizing eye bank eyes and keratoplasty techniques to teach phacoemulsification. *Ophthalmic Surg Lasers* 1997; **28**: 957–960.
19 Collins DW, Coroneo MT. Removal of corneal foreign bodies: an instructional model. *Ophthalmic Surg* 1994; **25**: 99–101.
20 Coroneo MT. The bovine eye as a model for the novice cataract surgeon. *Ophthalmic Surg* 1990; **21**: 772–777.
21 Atsushi M, Junko N, Jiro N, Hirohumi H, Takashi K, Kazutaka K. Cataract surgery training using pig eyes filled with chestnuts of various hardness. *J Cataract Refract Surg* 1999; **25**: 622–625.
22 Hashimoto C, Kurosaka D, Uetsuki Y. Teaching continuous curvilinear capsulorhexis using a postmortem pig eye with simulated cataract. *J Cataract Refract Surg* 2001; **27**: 814–816.
23 Sugiura T, Kurosaka D, Uezuki Y. Creating cataract in a pig eye. *J Cataract Refract Surg* 1999; **25**: 615–621.
24 Dada VK, Sindhu N. Cataract in enucleated goat eyes: training model for phacoemulsification. *J Cataract Refract Surg* 2000; **26**: 1114–1116.
25 Sudan R, Titiyal JS, Rai H, Chandra P. Formalin-induced cataract in goat eyes as a surgical training model for phacoemulsification. *J Cataract Refract Surg* 2002; **28**: 1904–1906.
26 Sudan R, Titiyal JS, Sethi HS, Rai HK. Animal model for teaching phacoemulsification. *J Cataract Refract Surg* 2002; **28**: 4–5.
27 Tolentino FI, Liu HS. A laboratory animal model for phacoemulsification practice. *Am J Ophthalmol* 1975; **80**: 545–546.
28 Yip CC, Heng WJ, Au-Eong KG, Yong VS. A novel approach for the fixation of enucleated eyes during microsurgical procedures using common household plumbing accessories. *Ophthalmic Surg Lasers* 2001; **32**: 166–167.