



A Simple, Novel Approach to Capsulorhexis Formation in the Setting of A Mature Cataract and Miotic Pupil

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Purpose: To report a simple, effective technique for surgeons creating a capsulorhexis in patients with pupillary miosis and a dense, mature cataract.

Methods: A single center, two-year retrospective chart review examined 1408 phacoemulsification cataract surgeries. The criteria for inclusion involved a dense, mature cataract and a pupil that was unresponsive to pharmacologic dilation preoperatively. A standardized technique was used for all cases consisting of a 1mm corneal paracentesis and 2.4mm temporal clear corneal incision. Synecholysis was performed if present, followed by the insertion of a 6.25mm malyugin ring under cohesive viscoelastic. The cohesive viscoelastic was removed via the irrigation aspiration tip. The paracentesis was sealed with a small amount of viscoelastic and an air bubble was placed in the anterior chamber. The anterior capsule was then painted with trypan blue. The air bubble and trypan blue were then replaced by a dispersive viscoelastic. Curvilinear capsulorhexis was performed followed by standard phacoemulsion.

Results: Nine patients ranging from 76 ± 12 years (mean \pm standard deviation) met the criteria with a 4+ NS (n=5), white mature (n=3), or deep brunescant (n=1) cataract and 3mm pupil preoperatively. Pupillary miosis was caused by posterior synechia in 44.5% of the cases followed by pharmacologic interactions from tamsulosin and donepezil in 22.25% of cases respectively. One case involved idiopathic miosis likely from aging. Capsulorhexis formation was successful in all cases with no capsular tear, vitreous loss, or conversion to extracapsular cataract extraction (ECCE). However, one case had cortex retention requiring a second procedure for removal.

Conclusion: Dense, mature cataracts and small pupils both compromise the view for the surgeon and may be significant risk factors for training ophthalmologists. Thus, good visualization of the anterior capsule and peripheral nucleus with our simple technique facilitates a reliable capsulorhexis, potentially limiting the risk of complications for ophthalmic surgeons.

Keywords: dense cataract, miosis, IFIS, dementia, novice surgeon, pupil ring

Introduction

Cataracts account for one of the leading causes of preventable blindness across the world. As a result, cataract surgery is a fundamental skill learned during ophthalmology residency. However, the art of cataract surgery has vastly evolved over the past few decades, especially in developed countries. Techniques have shifted from intracapsular cataract extraction (ICCE) and extracapsular cataract extraction (ECCE) to phacoemulsification. Nevertheless, the transition to phacoemulsification from ECCE has been associated with an increase in complications for training

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ophthalmologists.^{1,2} Complications, such as anterior capsule tears, posterior capsular rupture (PCR) with or without vitreous loss, zonular dialysis/dehiscence, and nuclear fragment loss, are often attributed to inadequate continuous curvilinear capsulorhexis (CCC) or poor visualization of the peripheral nucleus during phacoemulsification.² The increase in intraocular complications is likely due to a steep learning curve as complications such as vitreous loss have demonstrated to significantly decrease after the first 80 cases in training residents.³

Even with greater experience, certain patient demographics predispose young surgeons to increased complications. Patient-related risk factors often include dementia, anxiety, advanced age⁴ as well as individuals with deep-set eyes, prominent brows, and limited corneal visibility. However, some of the greatest intraocular risks for novice surgeons involve a miotic pupil,⁵ dense nuclear sclerosis,^{6–8} zonular pathology (antecedent trauma or pseudoexfoliation),^{6,9} and prior pars plana vitrectomy.¹⁰

However, the combination of pupillary miosis and dense cataracts may even be more problematic for novice surgeons as the view of the capsule and nucleus is significantly obscured, thus limiting the ability to create an adequate CCC without complication. Therefore, we

developed a standardized approach with our simple technique which may facilitate the creation of a capsulorhexis in patients with pupillary miosis and dense nuclear sclerosis.

Methods

A total of 1408 phacoemulsification cataract surgeries were examined at a single ambulatory surgical center at LoBue Laser and Eye Medical Center Inc. The retrospective study was conducted in accordance with the Declaration of Helsinki for human subjects in research. Individual consent was obtained for each subject who met the criteria for inclusion with all data anonymized to maintain confidentiality. Inclusion criteria involved patients with 4+ nuclear sclerosis (NS), white mature, or brunescant cataracts along with impaired preoperative pupillary dilation classified as 3mm or less. Patients were excluded if only one of the above criteria were met. All patients included in the study were operated by a single surgeon using a standardized technique described below. Phacoemulsification was performed with the Alcon Centurion (Fort Worth, TX).

A (superior on the right eye, inferior on the left) 1mm corneal paracentesis was created (Figure 1A). Methylparaben free xylocaine was injected intracamerally to numb the iris.

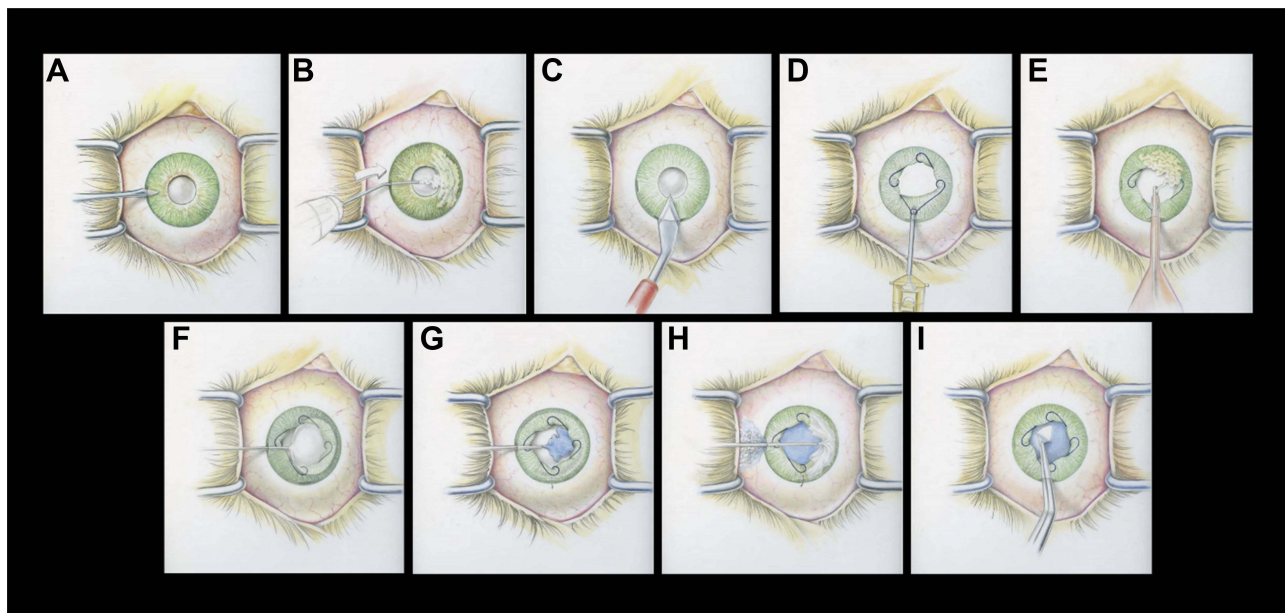


Figure 1 The right eye from the surgeon's perspective depicting pupillary miosis and a dense, mature cataract. A standardized technique was used to create a continuous curvilinear capsulorhexis (CCC). (A): 1mm corneal paracentesis. (B): Methylparaben free xylocaine was injected intracamerally to numb the iris then cohesive viscoelastic was used to fill the anterior chamber. (C): 2.4mm temporal clear corneal incision with a microkeratome blade. Posterior synechiae, if present, were broken with a collar button. (D): A 6.25mm malyugin ring was placed to expand the pupil. (E): Cohesive viscoelastic was then removed via an irrigating/aspiration tip. (F): A small amount of viscoelastic was then used to seal the paracentesis. A 27-gauge cannula was then used to inject air through the paracentesis. If air was leaking through the temporal corneal wound, a temporary single 10-0 nylon could be placed in the incision. (G): Trypan blue was then injected through the paracentesis to stain the anterior capsule. (H): The air bubble and trypan blue were subsequently removed by filling the anterior chamber with a dispersive viscoelastic through the paracentesis. (I): The 10-0 nylon suture was removed from the temporal incision if it was previously placed. A ~5mm CCC was initiated with a cystotome and completed using Utrata Forceps.

Cohesive viscoelastic was then used to fill the anterior chamber (Figure 1B). Next, a 2.4mm temporal clear corneal incision was made with a microkeratome blade (Figure 1C). Posterior synechiae, if present, was broken with a collar button. Subsequently, a 6.25mm malyugin ring was placed to expand the pupil (Figure 1D). Cohesive viscoelastic was then removed via an irrigating/aspiration tip, with careful attention to not damage the anterior capsule (Figure 1E). A small amount of viscoelastic was then used to seal the paracentesis. Next a 27-gauge cannula was then used to inject air through the paracentesis (Figure 1F). If air was leaking through the corneal wound, a temporary single 10–0 nylon could be placed in the temporal incision. Trypan blue was then injected through the paracentesis to stain the anterior capsule (Figure 1G). The air bubble and trypan blue were subsequently removed by filling the anterior chamber with a dispersive viscoelastic through the paracentesis (Figure 1H). Once again, importance was placed on visualizing the cannula within the air bubble so that the integrity of the anterior capsule was not compromised. The 10–0 nylon suture was removed from the temporal incision if it was previously placed. Finally, a ~5mm continuous curvilinear capsulorhexis was initiated with a cystotome and completed using Utrata Forceps (Figure 1I).

Results

Nine patients ranging from 76 ± 12 years (mean \pm standard deviation) met the criteria with a 4+ NS (n=5), white mature (n=3), or deep brunescence (n=1) cataract and 3mm pupil preoperatively (Table 1). Five out of the nine patients were female with preoperative best corrective visual acuity (BCVA) for distance ranging from 20/70 to hand motion vision. Postoperative visual acuity improved in all patients, ranging from 20/20 to 20/70 (Table 2). Visual acuity was 20/40 or better in 56% of the patients. Cataract surgery was uneventful in all nine patients. Capsulorhexis formation was successful in all cases with no capsular tear, vitreous loss, or conversion to ECCE. However, one case had cortex retention requiring removal (Table 2).

The past medical and eye history of the cohort was analyzed. Common conditions included glaucoma with either a trabeculectomy or Ahmed valve (n=2), severe keratitis with corneal transplant (n=1), severe uveitis secondary to HIV (n=1), benign prostatic hypertrophy (n=2), Alzheimer's dementia (n=2), proliferative diabetic retinopathy with vitrectomy (n=1), and hypothyroidism (n=1, Table 1). Pupillary miosis was caused by posterior synechia in 44.5% of the cases followed by pharmacologic interactions from

Table 1 Patient Demographics, History, and Cataract Grade

Age	Gender	Past Medical/Eye History	Cataract Grade
91	M	BPH	White mature
78	F	Glaucoma s/p Ahmed valve	White mature
73	F	Severe keratitis s/p corneal transplant	White mature
54	M	Severe uveitis from HIV	4+ NS
87	M	BPH	4+ NS
71	F	PDR, vitrectomy, Alzheimer's	4+ NS, 3+ CS, 2+ PSC
87	M	Glaucoma s/p trab	4+ NS
74	F	Alzheimer's	4+ NS, 3+ CS, 1+ PSC
68	F	Hyperthyroidism	4+NS, Deep brunescence

Abbreviations: PDR, proliferative diabetic retinopathy; Trab, trabeculectomy; S/P, status post; BPH, benign prostatic hypertrophy; NS, nuclear sclerosis; CS, cortical spoking; PSC, poster subcapsular cataract.

Table 2 Surgical Outcomes and Mechanism for Miosis

Preop VA	Postop VA	Complications	Mechanism for Miosis
HM	20/40	N/A	Tamsulosin
CF	20/30	N/A	Posterior synechia
HM	20/50	N/A	Posterior synechia
20/300	20/70	N/A	Posterior synechia
20/80	20/40	N/A	Tamsulosin
20/300	20/50	N/A	Donepezil
20/70	20/40	Retained Cortex	Posterior synechia
20/80	20/25	N/A	Donepezil
20/400	20/20	N/A	Idiopathic

Abbreviations: Preop, preoperative; Postop, postoperative; VA, visual acuity.

tamsulosin and donepezil in 22.25% of cases respectively. One case involved idiopathic pupillary miosis likely secondary to iris sphincter sclerosis from aging.

Discussion

Cataract extraction is one of the most common intraocular procedures in medicine. Although common, cataract extraction is a very technical surgery, where each phase of the procedure is fundamentally based on the success of the previous step. Since the transition from ECCE to phacoemulsification, one of the most critical aspects of cataract extraction involves the formation of the CCC.

However, new surgeons often perceive CCC or phacoemulsification as one of the most challenging techniques to initially master.^{1,2} Yet, these technical procedures become significantly more difficult when the view of the capsule becomes obscured due to dense nuclear sclerosis^{6–8} or miosis.⁵ Impaired peripheral capsule visibility increases the risk of PCR which may result in vitreous loss, dislocated intraocular lenses, glaucoma, uveitis, cystoid macular edema, and retinal detachment.¹¹ In order to improve capsular visibility while minimizing complications, we developed a simple, standardized technique which facilitates the creation of a capsulorhexis and aids in phacoemulsification in patients with pupillary miosis and dense cataracts.

As mentioned above, small pupils are a well-known risk factor for posterior capsule tears, retained lens fragments, and vitreous loss during phacoemulsification. The minimum threshold for successful capsulorhexis and phacoemulsification typically involves pupil diameters of 4.5–5.0 mm for experience surgeons¹² and 6mm for novice surgeons.⁵ The etiology of pupillary miosis is vast but can range from sphincter sclerosis from aging, diabetes mellitus, pseudoexfoliation, Intraoperative Floppy Iris Syndrome (IFIS), cholinergic agonists, surgical trauma, synechia, uveitis, glaucoma, and miosis following femto-second capsulotomy.

In our cohort, 44.5% of the patients developed miosis due to posterior synechia secondary to previous surgery, uveitis, or glaucoma. Typically, adhesions between the iris and the anterior lens capsule can be efficiently lysed with a spatula or a collar button as demonstrated in our technique. We favor a collar button in order to minimize damage to surrounding structures during synechiolysis. On the other hand, 44.5% of patients developed pharmacologic induced miosis from either tamsulosin or donepezil. Acetylcholinesterase inhibitors such as donepezil are first-line symptomatic treatments for Alzheimer's dementia which function by inhibiting degradation of acetylcholine in the synaptic clefts, thereby improving cholinergic neurotransmission. Estermann et al found that mean pupil diameter significantly decreases after four weeks of oral treatment of donepezil.¹³ Yet, the most important facet to recognize is that dementia is a strong independent risk factor for intraoperative complications during phacoemulsification.¹⁰ Patients with even mild dementia may become disoriented, agitated, and uncooperative once placed under a drape, leading to excessive head movements. In our cohort, we had two patients affected by dementia. In patients with high levels of anxiety or known history of

dementia, we stagger single intravenous push sedation in order to keep patients calm and comfortable. Typically, 1mg Versed is given immediately prior to moving the patient into the operating room (OR). Once in the OR, 25mcg of fentanyl is subsequently given during time out. Then as the surgeon is scrubbing for surgery, 10 mg of ketamine is delivered to the patient. Overall, ketamine is a great addition for anxious, demented patients as it controls pain and eye movement without affecting intraocular pressure.¹⁴ We also find in our practice that patients generally enjoy the ketamine sedation and report an overall positive experience with minimal adverse reactions.

Nonetheless, the pharmacological effects of tamsulosin are associated with more concerning effects, even for experienced surgeons. Alpha-1A antagonists, such as tamsulosin, have been linked with a clinical triad including fluttering or billowing of the iris stroma, propensity for iris prolapse, and progressive pupillary constriction known as IFIS.^{15,16} This triad significantly increases the complexity of cataract surgery and risk for intraoperative complications. Since complications may be as high as 12.5%,¹⁵ several methods have been developed to mitigate these risks. Hashemi et al detail techniques ranging from intracameral buffered lidocaine and epinephrine (e.g., Epi-Shugarcaine),¹⁷ viscomydriasis by combining cohesive and dispersive ophthalmic viscosurgical device (OVD),¹⁸ iris hooks or retractors, and expanding pupillary rings.^{16,19}

Our technique incorporates both pupillary rings and two types of OVD, which is effective in facilitating mydriasis and stabilization of the iris. Cohesive viscoelastic is inserted through the paracentesis which temporarily deepens the anterior chamber, widens the pupil, and supports the iris. Next, a malyugin ring is inserted through the self-sealing, triplaner cornea wound, docking on the nasal and superior or inferior iris. All patients in our study had poor pupil dilation not exceeding 3mm which improved to ~6.25mm after insertion of the ring. Poor preoperative pupil dilation is a predictive test for the severity of IFIS.²⁰ Thus, even with patients demonstrating attributes of severe IFIS, we experienced no intraoperative complications. The growing understanding of IFIS and its management techniques has led to a dramatic decrease in complications, as low as 0 to 0.6% for PCR and vitreous loss.^{21,22} Using expanding pupillary rings, such as our technique, is highly effective in stabilizing the iris and improving the field of view of miotic conditions such as IFIS.^{16,19,21,23} Although iris retractors may also have a role in improving the field of view,¹⁹ the process is more

invasive,^{19,24} tedious, and requires strategic placement in conditions of IFIS.²⁵

The view of the surgeon is also significantly affected by the grade of the cataract. In our retrospective study, all patients had dense nuclear sclerosis which ranged from 4+ NS, white mature, or brunescant cataracts. The red reflex was absent in all cases, limiting our view of the anterior and posterior capsule. Without an adequate view of the capsule, CCC becomes significantly more difficult, increasing the risk for radial tears toward or beyond the lens equator, vitreous loss, nuclear drop, and intraocular lens displacement. Previous studies among experienced surgeons (without capsular dye) have demonstrated that denser nuclear cataracts, paralleled increasing PCR rates from 0.7% to 16.7%.² Capsulorhexis failure were also significantly affected by nuclear density, reaching 36.7% with the densest cataracts.²

A common approach to improve anterior capsular visibility in dense cataracts often incorporates intracapsular dye such as trypan blue. However, there are several methods in which the dye can be delivered, ranging from under air,²⁶ under OVD,²⁷ OVD + BSS, mixing with OVD,²⁸ or one step intracameral injection. Although the safety and effectiveness of trypan blue under OVD versus air are similar,²⁹ there are select advantages to each method. Thus, we developed a staining technique which incorporates both air and OVD.

In our technique, the paracentesis is sealed with a small amount of dispersive viscoelastic. The wound, if necessary, is sealed with a single 10–0 nylon suture before air is injected through a 27 gauge cannula through the paracentesis. In some instances, multiple air bubbles form in the anterior chamber which quickly coalesce into a single bubble after a few seconds. Trypan blue is then injected from the paracentesis, making sure to visualize the cannula in the air bubble. Our approach is advantageous for several reasons. For one, the anterior segment is well sealed, minimizing air leak and shallowing of the anterior chamber during capsular staining. Rapid changes of the lens-iris plane can lead to unintentional damage of the anterior capsule, compromising capsulorhexis formation. Secondly, staining under air prevents direct contact of the dye with the corneal endothelium and allows for better enhancement of the peripheral anterior capsule rim. As a result of better visualization, the rate of successful capsulorhexis formation significantly improves. The success rate for CCC for mature or hypermature cataracts may be as high as a 100%³⁰ as in our study when a capsular dye is used. The uniform staining of the anterior capsule with trypan may

even be helpful for all grades of cataracts, especially in training ophthalmologists.³¹

After successful staining of the anterior capsule, dispersive viscoelastic is used to evacuate dye and air from the anterior chamber. Dispersive viscoelastic is a vital part of our technique because it helps maintain the anterior chamber depth while also protecting the endothelium. A shallow, crowded anterior chamber increases the incidence of iris prolapse and will shift the posterior capsule closer to the phaco tip, thus increasing the risk for PCR. However, in some cases, OVD may obscure the stained anterior capsule interface. This pitfall can be avoided by injecting a small amount of trypan, such as 1cc, while creating a brush stroke motion with the cannula. Nevertheless, once the anterior capsule is punctured using a cystotome blade, the stark contrast between the stained capsule and cataract makes the leading edge of the capsulorhexis clearly visible.

Overall, there are several limitations to our study. Due to our selective inclusion criteria, our population size is small and may not accurately reflect the true complication rates. Also, all cataract surgery was performed by a single, experienced surgeon. A prospective study, including a broader range of surgeon experience, may be needed to validate our findings.

Conclusion

Dense, mature cataracts and small pupils both compromise the view for the surgeon and may be significant risk factors for PCR in training ophthalmologists. In order to improve capsular visibility while minimizing complications, we developed a simple, standardized technique which facilitates the creation of a capsulorhexis in patients with pupillary miosis and dense cataracts. The technique incorporates a pupil expansile ring and capsular staining under both air and dispersive viscoelastic. Our method may also be beneficial for experienced surgeons performing cataract surgery with patients exhibiting several high-risk factors such as white mature/deep brunescant cataracts and miosis associated with IFIS or a history of dementia. IFIS has been associated with a high rate of complications, which has significantly been mitigated with better identification of high-risk patients and presurgical planning. Our technique, using a Malyugin ring along with cohesive OVD, stabilizes the iris and provides consistent dilation throughout the course of the case, minimizing complications in our study. Lastly, dementia is a strong independent risk factor for intraoperative complications which may be

exacerbated in longer, more complex cases. We feel our technique along with an additional single, low dose IV sedation of ketamine, fentanyl, and versed are beneficial in creating a calmer, more cooperative patient.

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Disclosure

The authors report no conflicts of interest in this work.

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