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Dynamic Morphology of Sutureless Cataract Wounds—Effect of Incision Angle and Location

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Abstract. *Objective:* Sutureless cataract surgery has been growing in popularity over the last decade. These clear corneal incisions allow for rapid visual recovery after phacoemulsification, but may be associated with an increased risk of endophthalmitis. The purpose of this study was to evaluate the effect of intraocular pressure (IOP), location, and angle of cataract incisions on wound apposition and sealing in postmortem globes. *Methods*: This was an ex vivo laboratory investigation of 20 rabbit eyes and 14 human eyes. Self-sealing clear corneal, limbal, and scleral incisions were created and IOP was controlled with an infusion cannula. Incisions were made at a variety of angles. Optical coherence tomography was used to image the incisions in real time as the IOP was varied by raising and lowering the infusion bottle, so as to simulate the variation in IOP occurring with blinking or squeezing of the eye. *Results:* With each type of incision, optical coherence tomography demonstrated the dynamic nature of cataract wound morphology as IOP was varied. Higher IOPs, in general, were associated with more tightly sealed wounds than lower IOPs, but this varied according to the location and angle of the incisions. More perpendicular incisions, relative to the surface tangent, sealed less well than incisions created at smaller angles at higher levels of IOP; At lower IOPs, the reverse relationship was observed such that more perpendicular incisions sealed less well than smaller incision angles. *Conclusion:* Changes in IOP may result in variable and sometime poor wound apposition in sutureless cataract incisions. The type of incision and angle of the incision may affect the likelihood of inoculation of the aqueous humor with potentially pathogenic bacteria. For each type of incision, there may be a critical angle at which the incision is better able to withstand fluctuations in IOP. (**Surv Ophthalmol 49(Suppl 2)**:S62–S72, 2004. © 2004 Elsevier Inc. All rights reserved.)

Key words. cataract surgery • clear corneal cataract incisions • endophthalmitis • limbal incisions • optical coherence tomography • scleral incisions • wound structure

Sutureless cataract incisions allow for rapid visual rehabilitation after phacoemulsification, and incisions of this type have become increasingly popular among ocular surgeons worldwide in recent years.[1,5,18,25] In the most recent national surveys, sutureless cataract incisions were preferred among 95% of U.S., 94% of New Zealand, and 58% of Japanese ophthalmologists.[5,18,25] Some studies, however, suggest that sutureless cataract surgery and more specifically clear corneal wounds may be associated with an increased risk of postoperative endophthalmitis,[3,16,19,23,30] a serious, vision-threatening

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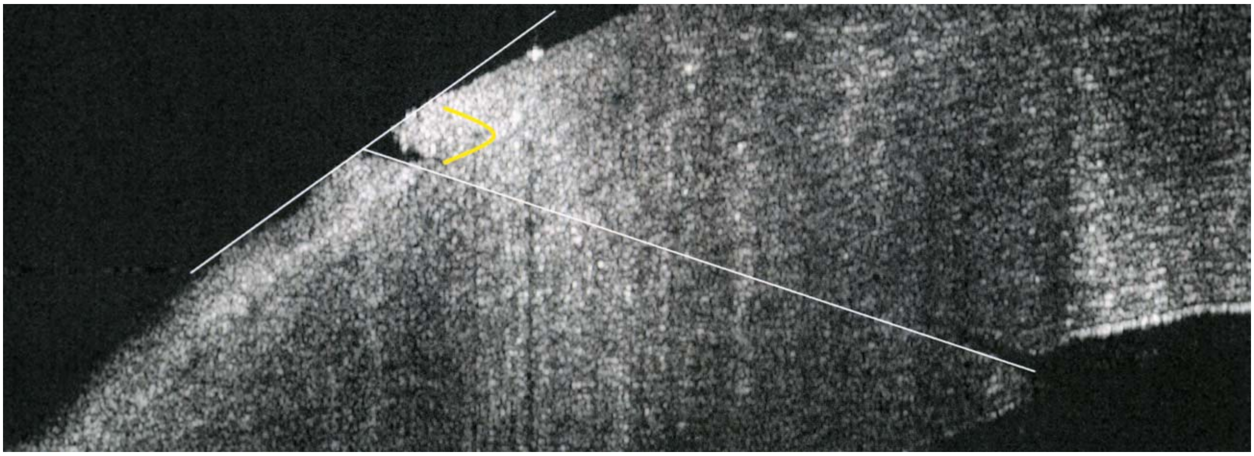

Fig. 1. Using the OCT image, the angle of incision was determined by drawing a line tangent to the corneal/scleral surface at the site of blade entry into the tissue, and then measuring the angle between that line and the end of the incision (Descemet's end) with a simple ruler and protractor.

intraocular infection that results from the inoculation of the interior of the eye with pathogenic bacteria. Although some reports suggest that the risk of blindness from endophthalmitis is dependent upon the infecting pathogen,[4,14,20] endophthalmitis is always a potentially devastating complication of ocular surgery.

The incidence of postoperative endophthalmitis is thought to be increasing and the type of surgical incision has been shown to be a risk factor. In a meta-analysis of studies conducted between 1979 and 1991, Powe and associates[27] reported a 0.13% incidence of acute postoperative endophthalmitis following cataract extraction. This period predates the introduction of sutureless corneal surgery. In a later study by John and Noblitt,[16] patient records from 1992 to 1996 revealed a 0.29% and 0.02% incidence of endophthalmitis following cataract extraction with sutureless clear corneal and scleral tunnel incisions, respectively. More recently, Nakagi et al[23] have also reported a statistically increased risk with clear corneal incisions (0.29%), in this case compared to sclerocorneal incisions (0.05%). These findings indicate a several-fold increase in endophthalmitis risk associated with clear corneal incisions compared to scleral and sclerocorneal incisions.[16,23]

Our recent report may elucidate the underlying cause of the increased risk of endophthalmitis with sutureless clear corneal incisions.[21] In that report, optical coherence tomographs demonstrated that transient fluctuations in intraocular pressure (IOP) of a magnitude not uncommon in the postoperative period resulted in gaping of the wound margins, particularly at the internal aspect of the incisions. This effect was more pronounced at lower IOPs and less pronounced when the eye was well-pressurized for standard self-sealing incisions. Interestingly, in the case of a more perpendicular incision to the corneal surface, the changes in wound morphology were opposite those seen with the self-sealing tunnel incisions in that low IOPs resulted in better apposed wound edges, whereas higher IOPs caused wider separation of wound edges. However, this study evaluated clear corneal incisions only and did not consider the location or specific angles of the surgical wounds.

Although valuable, earlier studies, using non-optical coherence tomography (OCT) techniques to define the stability of cataract incisions, have failed to reveal the continuous dynamics of wound morphology that occurs during pressure application.[6,7] The purpose of the present study was to characterize the effect of transient fluctuations in IOP on wound apposition and sealing and evaluate whether location or angle of the incision have any influence on the wound dynamics using OCT.

Methods

TISSUE PREPARATION AND SURGICAL PROCEDURES

Twenty freshly enucleated New Zealand white rabbit eyes were obtained from a local abattoir and 14 intact human globes ranging from 1–4 days postmortem were obtained from the San Diego Eye Bank. All globes were kept at 4°C in a moist chamber. Globes were placed in a globe holder and oriented so that the temporal cornea was placed at the 12 o'clock position under the operating microscope. A 23-gauge butterfly needle inserted through the limbus at approximately the 6 o'clock position, 90–180 degrees from the incision site, was connected by intravenous tubing to a 250 ml bottle of balanced salt solution. IOP was based on and varied by adjusting the height of the bottle, which was previously calibrated using a manometer (Digimano 1000, Netech Corp., Hicksville, NY).

All surgical incisions were performed by an experienced ophthalmic surgeon. Standard single-planed cataract incisions were created under microscopic visualization using a 3.0 mm disposable keratome (Alcon, Forth Worth, TX) and with the aid of a crescent knife (Alcon, Forth Worth, TX) in case of scleral tunnels. Incisions were made approximately 1–2 mm anterior to the limbus (clear corneal incisions), at the limbus (limbal incisions), or 1–2 mm posterior to the limbus (scleral incisions). Incision tunnel lengths varied from 0.5 to 2.5 mm. The angle of the knife relative to the local ocular surface was varied so as to create incisions with a wide variety of morphologies. After the incisions were created, the ocular surface peripheral to the incision was depressed with a cellulose acetate sponge to test for leakage.

In order to maximize the number of incisions examined, six of the human globes underwent a second incision 90° away from the initial incision if the first wound was found to be completely self-healing (no leakage).

TABLE 1

Clear Corneal Incision Data for Human and Rabbit Globes

		Best Seal at IOP^	
	Angle	High	Low
Human Eyes	25	x	
	30	x	
	38[a]	x	
	42[a]	x	
	46	x	
	48[a]		x
	50 (vs 25)		x
	78		x
	81		x
	82		x
	84[a]		x
Rabbit Eyes	27	x	
	30	x	
	36	x	
	42	x	
	43	x	
	48		x
	56 (vs 26)		x
	72		x
	83		x
	99		x
	103		x

^IOP was based on and varied by adjusting the height of the bottle, which was previously calibrated using a manometer.

[a] Indicates a 2nd incision in an eye with a previously self-sealing wound (no leakage).

TABLE 2

Limbal Incision Data for Human and Rabbit Globes

		Best Seal at IOP^	
	Angle	High	Low
Human Eyes	36	x	
	48	x	
	49[a]		x
	50		x
	52		x
	54		x
	70[a]		x
Rabbit Eyes	38	x	
	42	x	
	59		x

^IOP was based on and varied by adjusting the height of the bottle, which was previously calibrated using a manometer.

[a] Indicates a 2nd incision in an eye with a previously self-sealing wound (no leakage).

OPTICAL COHERENCE TOMOGRAPHY

Direct visualization of the wound anatomy was performed with optical coherence tomography (OCT). OCT is a novel technology developed for high resolution (2–10 μm) imaging of biological tissue in vivo. The principle of OCT has been described in detail elsewhere.[8,9,13,24,28] Briefly, it is a non-destructive, non-contact imaging tool similar to ultrasound imaging except near infrared light is used instead of sound waves. The OCT setup used in our experiment was described previously.[21] We obtained two-dimensional cross-sectional images with axial and lateral resolutions of 8 μm and 15 μm, respectively.

Globes were oriented vertically under the laboratory OCT device described previously.[21] The anterior segment of each globe was scanned, transversing the center of the incision, and showing the wound in profile. Measurement of the angle of incision was performed by drawing a line tangent to the cornea/scleral surface at the site of blade entry into the tissue, and then measuring the angle between that line and the end of the incision (Descemet's end) with a simple ruler and protractor (Fig. 1). An angle of zero would indicate entry of the blade parallel to the surface, while an angle of 90° would indicate entry of the blade perpendicular to the surface.

Results

The angle of the incision and the IOP both influenced the degree of wound closure after cataract incision. Larger (more perpendicular) wound angles were associated with greater wound edge gaping as IOP was increased. Conversely, smaller wound angles were associated with tighter apposition of incision edges at high IOPs. Low IOPs of 10 mm Hg or

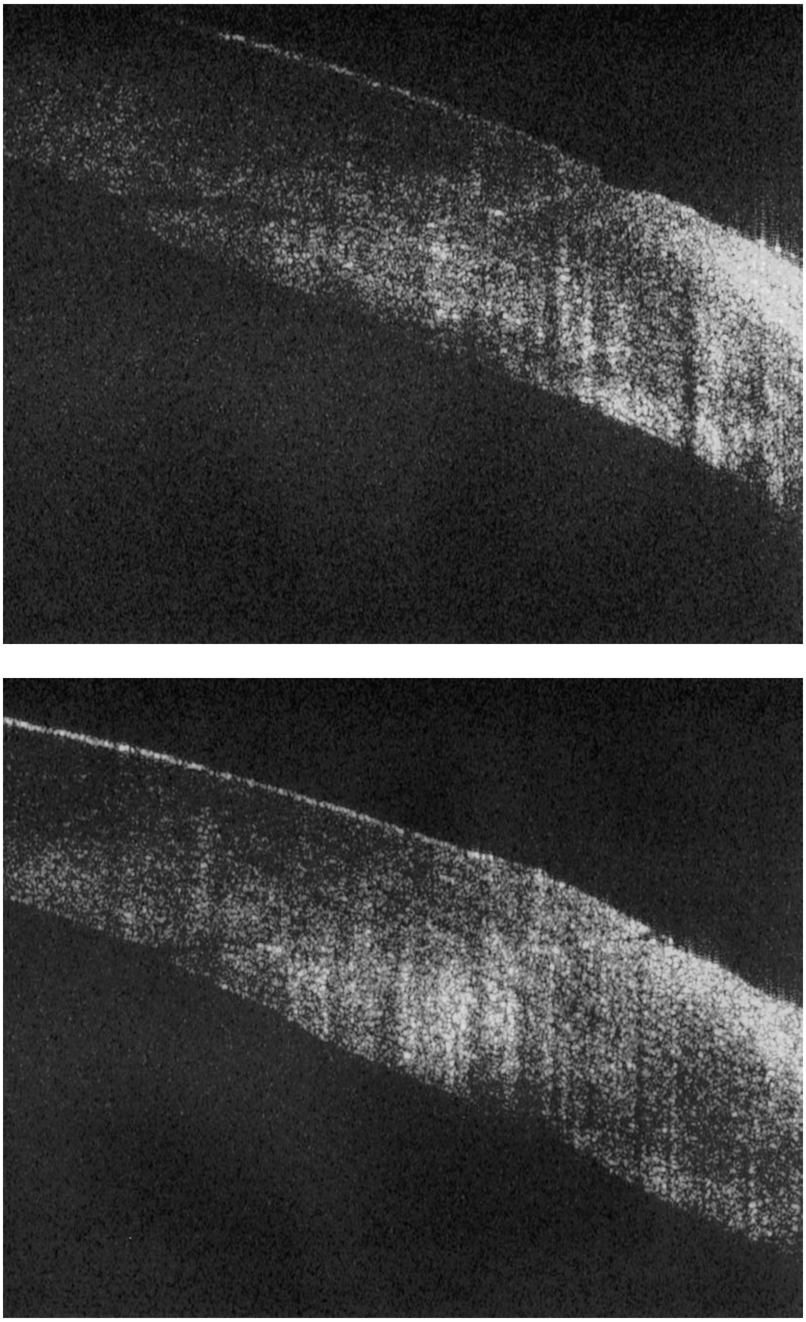

Fig. 2. OCT images of clear corneal cataract incisions in human globes with smaller wound angles at (*top*) low IOP and (*bottom*) high IOP. Smaller wound angles exhibited a better seal at high IOP than at low IOP.

less tended to result in gaping with low angle incisions, and improved wound apposition with larger angles.

In the human globes, clear corneal wound angles between 25° and 46° exhibited a better seal at high IOP than at low IOP (Fig. 2), whereas wound angles between 48° and 84° were associated with a more open wound edge at higher levels of IOP (Fig. 3, Table 1). Clear corneal wounds behaved similarly in rabbit eyes, as incisions made at angles ranging from 27–43° exhibited a tighter seal at high IOP than those made at angles ranging from 48–103° and vice versa at lower IOPs (Fig. 4).

Limbal incisions made in human globes at angles ranging from 36° to 48° exhibited tighter seals at high IOP than those made at angles ranging from 49° to 70° (Table 2). Similarly, limbal incisions in rabbit globes at angles ranging from 24–42° exhibited better seals at high IOP than did a single incision made at 59° (Fig. 5).

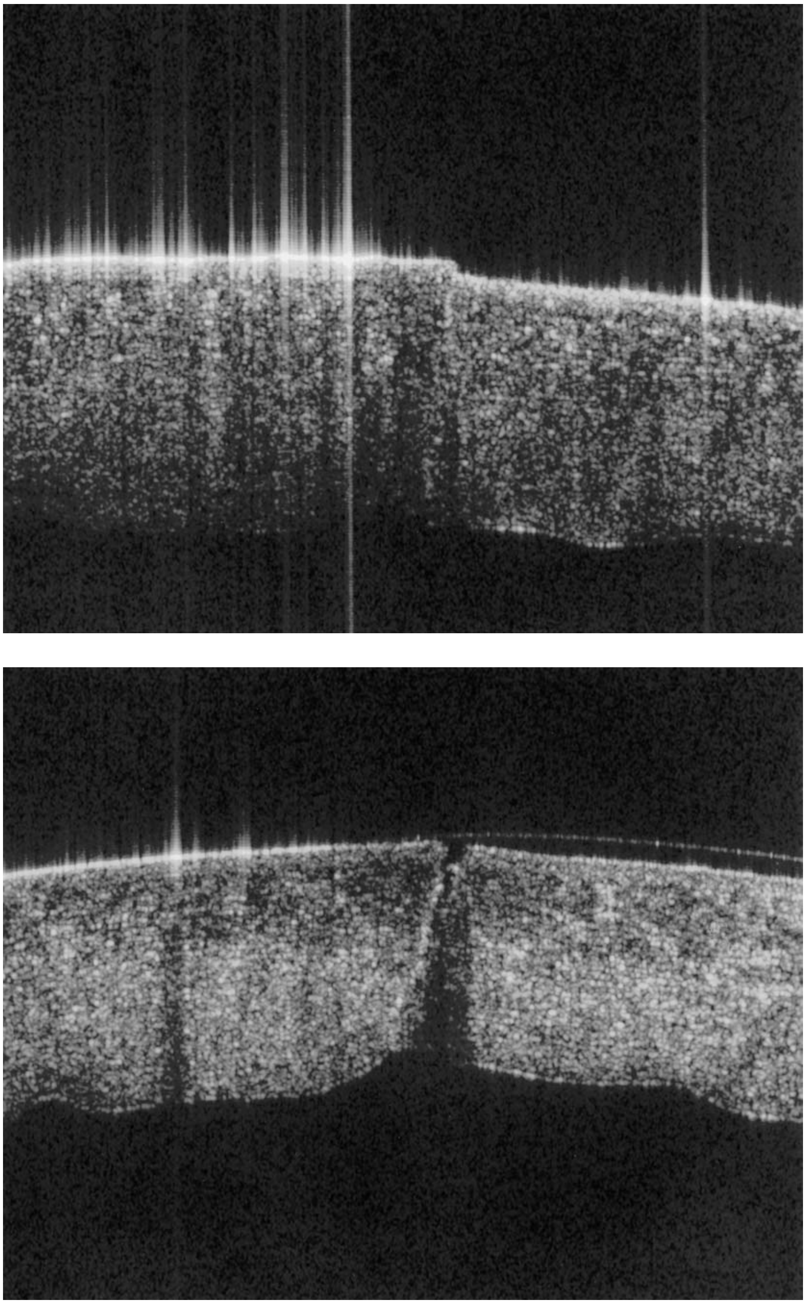

Fig. 3. OCT images of clear corneal cataract incisions in human globes with larger (more perpendicular) wound angles at (*top*) low IOP and (*bottom*) high IOP. Larger (more perpendicular) wound angles were associated with a more open wound edge at higher levels of IOP.

Results were less conclusive upon examination of the scleral incisions. Two incisions were evaluated in human eyes and each exhibited wide gaps in some regions, regardless of IOP or angle of incision (33° and 52°). Three incisions were evaluated in rabbit eyes, and a single incision made at 28° exhibited a better seal at high IOP than did two incisions made at 54° and 69° angles (Fig. 6). No other samples were available due to the inherent difficulty of performing scleral incisions in the thin sclera of rabbit eyes.

Interestingly, in two eyes with a distinct three-planed clear corneal incision, the wound morphology behaved as if the larger angle—angle between blade entry point and exit—was the dominant one (Fig. 7, 8). In other words, at high IOPs, the wounds were less apposed relative to at lower IOPs.

Discussion

The data in the present study suggest that, in the first hours after surgery, self-sealing surgical wounds

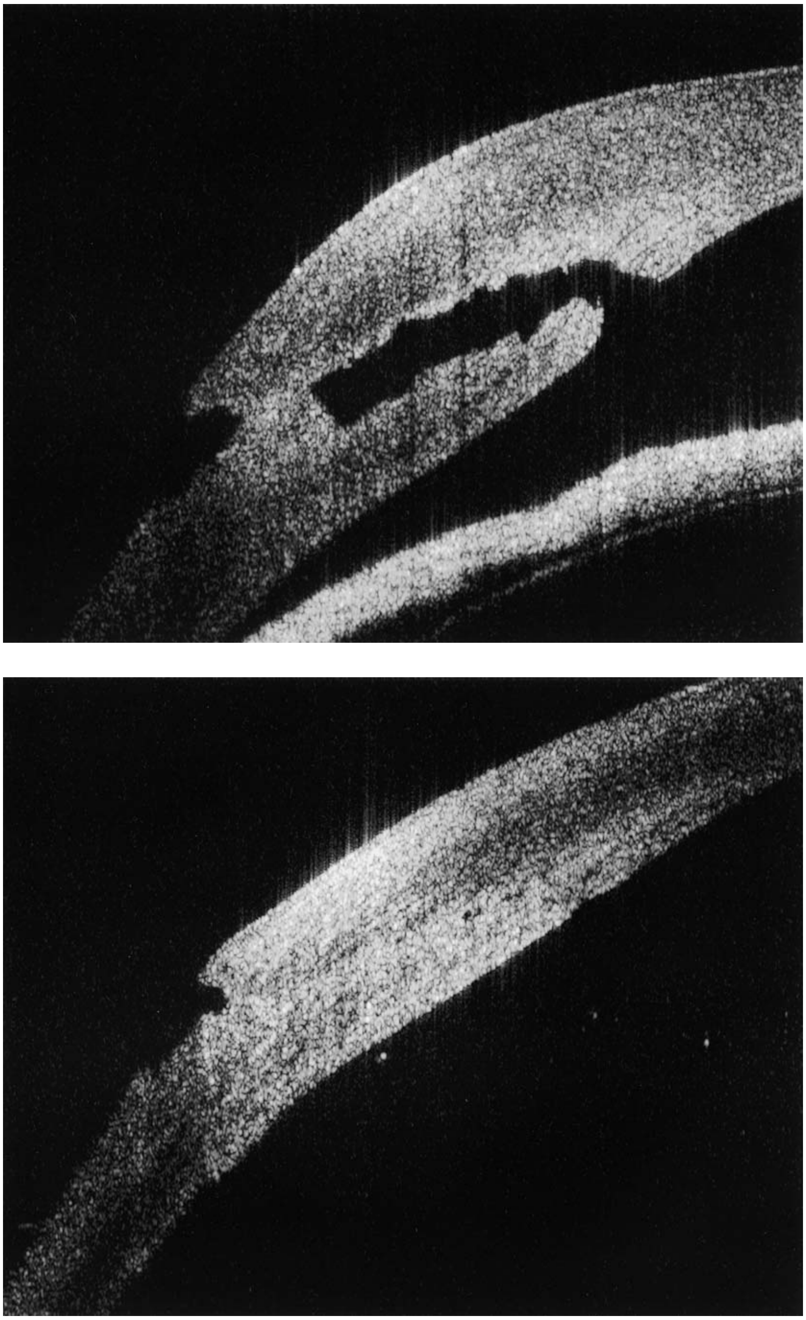

Fig. 4. OCT images of clear corneal cataract incisions in rabbit globes at (*top*) low IOP and (*bottom*) high IOP. As in human globes, smaller wound angles (as shown) exhibited a better seal at high IOP than at low IOP, whereas larger (more perpendicular) wound angles (not shown) were associated with a more open wound edge at higher levels of IOP.

exhibit a dynamic morphology, a period in which little, if any wound healing has taken place. Although this effect is due primarily to the variation in IOP that occurs during normal activities (eye blinking, eye rubbing, eye squeezing, etc.), the morphology of clear corneal and limbal incisions is clearly influenced by the angle of the blade entry used to create the surgical wound.

In well-pressurized eyes, the wound margins of self-sealing ocular incisions were largely well apposed along the length of the incision. However, fluctuations in IOP within a physiologic range (less than 5–40 mm Hg) designed to mimic those pressures measured in blinking animal eyes[26] and human eyes[2] after cataract surgery[29] resulted in movement and gaping of the wound edge. Further, the finding that approximately one-fifth of eyes experience drops in IOP to 5 mm Hg after clear corneal cataract surgery[29] suggests that many patients may be at risk for gaping wound edges postoperatively. The gaping

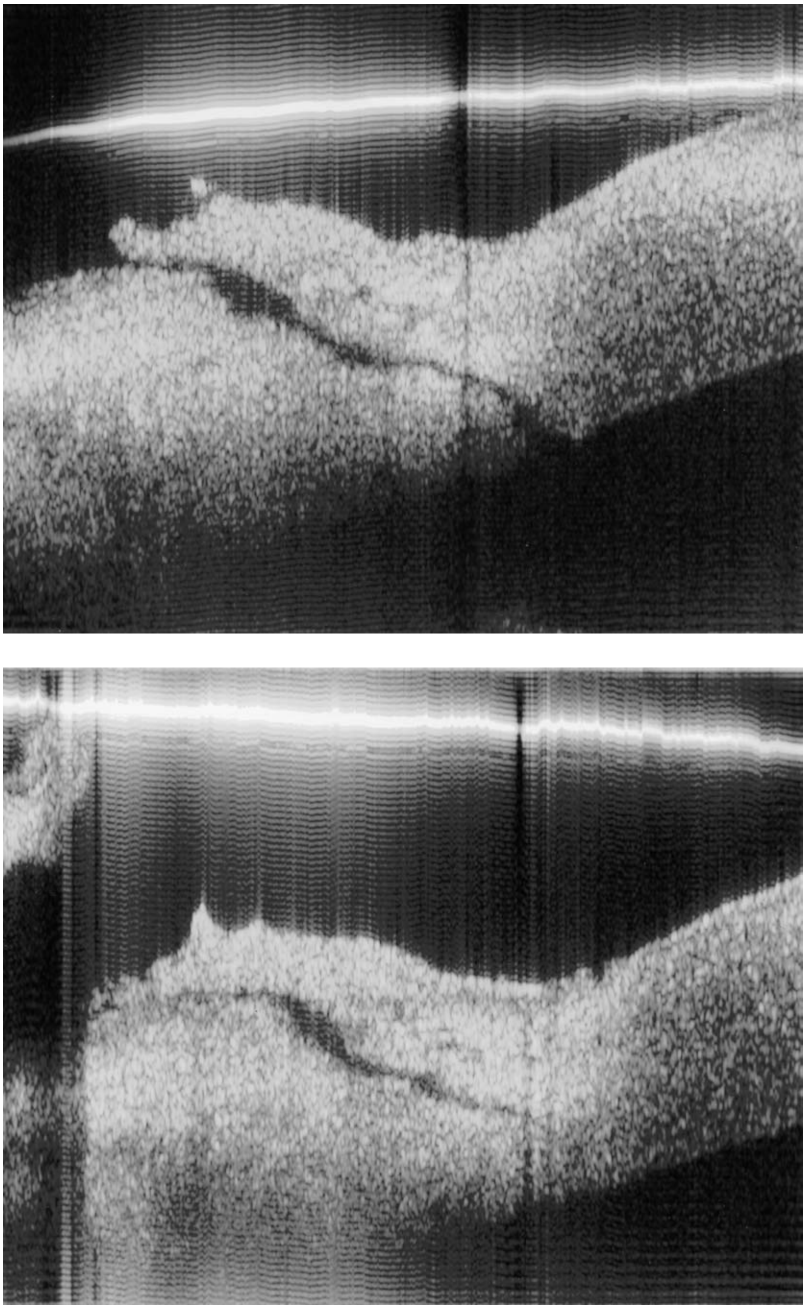

Fig. 5. OCT images of limbal incision in a rabbit globe at (*top*) low IOP and (*bottom*) high IOP demonstrating better wound apposition at high IOP.

of the internal aspect of the incision, which occurred consistently when the IOP dropped to 5 mm Hg or less, may allow for the inoculation of organisms into the aqueous, resulting in endophthalmitis and potential visual loss.

We recently examined the ex vivo dynamic changes in unhealed clear corneal cataract incisions that might adversely affect the risk of intraocular infection.[21] Methods similar to those used in the present study were used and, additionally, light microscopy with India ink staining was used to detect the flow of surface fluid along the incision. Histologic examination revealed the presence of India ink particles in all incisions, for up to three-fourths of the length of the wound. The variation in wound apposition and ability of surface fluid to traverse the wounds suggests a mechanism by which microorganisms from the ocular surface can gain access to the anterior chamber during the early postoperative period and possibly result in endophthalmitis.

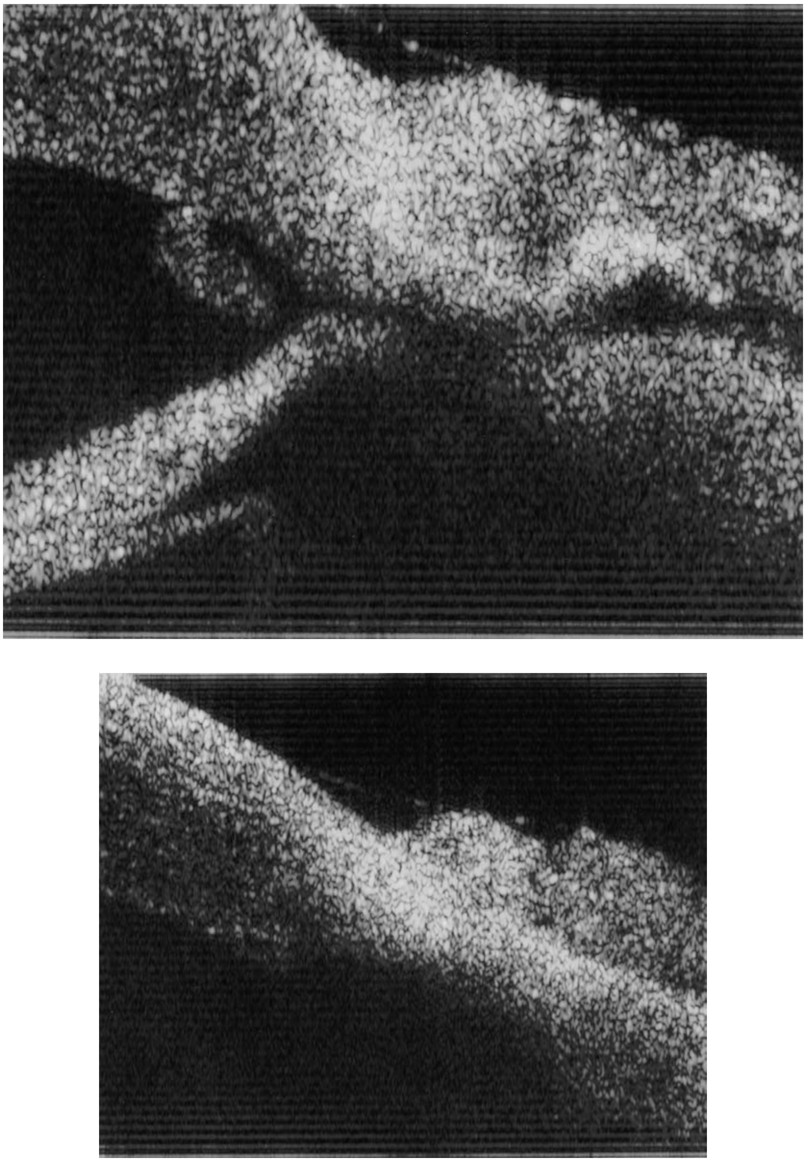

Fig. 6. OCT images of scleral incision in a rabbit globe at (*top*) low IOP and (*bottom*) high IOP demonstrating a better seal at high IOP.

The present study evaluated the impact of the angle of the single-planed incision and considering limbal and scleral incisions, in addition to clear corneal incisions. The findings suggest that for each type of surgical wound, there is a range of angles, for which the impact of IOP fluctuation on wound apposition may be minimized. In the human globes, the data suggest that the critical angle falls between 46° and 48° for clear corneal incisions, and between 36° and 49° for limbal incisions. Data from the scleral incisions were less conclusive but suggest a critical angle ranging from 33–52°. Overall, the data suggest that the critical angle for ocular incisions may be in the range of 36–49°. With smaller angles, wound edges were better apposed with high IOPs and tended to gape in response to low IOPs. With larger angles, the opposite relationship was observed—elevated pressures resulted in greater degrees of wound gape.

Data from the rabbit globes provide similar results, with the critical angle falling between 43° and 48° for clear corneal incisions and between 42° and 59° for limbal incisions. Data from the rabbit scleral incisions were again inconclusive, but the critical angle likely falls between 28° and 54°. An overall critical angle for incisions (excluding scleral incisions) in the rabbit globes appears to reside between 42° and 59°.

In general, for smaller (standard) angles in human globes, limbal incisions resulted in better wound apposition/sealing relative to clear corneal incisions.

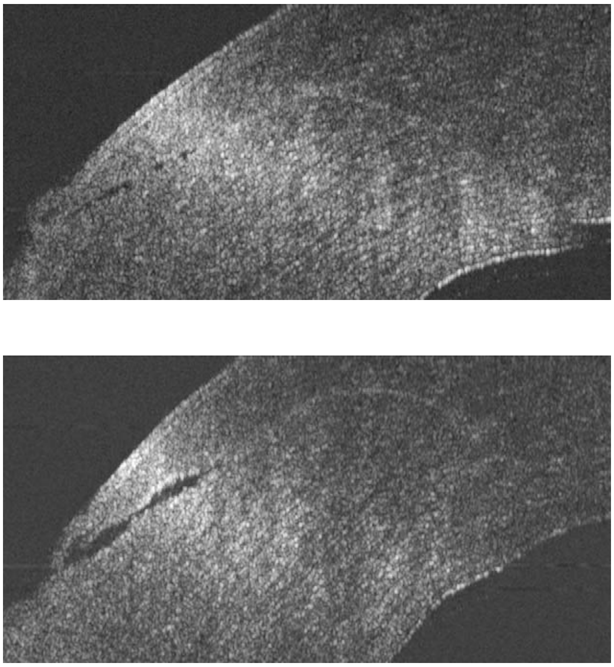

Fig. 7. OCT images of three-planed clear corneal incisions in human globes at (*top*) low IOP and (*bottom*) high IOP. The wound morphology behaved as if the larger angle—angle between blade entry point and exit—was the dominant one, demonstrating that at high IOPs, the wounds were less apposed relative to lower IOPs.

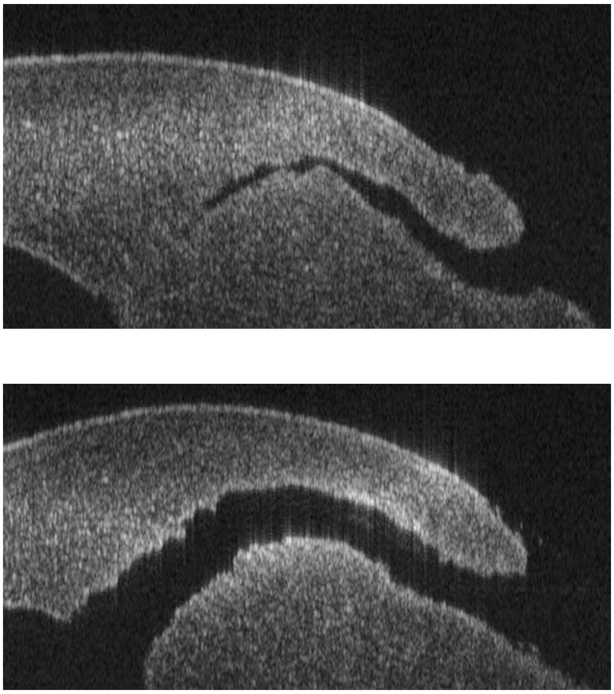

Fig. 8. OCT images of three-planed clear corneal incisions in rabbit globes at (*top*) low IOP and (*bottom*) high IOP. The wound morphology behaved as if the larger angle—angle between blade entry point and exit—was the dominant one, demonstrating that at high IOPs, the wounds were less apposed relative to lower IOPs.

In contrast, in rabbit eyes, this difference was not observed. Cataract wounds in rabbit eyes tended to be more labile and gape more with IOP fluctuation, likely due to inherent differences in the biomechanical properties of rabbit corneas compared to those of humans.[11,17]

The cataract incisions used by many surgeons are more complex than the single-planed incisions created in most of the eyes in this study. With single-planed incisions, the length of the incision as it traverses the corneal stroma increases as the angle increases between the normal to the cornea and the angle of blade entry. Multi-planed incisions may be much more complex, as they can only be described by specifying the angles and lengths for each component of the incision. Thus, the relationship between total incision length and the angles used may be unpredictable. Dissecting out the relative contributions of each variable associated with complex three-planed incisions will be a challenge for future studies. However, in this limited study, three-planed clear corneal incisions appeared to behave similarly to single planed incisions passing through two points: the penetration of Bowman's membrane and the penetration of Descemet's membrane (Fig. 7, 8).

It is important to note that the finding of a better seal at a particular pressure does not indicate that the wound was completely sealed. In fact, incisions commonly had some degree of imperfect wound apposition, regardless of the incision type, angle, or IOP. Our hypothesis is that detailed quantitative measures of wound geometry and associated wound instability will ultimately lead to more precisely and reproducibly constructed wounds with maximal stability.

The intermittent gaping of the wounds observed when the intraocular pressure is varied suggests a possible route by which organisms present on the ocular surface may gain access to the aqueous humor. As shown previously, the drawing of tear film into the wound as demonstrated with the India ink, followed by a transient gaping of the internal aspect of the incision, would allow bacteria to reach the aqueous without necessarily having a continuous gaping along the full-length of the cataract incision.[21] The "suction pump" mechanism proposed by McGowan may allow this fluid to enter the anterior chamber.[22]

This study represents an effort to experimentally explore cataract wound stability in human and rabbit eyes in the first several hours after surgery when the wound has not yet healed. Although further in vivo studies are necessary because of possible limitations of ex vivo experiments (e.g., lack of a functional endothelial pump, pressure applied to the globe by the eyelid), these findings indicate the importance of paying careful attention to the angle of cataract incisions. We plan future in vivo studies in order to examine the effects of the endothelium, patient age, wound healing, and other variables. Particularity, because at the more physiological IOPs, larger (more perpendicular) incision angles seem to have less wound apposition, the creation of a smaller angle incision as opposed to a simpler straight vertical incision is warranted.

These findings have several implications in the post-surgical management of patients. First, the clinician should carefully evaluate the wound for signs of leakage and gaping and should be prepared to more completely close the wound with a suture if needed. Second, the demonstrated improbability of achieving a perfectly sealed wound with the setting of constantly fluctuating IOP underscores the need for prophylactic anti-infective therapy in the early postoperative period. A broad-spectrum anti-infective agent, such as the recently approved fourth-generation fluoroquinolones, would likely reduce the risk of introducing pathogenic organisms into the eye by eliminating them from the ocular surface. Further, even if surface tear fluid did gain access to the interior of the eye, the fluid would contain concentrations of anti-infective sufficiently high to suppress bacterial replication in the aqueous humor.

In conclusion, the findings of the present study suggest that there are many variables that contribute to the dynamic morphology of cataract incisions in the early post-operative period. IOP, the location or type of incision (clear cornea, limbus or sclera), and angle of the incision all act together to determine the wound structure and hence its accessibility to potentially pathogenic organisms. Cataract surgeons should be aware of these variables when construing their wounds in order to minimize the risk for endophthalmitis.

The value of OCT as a tool for ophthalmic imaging is further supported by this investigation. Originally used for retinal and optic nerve imaging, in recent years, the applications of OCT have expanded to visualization of anterior segment components (Huang D et al: High-speed optical coherence tomography of anterior segment surgical anatomy and pathology. Presented at the Association for Research and Vision meeting in Ophthalmology, 2003).[1,10,12,15] Its non-invasiveness and high resolution makes it extremely attractive for the study of surgical wounds and the healing process during the immediate postoperative period.

Method of Literature Search

A review of the MEDLINE database (English language only) (1966–2003) was conducted using keywords such as *cataract surgery, endophthalmitis, wound structure, optical coherence tomography, clear corneal cataract incisions, limbal incisions, scleral incisions.* Relevant citations regarding application of optical coherence tomography in ophthalmology and the principle of its use were obtained. Further references regarding risk of endophthalmitis following cataract surgery and various techniques of cataract incision constructions were also obtained.

References

1. Agapitos PJ: Cataract surgical techniques. Curr Opin Ophthalmol 4:39–43, 1993
2. Coleman DJ, Trokel S: Direct-recorded intraocular pressure variations in a human subject. Arch Ophthalmol 82:637–40, 1969
3. Colleaux KM, Hamilton WK: Effect of prophylactic antibiotics and incision type on the incidence of endophthalmitis after cataract surgery. Can J Ophthalmol 35:373–8, 2000
4. Driebe WT Jr, Mandelbaum S, Forster RK: Pseudophakic endophthalmitis: diagnosis and management. Ophthalmology 93:442–8, 1986
5. Elder M, Leaming D: The New Zealand cataract and refractive surgery survey 2001. Clin Exp Ophthalmol 31:114–20, 2003
6. Ernest PH, Fenzl R, Lavery KT: Relative stability of clear corneal incisions in a cadaver eye model. J Cataract Refract Surg 21:39–42, 1995
7. Ernest PH, Lavery KT, Kiessling LA: Relative strength of scleral corneal and clear corneal incisions constructed in cadaver eyes. J Cataract Refract Surg 20:626–9, 1994
8. Fercher AF: Optical coherence tomography. J Biomed Opt 1:157–73, 1996
9. Fujimoto JG, Brezinski ME, Teraney GJ: Optical biopsy and imaging using optical coherence tomography. Nat Med 1:970–2, 1995
10. Hirano K, Ito Y, Suzuki T, et al: Optical coherence tomography for the noninvasive evaluation of the cornea. Cornea 20:281–9, 2001
11. Hoeltzel DA, Altman P, Buzard K, Choe K: Strip extensiometry for comparison of the mechanical response of bovine, rabbit, and human corneas. J Biomech Eng 114:202–15, 1992
12. Hoerauf H, Wirbelauer C, Scholz C: Slit-lamp-adapted optical coherence tomography of the anterior segment. Graefes Arch Clin Exp Ophthalmol 238:8–18, 2000
13. Huang D, Swanson EA, Lin CP: Optical Coherence Tomography. Science 254:1178–81, 1991
14. Irvine WD, Flynn HW Jr, Miller D: Endophthalmitis caused by gram-negative organisms. Arch Ophthalmol 110:1450–4, 1992
15. Izatt JA, Hee MR, Swanson EA: Micrometer-scale resolution imaging of the anterior eye in vivo with optical coherence tomography. Arch Ophthalmol 112:1584–9, 1994
16. John ME, Noblitt R: Endophthalmitis: Scleral tunnel vs. Clear Corneal Incision. in Buzard KA, Friedlander MH, Febbraro JL (eds): The Blue Line Incision and Refractive Phacoemulsification. Thorofare, NJ: Slack, 2001, pp 53–6
17. Jue B, Maurice DM: The mechanical properties of the rabbit and human cornea. J Biomech 19:847–53, 1986
18. Leaming DV: Practice styles and preferences of ASCRS members—2001 survey. J Cataract Refract Surg 28:1681–8, 2002
19. Lertsumitkul S, Myers PC, O'Rourke MT, Chandra J: Endophthalmitis in the western Sydney region: a case-control study. Clin Exp Ophthalmol 29:400–5, 2001
20. Mao LK, Flynn HW Jr, Miller D: Endophthalmitis caused by streptococcal species. Arch Ophthalmol 110:798–801, 1992
21. McDonnell PJ, Taban M, Sarayba MA: Dynamic morphology of clear corneal cataract incisions. Ophthalmology 110:2342–8, 2003
22. McGowan BL: Mechanism for development of endophthalmitis. J Cataract Refract Surg 20:111, 1994

23. Nagaki Y, Hayasaka S, Kadoi C: Bacterial endophthalmitis after small-incision cataract surgery. Effect of incision placement and intraocular lens type. J Cataract Refract Surg 29: 20–6, 2003
24. Neubauer AS, Priglinger SG, Thiel MJ: Sterile structural imaging of donor cornea by optical coherence tomography. Cornea 21:490–4, 2002
25. Oshika T, Amano S, Araie M: Current trends in cataract and refractive surgery in Japan: 1999 survey. Jpn J Ophthalmol 45:383–7, 2001
26. Percicot CL, Schnell CR, Debon C, Hariton C: Continuous intraocular pressure measurement by telemetry in alpha-chymotrypsin-induced glaucoma model in the rabbit: effects of timolol, dorzolamide, and epinephrine. J Pharmacol Toxicol Methods 36:223–8, 1996
27. Powe NR, Schein OD, Gieser SC: Synthesis of the literature on visual acuity and complications following cataract extraction with intraocular lens implantation. Cataract Patient Outcome Research Team. Arch Ophthalmol 112:239–52, 1994
28. Ren Z, Ding Z, Zhao Y: Phase resolved optical coherence tomography: simultaneous imaging of in situ tissue structure, blood flow velocity, standard deviation, birefringence, and Stokes vectors in human skin. Optics Letters 27:1702–4, 2002
29. Shingleton BJ, Wadhwani RA, O'Donoghue MW: Evaluation of intraocular pressure in the immediate period after phacoemulsification. J Cataract Refract Surg 27:1709–10, 2001
30. Stonecipher KG, Parmley VC, Jensen H, Rowsey JJ: Infectious endophthalmitis following sutureless cataract surgery. Arch Ophthalmol 109:1562–3, 1991

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