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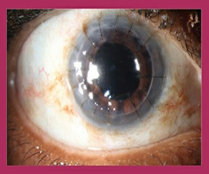
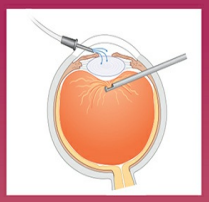
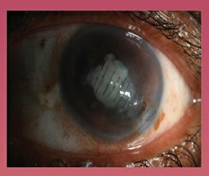
DUKE MANUALS OF OPHTHALMIC SURGERY

The Duke Manual of Corneal and Cataract Surgery







Nandini Venkateswaran, MD
Preeya Gupta, MD

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The Duke Manual of Corneal and Cataract Surgery

Preeya K. Gupta, MD

Associate Professor of Ophthalmology
Duke University School of Medicine
Durham, North Carolina

Nandini Venkateswaran, MD

Cataract, Cornea and Refractive Surgeon
Massachusetts Eye and Ear Infirmary
Waltham, Massachusetts
Instructor in Clinical Ophthalmology
Harvard Medical School
Boston, Massachusetts

Philadelphia • Baltimore • New York • London
Buenos Aires • Hong Kong • Sydney • Tokyo

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Preface

The art of corneal, cataract, and refractive surgery can take years to master. The variety of surgical procedures and techniques and the nuances of each can seem overwhelming to the training surgeon. In this manual, we have distilled the key aspects of various complex cataract, corneal, and refractive surgical procedures in a step-by-step manner that is easy to follow. We want this manual to be a go-to reference for training surgeons as they choose patients for surgery and mentally prepare for their surgical cases.

We have been fortunate to have many graduates of the Duke Eye Center Cornea and Refractive Fellowship program, current Duke Eye Center Cornea Service faculty members, and current Duke Eye Center cornea fellows contribute wonderful chapters to this manual. The wealth of information this book provides is unparalleled, and we hope that all readers find *The Duke Manual for Corneal and Cataract Surgery* to be an invaluable resource.

Enjoy!

Nandini Venkateswaran, MD
Preeya K. Gupta, MD

Series Foreword

When you need to know how to approach a case that you may not commonly take care of, want to review how to approach a white cataract, or even what to do next in the operating room when tackling a particularly challenging case, look no further. The answer lies in the pages of *The Duke Manual of Corneal and Cataract Surgery*, edited by Dr. Preeya Gupta and Dr. Nandini Venkateswaran. In one handy reference book such as this, you are able to explore reliable methods and techniques outlined by some of the most accomplished and competent ophthalmic surgeons, the majority of whom specialize in corneal and cataract surgery, in the United States in order to achieve your surgical goals. At the Duke Eye Center, we decided that not only should we share cornea and cataract surgical pearls in *The Duke Manual*, but also put into print some of the tips and tricks relied on in the operating room by some of the many other Duke Eye faculty in the various ophthalmic subspecialties through *The Duke Manuals of Ophthalmic Surgery* series. The intent of *The Duke Manuals* is not to circumvent traditional ophthalmic surgical training or create a substitute for the tried-and-true path to becoming a competent and skilled ophthalmic surgeon, but instead to provide the student, resident, fellow, or practicing physician with a review of the important factual and practical aspects of performing the different ophthalmic surgical procedures, step by step. *The Duke Manuals* series is also an invaluable resource for the surgical assistant as well as the operating room nurse as they prepare for the surgical case and anticipate the surgeon's next move. As the Series Editor of *The Duke Manuals*, it has been especially rewarding to collaborate with many outstanding individuals in the profession of ophthalmology across the

country who contributed to the series. All editors and authors have either trained at Duke or trained others as faculty at Duke. This series represents countless hours of involvement and work by so many busy surgeons; it could not have come together without their dedication to sharing their knowledge with all of you. It is our hope that *The Duke Manuals* series will serve as an excellent resource and valuable reference for students, residents, fellows, and practicing surgeons alike.

Sharon Fekrat, MD, FACS Series Editor

Contents

Contributors

Balamurali Ambati, MD, PhD
Cataract, Cornea and Refractive Surgeon,
Pacific Clear Vision Institute,
Eugene, Oregon

Brad P. Barnett, MD, PhD
Anterior Segment Surgeon,
NVISION Eye Center,
Sacramento, California

Sayan Basu, MBBS, MS
Director
Hyderabad Eye Research Foundation
LV Prasad Eye Institute
Hyderabad, India
Consultant Ophthalmologist
The Cornea Institute
LV Prasad Eye Institute
Hyderabad, India

Paramjit K. Bhullar, MD
Resident
Department of Ophthalmology
Duke University School of Medicine
Durham, North Carolina

Christopher S. Boelkhe, MD
Assistant Professor
Department of Ophthalmology
Duke University,
Durham, North Carolina

Lucas Bonafede, MD
Fellow
Department of Pediatric Ophthalmology and Strabismus
Duke Eye Center
Durham, North Carolina

Gordon T. Brown, MBChB, MPH
Honorary Clinical Lecturer
School of Medicine, Dentistry and Nursing
University of Glasgow
Glasgow, Scotland
Clinical Fellow
Department of Ophthalmology

University Hospital Ayr
Scotland, United Kingdom

Mattew Caldwell, MD
Assistant Professor
Department of Surgery
Uniformed Services University of the Health Sciences
Bethesda, Maryland
Chair, Department of Ophthalmology
Wilford Hall Eye Center
JBSA Lackland, Texas

Mona L. Camacci, MD, MS
Resident Physician
Department of Ophthalmology
Penn State Health Milton S. Hershey Medical Center
Hershey, Pennsylvania

Clara C. Chan, MD, FRCSC, FACS
Assistant Professor
Department of Ophthalmology and Vision Sciences
University of Toronto
Toronto, Ontario, Canada
Department of Ophthalmology
Toronto Western Hospital and St. Michael's Hospital
Toronto, Ontario, Canada

Melissa B. Daluvoy, MD
Assistant Professor
Department of Ophthalmology
Duke University
Durham, North Carolina

Andrew Rollin Davis, MD
Associate
Department of Ophthalmology
Medical Center Ophthalmology Associates
San Antonio, Texas

John J. DeStafeno, MD
Partner, Director of Cataract Service
Chester County Eye Associates
West Chester, Pennsylvania

Clayton L. Falknor, MD
Eye Associates of Colorado Springs, P.C.
Colorado Springs, Colorado

Brenton D. Finklea, MD

Assistant Professor
Department of Ophthalamology
Sidney Kimmel Medical College
Philadelphia, Pennsylvania
Attending Surgeon
Cornea Service
Wills Eye Hospital
Philadelphia, Pennsylvania

Garnett S. Frank, MD
Cornea, Cataract and Refractive Surgeon
Colorado Ophthalmology Associates
Denver, Colorado

Nicole Fuerst, MD
Vice President
Department of Ophthalmology
Fuerst Eye Center
Los Angeles, California

Mark Frank Goerlitz-Jessen, MD
Cornea Fellow
Minnesota Eye Consultants
Bloomington, Minnesota

Karen E. Grove, MD
Partner Physician
Orian Eye Center
Bend, Oregon

Abhilash Guduru, MD
Resident
Department of Ophthalmology
Duke University
Durham, North Carolina

Christopher W. Heichel, MD, FACS
Clinical Professor
Shiley Eye Institute
University of California San Diego
San Diego, California

Amber Hoang, MD
Cornea, Refractive & External Disease Fellow
Department of Ophthalmology
Duke University Medical Center
Durham, North Carolina

Carol L. Karp, MD

Professor
Department of Ophthalmology
Bascom Palmer Eye Institute
Miami, Florida

Wei Boon Khor, MBBS, FRCSEd, FAMS
Clinical Assistant Professor
Department of Ophthalmology & Visual Sciences Academic Clinical Program
Duke-NUS Graduate Medical School
Singapore
Senior Consultant
Clinical Assistant Professor
Cornea and External Eye Disease Department
Singapore National Eye Centre
Singapore

Jeehee Kim, MD
Polaris Eye & Laser, Inc.
Los Gatos, California

Michelle J. Kim, MD
Associate
Department of Ophthalmology
Kaiser Permanente
Irwindale, California

Terry Kim, MD
Chief, Cornea and Refractive Surgery Division
Professor
Department of Ophthalmology
Duke University Eye Center
Durham, North Carolina

Kyle Kirkland, DO
, Cornea, Refractive & External Disease Fellow
Department of Ophthalmology
Duke University Medical Center
Durham, North Carolina

Narae Ko, MD
Assistant Professor
Department of Ophthalmology
Tufts University School of Medicine
Boston, Massachusetts
Assistant Professor
Department of Ophthalmology
New England Eye Center/Tufts Medical Center
Boston, Massachusetts

Anthony N. Kuo, MD
Associate Professor
Department of Ophthalmology
Duke University School of Medicine
Durham, North Carolina

Gary L. Legault, MD
Assistant Professor
Department of Surgery
Uniformed Services University
Bethesda, Maryland
Residency Program Director
Department of Ophthalmology
Wilford Hall Eye Center
San Antonio, Texas

Wonchon Lin, MD
Clinical Assistant Professor
Department of Surgery
UNLV School of Medicine
Las Vegas, Nevada
Medical Director
Department of Ophthalmology
Westwood Eye
Las Vegas, Nevada

Austin R. Meeker, MD
Cornea, External Disease and Refractive Surgery Fellow
Department of Ophthalmology
Duke University Hospital
Durham, North Carolina

Jay J. Meyer, MD, MPH
Senior Lecturer
Department of Ophthalmology
University of Auckland
Auckland, New Zealand
Senior Medical Officer
Department of Ophthalmology
Greenlane Clinical Center
Auckland, New Zealand

Ashiyana Nairani, MD, MPH
Assistant Professor
Department of Ophthalmology
King Edward Memorial Hospital
Mumbai, India

Sanjay V. Patel, MD, FRCOphth

Professor & Emeritus Chair of Ophthalmology
Department of Ophthalmology
Mayo Clinic,
Rochester, Minnesota

Victor L. Perez, MD
Professor
Department of Ophthalmology
Duke University
Durham, North Carolina
Director Foster Center for Ocular Immunology
Ophthalmology
Duke Eye Center at Duke University
Durham, North Carolina

Kristen Marie Peterson, MD
Ocular Immunology Comprehensive Ophthalmologist
Department of Ophthalmology
Birmingham, Alabama
Active Staff
Department of Ophthalmology
Callahan Eye Hospital (UAB)
Birmingham, Alabama

Terry M. Semchyshyn, MD
Assistant Professor
Department of Ophthalmology
Duke University
Durham, North Carolina

Brian M. Shafer, MD
Cornea, Refractive, Glaucoma and Cataract Fellow
Cornea, Refractive, Glaucoma, and Cataract
Vance Thompson Vision
Sioux Falls, South Dakota

Matias Soifer, MD
Ocular Immunology Fellow
Foster Center for Ocular Immunology
Duke University Eye Center
Durham, North Carolina

Christine Shieh, MD
Assistant Professor
Department of Ophthalmology
Vanderbilt Eye Institute
Nashville, Tennessee

Mark A. Terry, MD

Professor of Clinical Ophthalmology
Department of Ophthalmology
Oregon Health Services University
Portland, Oregon
Director, Corneal Services
Department of Ophthalmology
Devers Eye Institute
Portland, Oregon

Patrick C. Tso, MD
Senior Physician
Department of Ophthalmology
Kaiser Permanente Medical Center
Fremont, California

Robin R. Vann, MD
Associate Professor
Department of Ophthalmology
Duke University
Durham, North Carolina
Medical Director of Duke Operating Rooms
Department of Ophthalmology
Duke University
Durham, North Carolina

Gargi K. Vora, MD
Assistant Professor
Department of Ophthalmology
Penn State Hershey Medical Center
Hershey, Pennsylvania

Lloyd B. Williams, MD, PhD
Assistant Professor
Department of Ophthalmology
Duke University
Durham, North Carolina

List of Abbreviations

5-FU 5 fluorouracil
ABMD anterior basement membrane dystrophy
AC anterior chamber
ACD anterior chamber depth
ACIOL anterior chamber intraocular lens
AL axial length
AMG amniotic membrane graft
ARMD age-related macular degeneration
AS-OCT anterior segment optical coherence tomography
ATR against the rule
BID two times daily
BSS balanced salt solution
CCC continuous curvilinear capsulorrhexis
CDE cumulative dissipated energy
CE cataract extraction
CLAL conjunctival limbal allograft
CLAU conjunctival limbal autograft
CME cystoid macular edema
CT computed tomography
CTR capsular tension ring
CTS capsular tension segment
CXL corneal crosslinking
D diopter
DALK deep anterior lamellar keratoplasty
DLK diffuse lamellar keratitis
DM Descemet membrane
DMD Descemet membrane detachment

DMEK Descemet membrane endothelial keratoplasty
DSA donor-specific antibodies
DSAEK Descemet stripping automated endothelial keratoplasty
DTP death to preservative time
EBAA Eye Bank Association of America
ECCE extracapsular cataract extraction
EDOF extended depth of focus
EK endothelial keratoplasty
ELP estimated lens position
ERM epiretinal membrane
ERSS ectasia risk score system
FDA Food and Drug Administration
FD-OCT Fourier domain optical coherence tomography
FLACS femtosecond laser-assisted cataract surgery
G gauge
hAM human amniotic membrane
HIV human immunodeficiency virus
HLA human leukocyte antigen
HM hand motions
HOA higher order aberration
HR-OCT high-resolution optical coherence tomography
IAC irrigation-aspiration-cut
ICA irrigation-cut-aspiration
ICCE intracapsular cataract extraction
ICL implantable collamer lens
IFIS intraoperative floppy iris syndrome
IFN interferon
IOL intraocular lens
IOP intraocular pressure
K keratometry
KLAL keratolimbal allograft
LASEK laser epithelial keratomileusis
LASIK laser-assisted in situ keratomileusis
LP light perception
LPI laser peripheral iridotomy

Lr-CLAL living related conjunctival limbal allograft
LRI limbal relaxing incisions
LSCT limbal stem cell transplant
LT lens thickness
MfIOL multifocal intraocular lens
mg milligram
mL milliliter
mm Hg millimeters of mercury
mm millimeter
MMC mitomycin C
MMP-9 matrix metalloproteinase 9
MRI magnetic resonance imaging
MRSA methicillin-resistant ***Staphylococcus*** *aureus*
MRSE manifest refraction spherical equivalent
MSICS manual small incision cataract surgery
MST microsurgical technology
MVR microvitreoretinal
mW milliwatts
NSAID nonsteroidal anti-inflammatory drug
OCT ocular coherence tomography
OR operating room
OSSN ocular surface squamous neoplasia
OVD ophthalmic viscosurgical device
PAS peripheral anterior synechiae
PCO posterior capsular opacification
PCR posterior capsular rupture
PET positron emission tomography
PI patient interface
PISK pressure-induced stromal keratopathy
PKP penetrating keratoplasty
PMMA polymethyl methacrylate
PRK photorefractive keratectomy
PTA percent tissue altered
PTK phototherapeutic keratectomy
Q1H every 1 hour

Q2H every 2 hours
QID four times daily
RGP rigid gas permeable
RK radial keratotomy
RSB residual stromal bed
SF6 sulfur hexafluoride 6 gas
SI systemic immunosuppression
SLET simple limbal epithelial transplant
SMILE small incision lenticule extraction
TASS toxic anterior segment syndrome
TBUT tear break-up time
UBM ultrasound biomicroscopy
UHR-OCT ultra high-resolution optical coherence tomography
VEGF vascular endothelial growth factor
WBC white blood cell
WTR with the rule
WTW white to white

Section 1

Just the Basics

CHAPTER 1

Phacodynamics: The Highlights

Wei Boon Khor, MBBS, FRCSEd, FAMS

Popularized by Dr Barry Seibel,[1] "Phacodynamics" refers to the physics involved in phacoemulsification; understanding the interaction of **fluidics** and the generation of "**phaco**" (ultrasound) energy makes us better, safer, and more thoughtful surgeons.

FLUIDICS

- Basic idea: there is a need to balance the **inflow** and **outflow** of BSS in the AC to maintain a stable, pressurized chamber during phacoemulsification.

Inflow

- Inflow is entirely from the **irrigation** of BSS and is activated by position 1 on the foot pedal or set as a continuous irrigation.
- BSS flows into the AC passively through gravity (eg, infusion bottle on a drip stand) or owing to an active driving force (eg, gas infusion, pressure plates).
- The **purpose of irrigation** is to maintain AC stability during surgery.
- **If inflow < outflow**, there is shallowing of the AC, bouncing of the posterior capsule (PC) toward the phaco probe, and risk of tissue damage and PCR.
- **If inflow > outflow**, there is marked deepening of the AC, which can make phaco surgery more difficult (as there is a need to angle instruments deeper into the AC), and more zonular stress is

induced.

- Raising the bottle height results in greater BSS flow into the AC, thus deepening it; the converse happens when the bottle height is lowered.

Outflow

- Outflow is mainly through **aspiration** of BSS and is activated by position 2 on the foot pedal.
- A variable amount is also lost through leakage from the phaco incisions.
- Fluid is actively pumped out of the AC by the phaco machine; the **aspiration flow rate** is measured in mL/min (volume in milliliters removed per minute).
- The **purpose of aspiration** is to draw fluid into the phaco probe, which also serves to "attract" cataract fragments to the tip for phacoemulsification. The flow of fluid also helps cool and dissipate the energy generated at the phaco tip.
- There are two major ways to pump fluid out of the eye; with a **flow** pump or a **vacuum** pump.

PUMPS

- Basic idea: different types of pumps generate vacuum by different mechanisms; understanding this allows one to understand why different machines react differently during surgery.
- **Purpose of generating vacuum**: apart from aspirating fluid, it also holds the cataract fragment at the phaco tip for phacoemulsification (the "holding power").
- There are two main types of outflow pumps:

- Flow pumps: for example, **peristaltic** pump (Fig. 1.1)
    - Flow and vacuum are created when a flexible aspiration tubing is compressed by spinning rollers; the spinning of the rollers "milks" the fluid along, driving it through the tube and into a soft bag; the faster the rollers spin, the higher the aspiration flow rate.
- Vacuum pumps: for example, **Venturi** pump (Fig. 1.2)
    - Pressurized gas (eg, nitrogen) flowing with high velocity but low pressure over an aperture generates vacuum, which in turns draws fluid from the aspiration tubing into a rigid cartridge/cassette; the faster the gas flow, the greater the vacuum generated.
- Differences between the two pumps (Table 1.1)
    - **Peristaltic** pumps generate the maximum vacuum **only when the phaco tip is occluded**; there is a delay (the "rise time") between time of occlusion and when the maximum vacuum is reached.
    - When the phaco tip is not occluded, the vacuum is low and cataract fragments do not come as easily to the phaco tip (but neither does the iris or PC).
    - A surgeon can both control the aspiration flow rate and set the maximum amount of vacuum generated when the phaco tip is occluded.
        - Increasing the flow rate moves more fluid through the AC; irrigation needs to match this and events tend to occur **faster**; conversely if you want to go low and **slow**, reduce the aspiration flow rate.
    - **Venturi** pumps **generate vacuum even without occlusion**; the level of vacuum is directly controlled by the amount of foot pedal depression.

- The surgeon can only set the maximum vacuum on a Venturi pump, there is no independent control of flow; the flow varies with the level of vacuum generated.
- Venturi pumps tend to attract and hold cataract fragments to the phaco probe more readily; less moving of the tip to "chase" fragments.
    - Maximum vacuum is reached near instantaneously with occlusion, which can increase the risk of accidently attracting and holding the iris or PC.

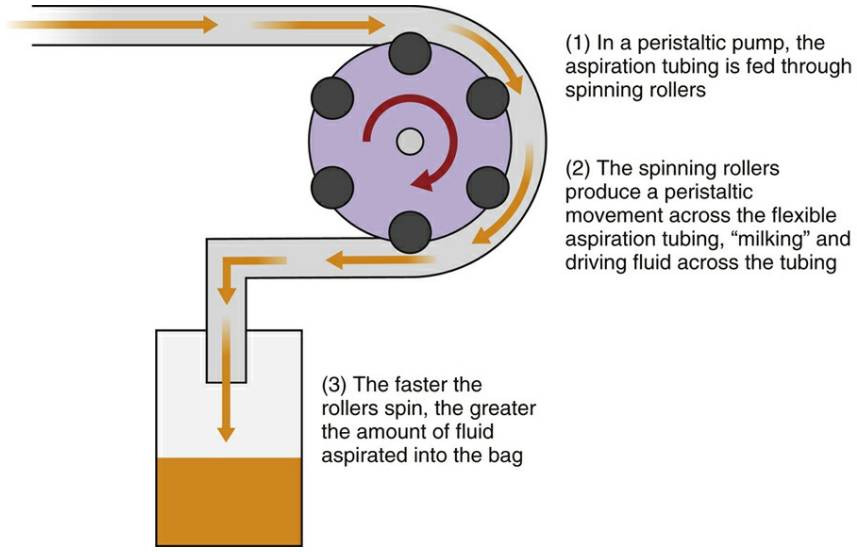

FIGURE 1.1 Diagram of a peristaltic pump. Fluid is pumped out of the eye via a flexible aspiration tubing fed through spinning rollers; the spinning of the rollers "milks" the fluid along, driving it through the tubing and into a soft bag.

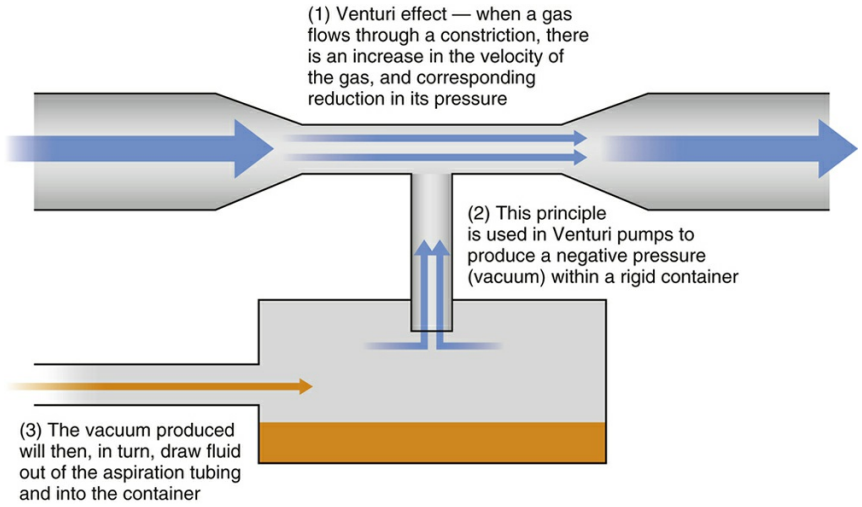

FIGURE 1.1 Diagram of a Venturi pump. Venturi effect: when a fluid/gas flows through a constriction, there is an increase in velocity and corresponding reduction in pressure. This principle is used in Venturi pumps to produce a negative pressure ("vacuum") that in turn draws on a second fluid; in this case, BSS is drawn out of the aspiration tubing and into a rigid container.

TABLE 1.1 Differences Between Peristaltic and Venturi Pumps

Peristaltic Pump	Venturi Pump
Flow-based pump	Vacuum-based pump
Flow is constant and under direct surgeon control	Flow varies with the vacuum created; there is no independent control
Maximum vacuum is generated with full occlusion of the phaco tip	Vacuum is created continuously regardless of phaco tip occlusion
There is a set interval (rise time) before maximum vacuum is achieved	Maximum vacuum is achieved instantaneously

SURGE

- Surge occurs when there is rapid influx of fluid through the phaco tip when occlusion is cleared (**occlusion break**), resulting in an abrupt shallowing of the AC and anterior movement of the PC.
    - It is more apparent when the aspiration tubing is very compliant, as the high vacuum built up during occlusion can cause the tubing to collapse on itself; with

occlusion break, the tubing bounces back to the original diameter, which results in extra fluid aspiration.

- Surge is mitigated by increasing irrigation (eg, bottle height), reducing the aspiration flow rate and vacuum; phaco machines also use less compliant tubing and new technologies to prevent surge.

PHACOEMULSIFICATION (ULTRASOUND ENERGY)

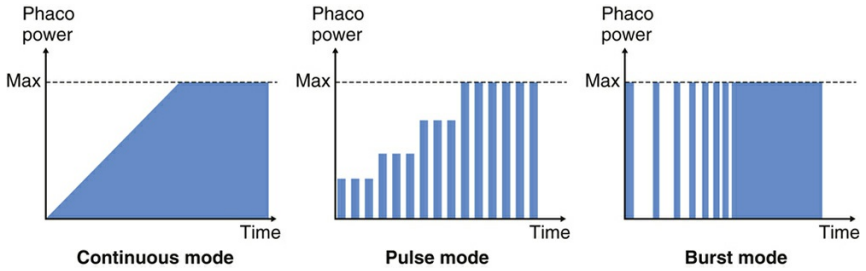

FIGURE 1.3 Diagrams representing different phaco power modulations. The x-axis represents the relative amount of time that phaco power is switched on; the y-axis represents the amount of phaco power generated as the foot pedal is progressively depressed on position 3. (For more detailed explanation on power modulations, please refer to the references.)

- Basic idea: use the least amount of phaco energy to emulsify the cataract efficiently, while minimizing the side effects of excessive heat production (eg, cornea wound burns, endothelial damage).
- Piezoelectric crystals in the phaco handpiece generate ultrahigh-frequency oscillations of the phaco tip, which is activated by position 3 on the foot pedal.
  - The ability of the phaco tip to break up the cataract is due to multiple factors:
    - **Oscillation frequency**, typically in the range of 28 to 45 kHz (thousands of cycles a second).
    - **Stroke length**, ie, the amount of **longitudinal** to-and-fro excursion of the phaco tip; the greater the stroke length, the greater the power generated;

100% phaco power = maximal stroke length.

- However, the longitudinal movement of the phaco tip also repulses cataract fragments away ("chatter").
- Newer phaco tips can also oscillate side to side (eg, **"torsional"** phaco), which can improve efficiency and holding power.

- The phaco tip emulsifies the cataract through a combination of a "**jackhammer**" mechanical striking of the cataract + "**cavitation**" effect, where the rapid to-and-fro oscillations of the phaco tip alternately creates and compresses cavitation microbubbles that implode, generating intense heat and pressure waves (but within a minute range).
- Phaco delivery can be **modulated** [2] so that phaco power is not delivered continuously but in cycles where phaco power is switched on and off.
  - Examples of **power modulations** include **pulse** and **burst** modes (Fig. 1.3).
  - Periods when there is no phaco power allows time for vacuum to aspirate the emulsate and heat to dissipate and improves holding power and followability.

FOLLOWABILITY

- It is the ability of the phaco tip to attract cataract fragments.
- Balancing the aspiration flow rate (to attract the fragment), the vacuum (to hold the fragment), and phaco power (to minimize repulsion during phacoemulsification) enhances followability.

References

1. Seibel BS. *Phacodynamics*: Mastering the Tools and Techniques of Phacoemulsification Surgery. 4th ed. SLACK, Incorporated; 2004.
2. Phacodynamics, on EyeWiki. Accessed January 12, 2021. https://eyewiki.aao.org/Phacodynamics

CHAPTER 2

Phacoemulsification Machine Settings

John J. DeStafeno, MD Brian M. Shafer, MD

Significant variability exists among the different types of phacoemulsification machines. By utilizing basic phacodynamic principles, the surgeon can adjust settings to match the specific needs of a given clinical scenario.

PHACODYNAMIC PRINCIPLES

These four factors must be adjusted throughout each case to facilitate safe, effective, and efficient removal of the lens.[1]

- Power (%)—the energy used to break up the lens.
- Aspiration flow rate (mL/min)—how quickly lens pieces come to the tip.
- Vacuum (mm Hg)—how strongly the pieces are held by the occluded tip.
- Bottle height (cm)—determines the IOP based on the infusion gradient.

THE FOOT PEDAL

The foot pedal (Fig. 2.1) controls all of the settings of the phacoemulsification machine. While engaging further through

positions 2 and 3, the flow rate, vacuum, and phaco energy are incrementally adjusted.

Position 1: Irrigation only.

Position 2: Irrigation and Aspiration.

Position 3: Irrigation, Aspiration, and Phaco Power.

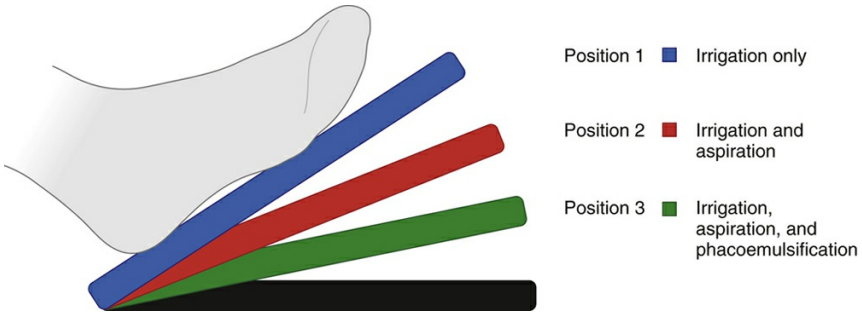

FIGURE 2.1 **Foot pedal positions for phacoemulsification.**

CATARACT REMOVAL

The specific parameter values listed below are based on the Alcon Centurion phaco machine. These values are meant to serve as a guide but may not apply to your phaco machine and/or handpiece.[2]

Sculpting

Goal: To emulsify nuclear material without generating occlusion to prevent grasping and displacing the lens while creating a central groove.

- Power—High (*45% to 55%*)
- Flow rate—Low (*20 to 25 mL/min*)
- Vacuum—Very low (*120 to 135 mm Hg*)
- Bottle height—Moderate (*70 to 80 cm*)

Chopping

Goal: To impale nuclear material and generate occlusion to maintain a tight grasp to allow for effective chopping.

- Power—High (*45% to 55%*)
- Flow rate—Moderate (*35 to 40 mL/min*)
- Vacuum—High (*400 to 500 mm Hg*)
- Bottle height—Moderate to high (*75 to 100 cm*)

Quadrant Removal

Goal: To generate occlusion with high vacuum to tightly grip nuclear material and emulsify it after it has been chopped or separated.

- Power—High (*60% to 70%*)
- Flow rate—Moderate to high (*35 to 45 mL/min*)
- Vacuum—High (*500 to 600 mm Hg*)
- Bottle height—High (*80 to 90 cm*)

Epinucleus

Goal: To generate occlusion and use primarily vacuum to remove the epinuclear shell but with a lower flow rate in order to avoid aspirating the posterior capsule.

- Power—Low (*30% to 45%*)
- Flow rate—Low (*30 to 40 mL/min*)
- Vacuum—Moderate (*300 to 400 mm Hg*)
- Bottle height—Moderate to high (*75 to 90 cm*)

Cortex Removal

Goal: To use high vacuum to strip cortex from the capsule without

using any phaco energy.

- Power—None
- Flow rate—Moderate (*35 to 45 mL/min*)
- Vacuum—High (*550 to 650 mm Hg*)
- Bottle height—Moderate (*65 to 75 cm*)

Capsular Polish

Goal: To gently remove small bits of lens material adherent to the posterior capsule.

- Power—None
- Flow rate—Very Low (*5 to 10 mL/min*)
- Vacuum—Very low (*8 to 12 mm Hg*)
- Bottle height—Moderate (*65 to 75 cm*)

Viscoelastic Removal

Goal: To generate significant currents through the anterior segment to mobilize and remove all remaining viscoelastic.

- Power—None
- Flow rate—High (*40 to 45 mL/min*)
- Vacuum—High (*700+ mm Hg*)
- Bottle height—Low to moderate (*60 to 75 cm*)

If you are experiencing too much chatter, decrease phaco power and increase vacuum.[3]

References

1. Seibel BS. *Phacodynamics*: Mastering the Tools and Techniques of Cataract Surgery. 3rd ed. Slack; 1999.
2. Devgan U. Phaco fluidics and phaco ultrasound power modulations. *Ophthalmol Clin North Am*. 2006;19(4):457-468.
3. Yow L, Basti S. Physical and mechanical principles of phacoemulsification and their clinical relevance. *Indian J Ophthalmol*. 1997;45:241-249.

Section 2

Cataract Removal

CHAPTER 3

Soft Cataract Removal Techniques

Jay J. Meyer, MD, MPH

PREOPERATIVE CONSIDERATIONS

Increasing visual demands and improvements in IOL designs for treatment of presbyopia have resulted in more patients presenting at earlier stages for lens replacement surgery. Removal of a soft lens can sometimes be more challenging than removing a more mature lens that is "brittle" and easily fractured into smaller pieces. These challenges include rotating and fracturing the nucleus, difficulty occluding the phaco tip and holding lens material, and a tendency for the phaco tip to rapidly core through the lens.

SURGICAL PLANNING

It is important to adjust your phacoemulsification settings and/or technique for these cases. Consider working with your phaco machine representative to include a "soft" cataract setting. Although the density of a lens can be judged preoperatively, the choice for the exact technique may need to be made intraoperatively based on the nuclear density.

SURGICAL PROCEDURE

Capsulorhexis

Avoid making the capsulorhexis too small as this can make it more

difficult to prolapse the lens out of the capsular bag (see below). However, ideally, it should still be small enough to overlap the IOL optic 360 degrees.

Hydrodissection

Complete hydrodissection is beneficial in these cases, especially for in-the-bag removal techniques that require rotation of the lens. Hydrodissection with fluid waves in multiple quadrants is recommended to ensure mobility of the lens. Cortical cleaving hydrodissection also makes later cortex removal easier as the cortex may be thicker and more adherent to the capsule in younger eyes with a less mature lens.

Hydrodelineation

This can provide visualization and separation of the nucleus from the epinucleus for easier stepwise removal.

Nucleus Removal

- **With Nucleus Disassembly/Fragmentation.** These techniques are most helpful for removal of soft lenses that are mature enough that they can still be fractured. For lenses too soft for fragmentation, or if difficulty is encountered during disassembly, see part B, below. There are many techniques for fragmentation and disassembly of the nucleus, including use of mechanical force (chop or prechop), phacoemulsification (sculpting/grooving), laser energy (femtosecond laser assisted), or a combination of these methods. For most surgeons, use of their standard technique with some modifications can often be employed.
    - *Chop.* A “prechopper” instrument can be used to quickly separate a lens into segments that can subsequently be removed with the phacoemulsification probe. As different designs of prechoppers are available, it is worth considering one that is designed for soft cataracts (Video 3.1).

Alternatively, a horizontal or vertical chopper can be used in combination with the phacoemulsification probe to fragment the nucleus. If impaling the nucleus with the phaco tip, care must be taken to not impale too deeply or aspirate too much lens material. Alternatively, chopping can be performed without impaling by simply holding the phaco tip against the nucleus to provide countertraction for the chopper.

- *Phacoemulsification.* The traditional “divide and conquer” technique can remove much of the nuclear material, making it difficult to crack the grooves without the lens turning into a “bowl” or “mush.” So, if using a sculpting technique, it may be easier to sculpt one narrow groove, separate the two heminuclei, and remove each heminucleus without further disassembly. It is valuable to adjust the “sculpt” setting by reducing the phaco power and aspiration to decrease the chances of phacoemulsification through the entire lens and into the posterior capsule.

- *Laser.* A femtosecond laser can also be used to perform a capsulorhexis of ideal size and to fragment the lens. These fragments can then be removed using the phacoemulsification probe as above but may need to be further separated with a prechopper or another instrument.

- **Without Nucleus Disassembly/Fragmentation.** These techniques work particularly well for lenses that are too soft to be easily fragmented using standard techniques. Two main techniques exist, in-the-bag removal and supracapsular removal.

    - *In-the-Bag Removal.* Following hydrodissection and hydrodelineation, the nucleus can be removed *en bloc* with the phaco probe using mostly aspiration (Video 3.2). The epinucleus and cortex can then be removed in standard fashion within the capsular bag using the irrigation/aspiration (I/A) probe. Extremely soft lenses may be removed entirely using the I/A probe. This can be performed using either a

unipolar or bimanual handpiece. The bimanual technique may provide an added measure of safety by allowing the surgeon to place the irrigation tip between the lens and the capsule (once that plane has been established), while the aspiration tip aspirates the lens. If difficulty is encountered at any stage, consider moving to the supracapsular technique, below.

- *Supracapsular Removal. This is my preferred technique for very soft lenses.* This technique involves hydrodissection of the lens until the lens is partially or completely prolapsed out of the capsular bag (hydroprolapsed) (Video 3.3). Should there be incomplete or temporary prolapse of the lens from the capsular bag, viscoelastic can be used to viscoprolapse the lens from the capsule prior to emulsification/aspiration. Once the lens is tilted out of the bag or completely prolapsed into the anterior chamber, it can be removed using gentle phacoemulsification or aspiration at the iris plane or in the anterior chamber. When using the phaco probe, the settings can be adjusted to lower the phaco power. Alternatively, an "epinucleus" setting can often be used to more safely remove both the nucleus and epinucleus.

Epinucleus Removal

The epinuclear shell can be removed with the phaco probe using aspiration only or with minimal phaco power. If the epinucleus is within the capsular bag, the I/A probe can be used to strip away the cortex in multiple quadrants until the epinucleus in more centrally located and can be easily aspirated. Alternatively, the epinucleus can be hydro- or viscoprolapsed into the anterior chamber for removal.

Cortex Removal

It is prudent to aim for complete cortical removal because these patients are often young, leaving many years for any remaining lens epithelial cells to proliferate.

CHAPTER 4

Dense Cataract Removal Techniques

Gordon T. Brown, MBChB, MPH, Balamurali Ambati, MD, PhD, MBA

PREOPERATIVE CONSIDERATIONS

- Particular preoperative considerations arise when the surgeon is presented with a dense cataract, which makes surgery more complex and higher risk:
    - Eyes with mature cataracts may have other ocular comorbidities: eg, glaucoma, weak zonules, pseudoexfoliation syndrome, or retinal pathology.
    - Systemic past medical history may offer clues to underlying etiology or contributing factors such as diabetes, previous trauma, or radiation therapy.
- Counsel the patient regarding additional risk profile and potential for further surgeries.

Examination

- Is corneal pathology present, eg, guttae or epithelial bullae suggestive of Fuch endothelial dystrophy?
- Is there evidence of zonular weakness? Check for iridodonesis, phacodonesis, or vitreous in the AC, especially if there is a history of prior ocular trauma.
- Is the AC shallow due to increased dimensions of the dense lens?

This can be assessed on slit-lamp examination and can also be checked using biometry.

- Are there coexisting conditions or prior surgeries that may complicate surgery or recovery? For example, prior pars plana vitrectomy or trabeculectomy.
- It may be difficult or impossible to perform indirect ophthalmoscopy, optical coherence tomography, or biometry due to the degree of lens opacity. In such cases, B-scan ultrasonography should be performed for gross assessment of the retina to assess for pathology such as a vitreous hemorrhage, retinal detachment, or intraocular foreign body or tumor, and A-scan should be performed to determine axial length.

Surgical Planning

- If possible, treat coexisting conditions preoperatively (eg, additional oral and/or topical steroids in eyes with a history of uveitis).
- Establish if patient is taking any medications (eg, Flomax) that could impact surgery.
- Surgeries can likely take longer than a routine case, so consider most suitable anesthesia (eg, supplement topical anesthesia with intracameral agents or administer sub-Tenon, peribulbar, or retrobulbar blocks).
- Ensure the patient is able to comfortably lie flat for an extended period of time (eg, 30 minutes or longer).
- Consider administration of intravenous mannitol preoperatively to desiccate the vitreous in an eye with a shallow AC and raised intraocular pressure.[1]
- Use Trypan blue to stain the anterior capsule to facilitate creation of a continuous curvilinear capsulorhexis.

- Is the pupil small (poor dilation or presence of posterior synechiae) or is there a high risk for intraoperative floppy iris syndrome? Consider intracameral mydriatic agents or pupil expansion devices, such as a Malyugin ring or iris hooks.
- Is there possible zonulopathy? Are a capsular tension ring or Mackool capsular support hooks required for capsular support?
- If the cataract looks too dense for phacoemulsification, be prepared to employ an alternative surgical plan to offer the best surgical outcome, for example,
    - ECCE or manual small-incision cataract surgery.
    - Lensectomy and placement of ACIOL or scleral fixation of the IOL.

SOFT-SHELL SURGICAL TECHNIQUE

Protecting the corneal endothelium is of paramount importance in these complex cases. Various "soft-shell" techniques have been described that utilize the physical properties of different OVDs to create and maintain distinct spaces within the AC.[2, 3]

In principle, the key steps are outlined below:

- Following creation of the phaco incision and/or following hydrodissection, dispersive OVD (eg, Viscoat, EndoCoat) is injected over the surface of the anterior capsule.
- A viscocohesive (eg, Healon GV, ProVisc) or viscoadaptive (eg, Healon 5) OVD is then injected underneath the dispersive OVD on the surface of the anterior capsule, thereby buffering the dispersive OVD up toward the cornea and forming a protective layer under the endothelium, while leaving a central shell of more cohesive OVD in the AC. Injection of this cohesive or adaptive OVD should continue until the pupil stops dilating but before the eye becomes firm.

- More recent variants of the original soft-shell surgical technique (SST) (eg, ultimate soft-shell technique [USST], tri-soft shell technique [TSST], or soft-shell bridge [SSB]) may also recommend injection of BSS to create a third "low-viscosity" space underneath the chosen cohesive or adaptive OVD.
- Trypan blue should be used to stain anterior capsule, followed by creation of a 5.0 to 5.5 mm capsulorhexis.
- Multiquadrant hydrodissection should be performed slowly and gently to allow for lens rotation. Intermittently depress the lens slightly so that fluid can exit the bag, which will help avoid trapped fluid. Trapped fluid can force the nucleus forward and cause capsular-lenticular block, which can increase the risk of posterior capsule rupture.
- Various chop techniques have been described,[4] with our preference being to employ a vertical chop technique that involves spearing the lens nucleus with the sharp chopper depressed posteriorly, while embedding the phaco tip into the core of the nucleus and lifting anteriorly. The shearing forces created by the chopper and phaco tip opposition creates a fracture in the lens. About 2 tip-widths of exposed phaco tip is helpful for achieving good purchase of the nucleus, and a steep angle of attack (about 60°) is essential to achieve sufficient depth within the nucleus. High phaco vacuum is particularly helpful for this step, and the use of on-off phaco, as well as decreasing the duty cycle reduces risk of thermal injury.
- Repeat with the tip burying into the central plane of the lens fragments to further divide the lens and remove the smaller fragments with phacoemulsification. Keep the phaco tip deep to the rhexis to minimize shell disturbance and protect the endothelium from thermal injury as well as mechanical trauma from lenticular fragments during this step.
- The miLOOP (ZEISS) is a self-expanding nitinol filament ring that can be inserted into the capsular bag and used to fragment a

dense lens nucleus without any phacoemulsification energy (Video 4.1). Once the nucleus has been fragmented, phacoemulsification can be used to emulsify the lens pieces, and further horizontal and vertical chopping techniques can be employed.

- Once all fragments have been removed, insert the IOL into the capsular bag and aspirate residual OVD using a rock "n" roll technique to ensure complete evacuation.

Pearls and Potential Pitfalls

- Tight/small phaco incisions are at higher risk for wound burn, while posterior incisions and larger incisions are at risk of iris prolapse.
- Consider a scleral tunnel for the original incision if high likelihood of converting to ECCE intraoperatively.[5]
- White cataracts may contain liquified cortex that could impede visualization during capsulorhexis creation and may need to be aspirated prior to continuing. In such cases, it is often advisable to take a 25G, 27G, or 30G needle and puncture through the central capsule to aspirate liquid cortex prior to initiating the capsulorhexis.[6]
- Continuously recoat the endothelium with dispersive OVD during phacoemulsification to account for OVD shell loss as a result of irrigation and aspiration. The cohesive/adaptive shells can also be reformed.
- Some surgeons prefer to use chilled BSS, which may help protect corneal endothelium from thermal injury, as well as reduce postoperative inflammation.[7] Use of immediate postoperative chilled irrigation solution was found to reduce corneal metabolic activity up to 50%,[8] and a recent randomized controlled trial demonstrated less early postoperative corneal edema and inflammation in hard cataract cases using chilled versus room

temperature BSS.[9]

- Beware of the potential for blowing out the posterior capsular rupture during hydrodissection. This step needs to be performed slowly and methodically to prevent this.
- Some surgeons advocate pausing phaco once enough of the nucleus is removed and the posterior capsule is first visualized, then instilling dispersive OVD to create a protective wall for the posterior capsule, separating the nucleus from posterior capsule, and potentially reducing the risk of posterior capsule rupture.[10]
- Use higher than usual power (up to 70% on the Centurion and up to 50% on the Stellaris). If you see milk when you try to bury the tip, you have insufficient power.
- Lower flow rates during phacoemulsification tend to preserve the OVD shells better.
- Cumulative dissipated phaco energy delivered is likely to be higher, which may cause excess stress on the capsular bag-zonular complex, as well as potential corneal heat damage from continuous phaco energy, particularly if the phaco tip becomes occluded with OVD and lenticular debris.[11]

POSTOPERATIVE CONSIDERATIONS

- Expect more postoperative inflammation and corneal edema on postoperative day 1 which can persist for several weeks. Consider adding additional topical or oral steroids and/or NSAIDs. Sub-Tenon Kenalog injection may also be advisable.
- Counsel patients that recovery will take longer than the average patient.
- Monitor for high IOP postoperatively.
- Examine thoroughly for potential retained lenticular fragments.

Many times, focal cornea edema (often inferior) can be a sign of a retained lens fragment.

- Patients are at higher risk for IOL subluxation or dislocation postoperatively, given the tendency for zonular weakness in these cases. Monitor carefully for this.

References

1. O'Keeffe M, Nabil M. The use of mannitol in intraocular surgery. *Ophthalmic Surg*. 1983;14:55-56.
2. Arshinoff SA, Norman R. Tri-soft shell technique. *J Cataract Refract Surg*. 2013;39:1196-1203.
3. Arshinoff SA. Dispersive-cohesive viscoelastic soft shell technique. *J Cataract Refract Surg*. 1999;25:167-173.
4. Chang D. *Phaco Chop Techniques*: Horizontal Versus Vertical Chop. CRST; 2002. Accessed April 8, 2020. https://crstoday.com/articles/2002-sep/0902_181-html/
5. Crispim J, Jung LS, Paz L, et al. The surgical challenges dense brunescent cataracts present. *Expert Rev Ophthalmol*. 2014;10:13-22.
6. Seibel BS, Cionni RJ. *Traumatic Cataract*. CRST; 2010. Accessed April 8, 2020. https://crstoday.com/articles/2010-apr/traumatic-cataract/
7. Jabbour NM, Schepens CL, Buzney SM. Local ocular hypothermia in experimental intraocular surgery. *Ophthalmology*. 1988;95(12):1687-1690.
8. Findl O, Amon M, Kruger A, et al. Effect of cooled intraocular irrigating solution on the blood-aqueous barrier after cataract surgery. *J Cataract Refract Surg*. 1999;25:566-568.
9. Wan W, Jiang L, Ji Y, et al. Effect of hypothermic perfusion on phacoemulsification in eyes with hard nuclear cataract: randomized trial. *J Cataract Refract Surg*. 2019;45:1717-1724.
10. Steinert RF, Chu YR. *Dense Cataract*. CRST; 2010. Accessed April 9, 2020. https://crstoday.com/articles/2010-apr/dense-cataract/
11. Ernest P, Rhem M, McDermott M, et al. Phacoemulsification conditions resulting in thermal wound injury. *J Cataract Refract Surg*. 2001;27:1829-1839.

CHAPTER 5

White Cataract Removal Techniques

Kristen Marie Peterson MD

PREOPERATIVE CONSIDERATIONS

In an eye with a white cataract, perform ultrasonography to evaluate for posterior pole pathology (ie, intraocular tumor, retinal detachment, or possible intraocular foreign body) and assess for lenticular debris posterior to the lens indicative of possible posterior capsular violation. At the same time, an immersion A-scan should be performed to determine the axial length as optical biometry may not be able to penetrate through the dense lens opacity. Assess for a relative afferent pupillary defect.

Keratometry Measurements

- Consider pupil-centered setting for biometry measurements due to patient's inability to fixate.[1]
- If the cataract is posttraumatic with prior corneal laceration, obtain corneal topography.
    - Suture removal is recommended prior to keratometry if able to safely delay surgery a few weeks to allow keratometry measurements to stabilize.

If there is irregular central astigmatism on topography, counsel the patient that, in order to obtain the best corrected visual acuity, a rigid gas-permeable contact lens may be required postoperatively. In

some scenarios, a penetrating keratoplasty may be required if the scar is very dense or if the patient cannot tolerate a contact lens.

Slit-Lamp Anterior Segment Examination

- Perform a thorough examination of the cornea:
    - Guttae: Owing to the potential need for increased CDE to emulsify dense nuclei, patients with guttae need to be counseled on the higher risk of future endothelial decompensation following surgery.
- Presence of iris transillumination defects could indicate prior intraocular foreign body resulting in either anterior or posterior capsular violation. An irregularly shaped or peaked pupil may indicate an area of vitreous prolapse into the AC.
- Phacodonesis is indicative of zonular instability.
- Evaluate for signs of liquefied intumescent cortex.
- Assess the density of the nucleus. Determine if the nucleus is soft, white, and intumescent versus dense with brunescence and a leathery/fibrotic backplate as these can affect the surgical technique of choice.

Surgical Planning

- Manage patient expectations
    - Discuss that owing to limited examination of the posterior segment, vision limiting pathology cannot be completely excluded.
    - There is a chance that multiple surgeries may be required to obtain the best corrected visual acuity postoperatively owing to the increased risk of complications.
- Let the operating room team know you need:

- Trypan blue (VisionBlue, Dutch Ophthalmic, USA) to stain the anterior capsule.
- Have in the room: Pupil expansion devices, capsular hooks, capsular tension rings and/or segments, preservative-free triamcinolone (dilution 1:4 with BSS), anterior vitrectomy pack.

SURGICAL PROCEDURE

- Consider intravenous mannitol 30 minutes prior to surgery if the large lens is causing shallowing of the AC.
- Perform a paracentesis incision using an MVR or sideport blade; inject 1% buffered intraocular lidocaine followed by air and then trypan blue.
- Pressurize the AC to flatten the anterior capsule by injecting a high-molecular-weight cohesive or viscoadaptive OVD.[1]
    - It is important to maintain AC pressure higher than intralenticular pressure to help prevent anterior capsular rent or extension (ie, “Argentinian flag sign”).
- Create the main wound using a microkeratome of choice.
- Perform the capsulorhexis. Multiple techniques exist. Monitor for signs of zonulopathy while performing (these include capsular striae when attempting to create a flap and movement of the lens/bag complex).
- Mature dense white cataract:
    - Use a cystotome to puncture the anterior capsule and then utrata forceps to complete a CCC.
        - Tip: Use of trypan blue will cause the anterior capsule to be less elastic and will improve visualization of the flap.

- Intumescent pressurized white cataract:
    - Puncture the capsule with a 27G needle bevel-up and immediately aspirate the liquefied cortex.[2]
        - Alternative: Use a cystotome to puncture the anterior capsule in a semicircular shape and then immediately aspirate the liquefied cortex.[2]
        - Alternative: Use a cystotome to puncture the anterior capsule working through the paracentesis and create an OVD tamponade to maintain a flat anterior capsule.[2]
- Repressurize the AC with OVD. Can use OVD in a sweeping motion to improve visualization of capsule limited by liquefied cortex.
- Complete the CCC with utrata forceps.

> Consider starting with a smaller capsulorhexis and then enlarging in a circular fashion to avoid peripheral run-out of the rhexis.

- Morgagnian cataract:
    - Start capsulorhexis by puncturing the anterior capsule with the cystotome. If needed, reinflate the capsular bag with OVD and then complete the CCC with utrata forceps.
- Consider the use of FLACS to perform capsulorhexis.
    - FLACS is especially helpful if there is a central fibrotic anterior capsule plaque.
    - It also may be helpful in intumescent white cataract cases to rapidly perform a CCC.
    - Alter laser settings to decrease the length of time needed to complete.

Be aware that there is a higher risk of microadhesions and incomplete capsulotomy, especially in intumescent cases.[3] Carefully watch while the capsulotomy is being created to see if there is incomplete penetration of the laser in a particular location of the rhexis. Use of FLACS also does not entirely exclude the risk of anterior capsular tear with extension in cases with high lenticular pressure.

Use trypan blue to stain the capsulorhexis prior to removal even in FLACS cases. This helps to better view areas where the capsulotomy is incomplete.

- Disassemble and remove the nucleus. Perform phacoemulsification.
    - In younger patients, the nucleus may be soft enough to allow for complete removal with irrigation/aspiration alone.
    - In mature cataracts with dense and leathery nucleus, disassemble using technique of choice taking care to protect the posterior capsule as often there will be minimal remaining cortical or epinuclear material to serve as a protective barrier.
- Remove any remaining cortex with irrigation-aspiration handpiece.
- Determine the preferred intraocular lens type and corresponding safest placement for intraocular lens based on the capsular and zonular status.
    - Inject the OVD into the capsular bag, or sulcus as indicated, followed by IOL if adequate capsular support.
- Carefully remove the OVD. Ensure that there is no sign of vitreous prolapse into the AC and that the lens is well centered. Perform stromal hydration to the corneal incisions. Bring the eye to physiologic pressure. Ensure wounds are secure. Place a suture in the main wound if there is any concern for wound

leakage. Remove the speculum and drapes.

POSTOPERATIVE CONSIDERATIONS

- Patients may have more postoperative inflammation and corneal edema than a routine cataract case and therefore may require a longer course of topical steroids.[1]
  - Consider a stronger topical ophthalmic steroid (ie, difluprednate).
  - In some cases, patients may benefit from an injection of periocular steroids at the time of surgery (ie, patients with a history of uveitis).
- Make sure to perform a thorough dilated fundus examination to evaluate for posterior segment pathology postoperatively.

References

1. Devgan U. Surgery in eyes with white cataracts poses challenges. *Ocular Surgery News U.S. Edition*. September 25, 2009. https://www.healio.com/ophthalmology/cataract-surgery/news/print/ocular-surgery-news/%7Bc95dcedc-a3d7-4cb1-8f9b-f6d08377cfe6%7D/surgery-in-eyes-with-white-cataracts-poses-challenges
2. Sood P. *I Don't Have a Femtosecond Laser; What Strategies Work Best for a White Cataract?* Cataract and Refractive Surgery Today; 2018. https://crstoday.com/articles/oct-2018/i-dont-have-a-femtosecond-laser-what-strategies-work-best-for-a-white-cataract/
3. Titiyal JS, Kaur M, Singh A, Arora T, Sharma N. Comparative evaluation of femtosecond laser-assisted cataract surgery and conventional phacoemulsification in white cataract. *Clin Ophthalmol*. 2016;10:1357-1364. doi:10.2147/OPTH.S108243

CHAPTER 6

Posterior Polar Cataract Techniques

Matias Soifer, MD

PREOPERATIVE CONSIDERATIONS

Surgical Planning

- Carefully assess for the possibility of preexisting PCR on the slit lamp examination. One can use UBM or AS-OCT to determine if the posterior capsule is intact.
- Always assess the contralateral eye as posterior polar cataracts are usually bilateral.
- Manage patient expectations on visual prognosis and risks for complications. Explain the risks of PCR and need for additional surgeries. If there is concern for PCR, do not recommend implantation of a premium IOL.
- Mention the possible need for future Nd:YAG capsulotomy for residual posterior capsular plaques.

SURGICAL PROCEDURE

Phacoemulsification of a Posterior Polar Cataract

- Let the operating team know that you might need to perform an anterior vitrectomy. Have a retina colleague on standby. Prepare

for a three-piece IOL or ACIOL insertion in the event of PCR.

- Once the main incision is made, create a capsulorhexis approximately 5 mm in diameter.
- Perform hydrodelineation. Hydrodissection is contraindicated as it can provoke a PCR.
- Nucleus disassembly: Perform “slow-motion” phacoemulsification. Avoid movements that can cause traction on the posterior capsule such as excessive rotation of the lens nucleus, bimanual cracking of the nucleus, or intermittent collapse of the AC.
- Soft nucleus: Aspirate the nucleus within the cushion of the epinucleus created with hydrodelineation.
- Hard nucleus: Create a bowl by doing contiguous trenches in the nucleus. If the nucleus must be divided, perform phaco-chop maneuvers.
- Epinucleus/cortex removal: The epinucleus and cortex should be gently aspirated with the irrigation and aspiration probe, aided by the second instrument to help pieces reach the port. If the lens is adherent to the capsule, viscodissection can be performed to slowly separate the lens material from the capsular bag. Remember to avoid withdrawing the irrigating instrument without preceding viscoelastic injection to avoid collapse of the AC.

Various Surgical Scenarios With Posterior Polar Cataracts

The Posterior Plaque Is Aspirated and There Is No PCR

- Once the cortex is aspirated, cohesive viscoelastic is injected to expand the capsular bag and then the one-piece IOL is implanted into the capsular bag.
- If there is some remaining posterior plaque, it is safer to perform a Yag capsulotomy postoperatively as opposed to attempting

multiple maneuvers to remove all remaining material intraoperatively owing to the risk of PCR.

There Is a PCR but No Vitreous Prolapse

- Once the PCR is noted, avoid pulling out the phacoemulsification probe from the AC while keeping it on position 1. Slowly inject dispersive viscoelastic over the rupture to keep the capsular bag inflated and tamponade the vitreous. This also prevents rapid decompression of the AC and prolapse of vitreous once the phacoemulsification probe is removed.
- If nuclear fragments remain, determine the best approach to remove these pieces.

> Many times, when a PCR is noted, nuclear pieces can be moved into the AC with viscoelastic and carefully emulsified above the capsular bag. If there is concern that the fragments can dislocate posteriorly, fragments can be moved to the AC and an IOL can be injected into the sulcus to serve as a scaffold to prevent posterior migration of lens fragments. Other times, if the PCR is small, nuclear fragments can be emulsified in the capsular bag but viscoelastic should be constantly injected to tamponade the location of the PCR and prevent vitreous prolapse.

- Assess the size of the PCR:

If there is a small rupture without vitreous prolapse, an IOL can often be placed in the capsular bag. If the rupture is small and central, a posterior capsulorhexis can be performed and the IOL optic can be captured through the posterior capsulorhexis for further stability.

There Is PCR With Vitreous Prolapse

- Avoid pulling out the phacoemulsification probe from the AC once the PCR is noted. Maintain your foot pedal on position 1

(irrigation) and gently inject dispersive viscoelastic over the location of the rupture.

- Once the AC is sufficiently pressurized, evaluate the size and number of residual lens fragments and the presence of vitreous on the AC. Suture the main wound and perform an anterior vitrectomy. Gently remove the lens fragments once the AC is clear of vitreous.
- After the vitreous and lens fragments have been adequately managed, an alternative position for the IOL must be selected including ACIOL implantation, sulcus implantation, or scleral fixation of the IOL.

POSTOPERATIVE CONSIDERATIONS

If a PCR occurred during the surgery, on postoperative day 1 assess for wound leak and presence of vitreous in the AC. Increase the frequency of topical corticosteroids to reduce intraocular inflammation. Since there is an increased risk for endophthalmitis and retinal detachment, alarm signs have to be explained to the patient with strict return precautions.

CHAPTER 7

Non Phacoemulsification Techniques for Lens Removal

Brenton D. Finklea, MD

PREOPERATIVE CONSIDERATIONS

When evaluating an eye with a visually significant cataract, it is necessary to determine if there are comorbid conditions or features of the cataract that make modern phacoemulsification techniques higher risk than traditional extracapsular cataract extraction. The primary indication for extracapsular cataract surgery is an advanced brunescent and/or mature cataract. These dense lenses would require very high phacoemulsification energy that may damage the corneal endothelium. Dense lenses that also have poor zonular support may also be ideal candidates for non-phacoemulsification cataract removal techniques to reduce the risk of posterior dislocation of the lens during surgery. Considerations for procedure selection:

Extracapsular Cataract Extraction

- Simple conversion intraoperatively from phacoemulsification to extracapsular cataract extraction ECCE by extending the existing clear-corneal incision.

Manual Small Incision Cataract Surgery (Video 7.1)

- MSICS is a modified technique of ECCE in which a corneoscleral tunnel which allows for improved chamber maintenance is created and may often be performed in a sutureless technique.

Intracapsular Cataract Extraction

- This technique is similar to ECCE or MSICS in wound creation and technique, but involves the removal of the cataract and capsule as a single unit. The technique is usually employed in cases of severe zonular instability and has an increased risk of vitreous loss and iatrogenic retinal tears.

Surgical Planning

- Preoperative biometry for IOL selection. Axial length measurements may need to be obtained with A-scan ultrasonography.
- Examination for comorbid posterior segment pathology may require ultrasonography owing to poor visibility through a dense cataract.
- Close examination for areas of capsular fibrosis or zonular weakness.
- Examine the red reflex to determine if trypan blue or alternative dyes will be necessary to visualize the anterior capsule during capsulotomy creation.
- If a small pupil is present, have iris hooks available to assist with pupillary expansion.
- Make note of prior glaucoma filtration surgeries such as tube shunts or trabeculectomy sites that you must avoid with your conjunctival peritomy. Eyes with comorbid glaucoma may benefit from a temporal approach to avoid disrupting the superior conjunctiva.

SURGICAL PROCEDURE

Manual Small Incision Cataract Surgery

- Anesthesia can be obtained with a sub-Tenon, peribulbar, or retrobulbar block. It is important to have good akinesia to assist in positioning of the globe.
- A bridle suture may be placed using a 4-0 silk suture passed under the superior rectus muscle. Note that surgeons may choose to skip this step if adequate control of the globe can be maintained with alternative techniques such as grasping the sclera with toothed forceps.
- A superior conjunctival peritomy can be performed using Westcott scissors to dissect Tenon capsule and conjunctiva for 2 to 3 clock hours centered on 12 o'clock. Any residual Tenon capsule can be scraped away using a crescent blade.
- Electocautery may be used for hemostasis of the exposed bare sclera.
- Calipers should be used to measure the external incision for the sclerocorneal tunnel. The average wound size should be approximately 7 mm in diameter, although this may vary from 6 to 8 mm depending on the size and density of the cataract (denser cataracts require larger openings). The internal margins of the wound are wider than the external wound and create a trapezoidal shape or "funnel." The internal wound should be sized to the diameter and density of the cataract.
    - The external incision can be shaped straight or as a frown or smile.
    - Frown incisions are often chosen owing to their lower magnitude of induced astigmatism and ability to maintain a water-tight seal without sutures.

The difference between MSICS and ECCE is primarily in the creation of the main incision. Traditional ECCE involves the creation of a limbal corneal incisions while MSICS uses a corneascleral tunnel.

- Paracenteses are created at the temporal and/or nasal limbus, taking care to avoid crossing the corneoscleral tunnel.
- The surgeon may choose to use an intracameral mydriatic if preoperative dilation was suboptimal.
- Dispersive viscoelastic is injected through the paracenteses to fill the anterior chamber of the eye.
- A keratome (2.2 to 3.0 mm) is used to enter the eye through the superior tunnel.

> The internal opening is kept small for the capsulotomy formation. When the capsulotomy is completed, the internal opening of the wound may be expanded for cataract removal. Experienced surgeons may open up the entire tunnel primarily in order to avoid an additional step later on in the case, but this can cause more chamber instability.

- The anterior capsulotomy can be created in a variety of methods. In all techniques, a large-diameter capsulotomy must be achieved to minimize stress on the capsule during lens removal, thereby avoiding a capsular tear-out.
    - CCC: The gold standard for capsulotomy owing to its tensile strength and consistency with IOL centration. The capsulorhexis must be a large-enough diameter to prolapse the lens, typically 7 to 8 mm on average.
    - Can opener: A good technique for capsulotomies when there is a poor view or when significant scarring/fibrosis of the anterior capsule is present. A cystitome is used to create a ring of small incisions into the anterior capsule that are subsequently connected in a postage-stamp fashion. The cut capsule is then removed from the eye.
    - Envelope: This is the primary technique for many high-

volume and high-speed surgeons. The keratome or cystitome is used to make an initial incision at the superior aspect of the lens. Scissors are used to create cuts on the nasal and temporal side of the initial incision. After the cataract is removed, the anterior capsule flap is cut or torn free to complete the capsulotomy.

- Hydroprolapse of the lens is performed using BSS on a 27G or 30G blunt-tipped cannula.
    - Once the lens is prolapsed at one pole, viscoelastic is injected into the capsular bag to prevent the lens from falling back into the bag.
- The lens is rotated into the anterior chamber using a Sinskey hook in a “dialing” technique. Viscoelastic is reinjected as needed to maintain a layer above and below the lens.
- Lens expression is performed with an irrigating vectis or lens loop inserted below the lens and is used to guide the lens out of the eye while placing gentle posterior pressure with the instrument to avoid trauma to the endothelium.
    - Alternative methods for lens removal are hydroexpression and viscoexpression.
    - The Blumenthal technique involves placement of an anterior chamber maintainer at the inferior limbus and using hydrostatic pressure to express the lens by placing gentle downward pressure on the posterior wall of the tunnel using McPherson forceps.
- Irrigation and aspiration can be performed through the paracenteses using a Simcoe cannula or bimanual irrigation and aspiration handpieces.
- Cohesive viscoelastic is used to fill the capsular bag and anterior chamber.
- A one-piece PMMA IOL or three-piece acrylic IOL is inserted into

the eye unfolded using McPherson forceps. The lens is dialed into position in the capsular bag with a Sinskey hook through the paracentesis.

- The eye is brought to physiologic pressure using BSS. The paracenteses and sclerocorneal tunnel are evaluated for leaks using Weck-cel sponges.

> A single 10-0 nylon suture can be placed into the sclerocorneal tunnel centrally to help reduce the induced against-the-rule ASTIGMATISM from the surgery.

- The conjunctival peritomy can be closed with an 8-0 vicryl suture or with bipolar electrocautery applied to apposed edges of the peritomy.
- Subconjunctival injections of steroid and antibiotic can be placed into the inferior or superior fornix.
- A patch and shield should be applied until the patient is seen for their post-op day 1 examination.

POSTOPERATIVE CONSIDERATIONS

- Standard postoperative cataract evaluations should be performed the day after surgery to look for proper positioning of the IOL, wound leaks, residual lens material, or intraocular pressure abnormalities.
- Confirm that the sclerocorneal tunnel site is completely covered with conjunctiva to reduce the risk of endophthalmitis.
- Look for a wound leak at the scleral tunnel site, which may appear as an unintended filtration bleb above the scleral incision.

CHAPTER 8

An Overview of Femtosecond Laser-Assisted Cataract Surgery

Abhilash Guduru, MD, Robin Vann, MD

Femtosecond lasers use infrared (1053 nm) neodymium:glass to generate thousands of frequency pulses per second. The ultrashort pulse of the laser is able to separate tissue in a process called photodisruption to an accuracy of 3 μm.[1] Photodisruption occurs through plasma formation, via the laser pulse, that expands as an acoustic shock wave, displacing the surrounding tissue. FLACS helps with the efficiency and accuracy of creating a capsulotomy, lens fragmentation or liquification, and corneal incisions in cataract surgery. Through lens fragmentation, it can also reduce the amount of phacoemulsification energy required during surgery.[1]

LASER COMPONENTS

TABLE 8.1 Femtosecond laser systems and imaging modality

LenSx (Alcon Laboratories, Inc)	3D spectral domain OCT
Catalys (Optimedica)	3D spectral domain OCT
Victus (Technolas)	3D spectral domain OCT
LensAR (Lensar, Inc)	3D ray-tracing confocal structural illumination (CSI) with Scheimpflug technology

- Solid state laser.
- Patient interface used for patient docking.
- Monitor for anterior segment visualization and OCT imaging.

- Different manufacturers (Table 8.1).[2,3]

PREOPERATIVE CONSIDERATIONS

Patient Factors

Positioning

- Able to lie flat?
- Kyphosis/spine issues may make difficult to position under laser.

Behavioral Factors

- Cooperative patient/mental status.
- Claustrophobia.

Anatomy

- Small palpebral fissures—may make it difficult to achieve suction.
- Corneal opacities—opacities may block the laser.
- Small nondilating pupil—this can impede capsulotomy creation and lens fragmentation.
- Broad nose—the cone of the laser sometimes can be impeded by contact with the nose.

Contraindications: Absolute and relative contraindications include corneal disease that precludes applanation of the cornea or ocular disease that impairs the transmission of laser wavelengths. These include corneal opacities, hyphemas, presence of corneal implants, or prior corneal incisions that may provide a potential space into which the gas produced by the procedure can escape. Retinal

vascular disease or severe glaucoma should also be relative contraindications considering possible acute IOP rises during the docking procedure and inability to properly dock the eye owing to the presence of filtering blebs from trabeculectomies or glaucoma shunt surgeries.[2, 4]

SURGICAL PROCEDURE

Preparation

- Confirm settings on the laser are appropriate for the patient.
    - Incision locations (main incision/secondary incision/arcuate incisions—make sure there is no overlap of these incisions).
    - Arcuate incisions (if performing laser arcuate incisions)—centration, arc length/axis, and distance from optical center.
    - Capsulotomy size.
    - Lens fragmentation profile.
    - Energy settings.
    - Cyclotorsion alignment options.
    - Manual reference mark with patient sitting upright.
        - Single mark at 6-o'clock location.
        - Can also consider marks at both the 3-o'clock and 9-o'clock positions using a toric marker.
        - Must be careful to not have ink marks cover incision locations.
    - Preoperative and intraoperative registration (available on certain machines such as LenSx Verion or Lensar).

Docking

Curved Contact Lens System

- LenSx can cause IOP rise of up to 16 mm Hg.
    - Verify treatment, incision plan, orientation, and location with respect to limbus.

Liquid Interface Between Laser System and Eye

- OptiMedica and LensAR.[2, 3]
- Prevents formation of corneal folds allowing for greater focus of laser.
- IOP rise of 15 mm Hg.
- Verify treatment, incision plan, orientation, and location with respect to limbus.

Maintain Centration

- Poor centration results in incomplete and improper treatment.

Positioning: Adequate docking and laser and patient positioning are key to have the most accurate outcomes. Patient head should be parallel to floor, on a firm surface, and the eye and the gurney must be parallel to the laser objective. In those with large noses, large brows, and high cheekbones, special care must be taken to ensure proper docking and reduce false-positive applanations.

ANTERIOR SEGMENT IMAGING

This procedure allows for laser pattern mapping. Specific boundaries are mapped, including the iris and the posterior surface of the lens. The posterior surface of the lens must be identified in order to avoid puncture of the posterior capsule. Preprogrammed variables and any optional LRIs can be adjusted for surgeon preference.

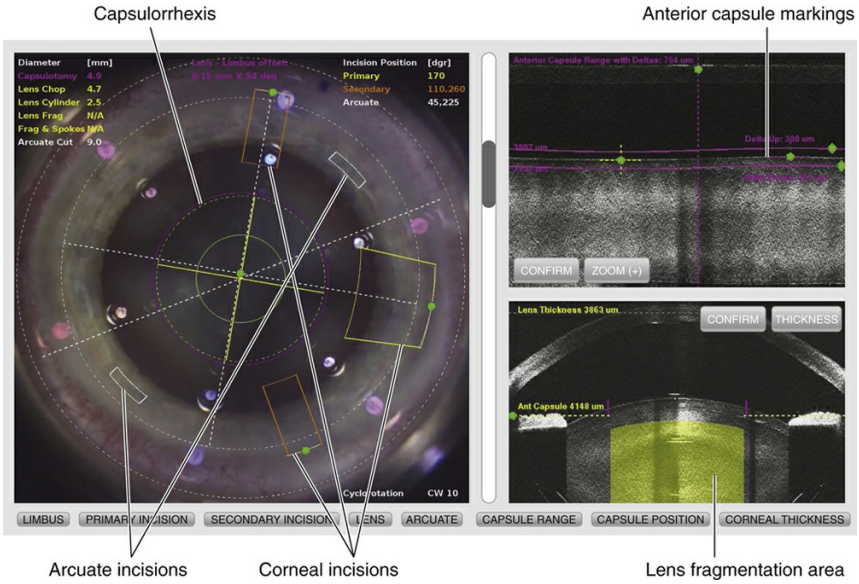

FIGURE 8.1 **Sample screen of anterior segment imaging software.**

- Image registration—performed prior to the real time capturing of the anterior segment.
    - Manual.
    - Automated image guided: use live iris features.
        - Verion for LenSx.
        - Internal native iris registration for LensAR.
- Imaging technology and acquisition.[2, 3]
    - FD-OCT technology.
        - LenSx and OptiMedica.
- Scheimpflug imaging technology.
    - LensAR.
- Sample screen (example, LenSx screen; Fig. 8.1).

Laser Treatment

Each laser incision is constructed in the posteroanterior plane.

Microcavitation bubbles created allow for scattering of the laser beam reducing the amount of energy to the retina. Since bubbles are posterior to laser target, no scattering is done before reaching target tissue.

Anterior Capsulotomy

Lens Fragmentation or Liquification (See Sidebar)

- Liquification has been suggested to be used for softer lens (up to LOCS grade 2.0).
- Fragmentation has been recommended for harder lenses (up to LOCS grade 4.0).[4]

Corneal Incisions

- Wound construction.
- LRIs.

Fragmentation: Studies have demonstrated in low to moderate lens density, grid fragmentation pattern should be used to reduce phacoemulsification time. For higher-density lenses the pie-cut pattern fragmentation pattern significantly decreased the use of phacoemulsification. Studies have also demonstrated less loss of endothelial cell count postoperatively and shorter phacoemulsification times with hybrid patterns compared with standard cross patterns.[5,6]

Once the above steps are performed, the patient is taken back to the operating room and, in sterile conditions, the lens in extracted and replaced with a new intraocular lens.

Possible Operative Complications

Pupillary Constriction

- Can occur secondary to the shock waves from plasma formation.

- Can use additional dilating drops and NSAID drops preoperatively and intraoperatively.
- Intraoperative irrigation with phenylephrine.

Capsular Blockage Syndrome

- Can arise during hydrodissection, where high-speed fluid ingress can impede the gas bubbles to escape. This may increase intralenticular pressure, which can result in posterior capsular rupture and possible dropped lens.
- In order to prevent the above-mentioned complication, slow titrated injection of hydrodissection fluid and careful splitting of the nucleus can be used to help release intralenticular gas bubbles, described as the “rock and roll” technique established by Nagy et al.[2 , 4]

Incomplete Capsulotomy and Incomplete Wound Creation

- Can occur secondary to blockage, air bubbles, opacities.
- Can attempt to increase energy or remove bubbles during treatment.
- Watch the laser treatment to determine if any parts of the capsulotomy were not completed. Use intraoperative trypan blue to better visualize the capsulotomy cap. Use Utrata forceps to carefully peel areas of possible incomplete capsulotomy to avoid an anterior capsular tear.

POSTOPERATIVE MANAGEMENT

- Subconjunctival hemorrhage.
  - Can occur secondary to docking.
  - Supportive care.

- Routine postoperative cataract surgery care.

References

1. Moshirfar M, Churgin DS, Hsu M. Femtosecond laser-assisted cataract surgery: a current review. *Middle East Afr J Ophthalmol*. 2011;18(4):285-291. doi:10.4103/0974-9233.90129
2. Nagy ZZ, McAlinden C. Femtosecond laser cataract surgery. *Eye Vis (Lond)*. 2015;2:11. doi:10.1186/s40662-015-0021-7
3. Optometry Times. *Effectively Comanaging Femtosecond Laser-Assisted Cataract Surgery*. 2020. Accessed May, 5 2020. https://www.optometrytimes.com/modern-medicine-cases/effectively-comanaging-femtosecond-laser-assisted-cataract-surgery
4. Trikha S, Turnbull AM, Morris RJ, Anderson DF, Hossain P. The journey to femtosecond laser-assisted cataract surgery: new beginnings or a false dawn? *Eye*. 2013;27(4):461-473. doi:10.1038/eye.2012.293
5. Shajari M, Khalil S, Mayer WJ, et al. Comparison of 2 laser fragmentation patterns used in femtosecond laser-assisted cataract surgery. *J Cataract Refract Surg*. 2017;43(12):1571-1574. doi:10.1016/j.jcrs.2017.09.027
6. Lyu D, Shen Z, Zhang L, et al. Comparison of perioperative parameters in femtosecond laser-assisted cataract surgery using three nuclear fragmentation patterns. *Am J Ophthalmol*. 2019;213:283-292. doi:10.1016/j.ajo.2019.12.017

CHAPTER 9

Floppy Iris Syndrome—Surgical Tips and Pearls

Wonchon Lin, MD

PREOPERATIVE CONSIDERATIONS

- Medications that can cause IFIS include tamsulosin and other alpha blockers that are commonly used to treat benign prostatic hyperplasia and hypertension.
    - There is no benefit to stopping the medicine prior to surgery as the effects of the medication on the iris tissue will persist.
- Identify poor preoperative dilation in the clinic and note this in your preoperative notes.
- Consider starting topical atropine and/or NSAIDs several days prior to surgery to improve intraoperative dilation.

INTRAOPERATIVE CONSIDERATIONS

- Communicating with the anesthesia team to administer adequate anesthesia in the event poor dilation causes the case to run longer or results in any complications (ie, posterior capsular rupture).
- Utilize pharmacologic agents to improve dilation including:
    - Intracameral epinephrine, epi-Shugarcaine
    - Omidria (phenylephrine 1% and ketorolac 0.3% intraocular solution) in the BSS infusion

- Use heavier-weight viscoelastic agents (such as Healon GV or Healon 5) for viscodilation to supplement pharmacologic agents.
- Create well-constructed and self-sealing corneal incisions.

> Consider making the incision longer and more anterior in a suspected IFIS case to avoid iris prolapse through the main wound.

- Utilize iris expansion devices to assist with visualization of the capsule and nucleus. Options include iris hooks (Fig. 9.1) and iris rings, the most common ones are the Malyugin Ring (Figs. 9.2 and 9.3) and I-Ring (Fig. 9.4).
- Figure 9.5 compares the effect of pupil expansion with different techniques, functionally similar degree of total effect.

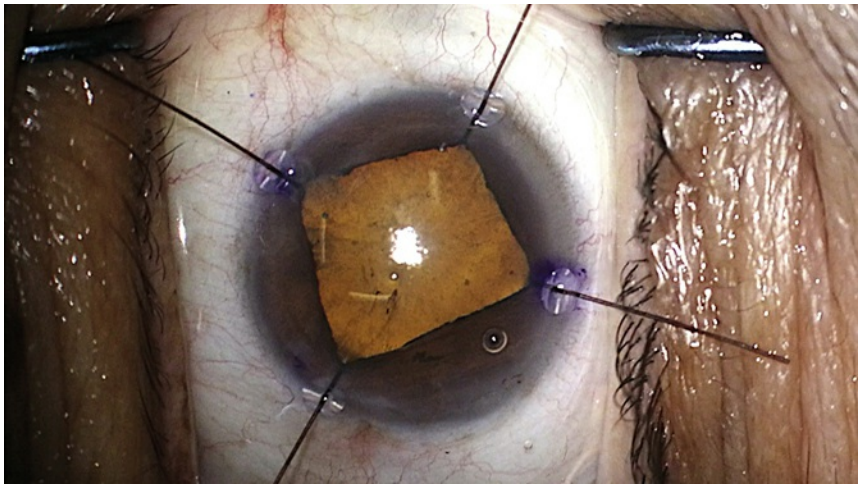

FIGURE 9.5 **Four iris hooks to manage a floppy iris. (Courtesy of Uday Devgan, MD, CataractCoach.com.)**

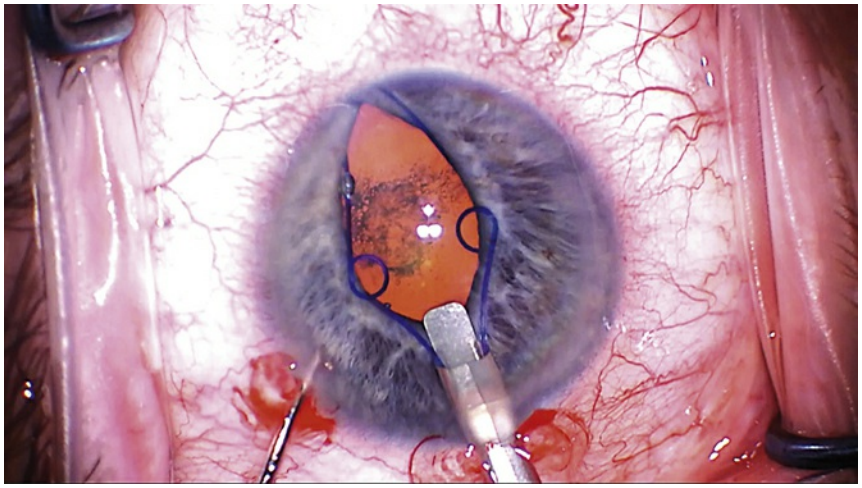

FIGURE 9.2 **Insertion of the Malyugin Ring with the injector. (Courtesy of Uday Devgan, MD, CataractCoach.com.)**

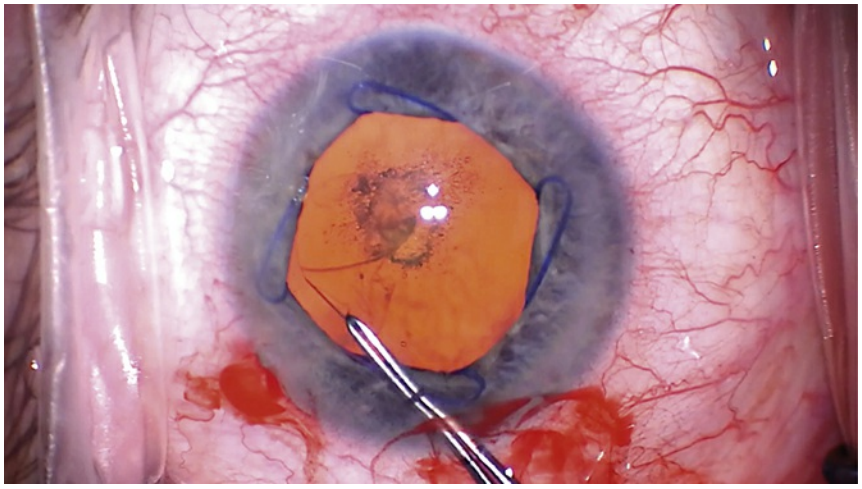

FIGURE 9.3 **Appearance of the Malyugin Ring after placement with good centration on the iris tissue. (Courtesy of Uday Devgan, MD, CataractCoach.com.)**

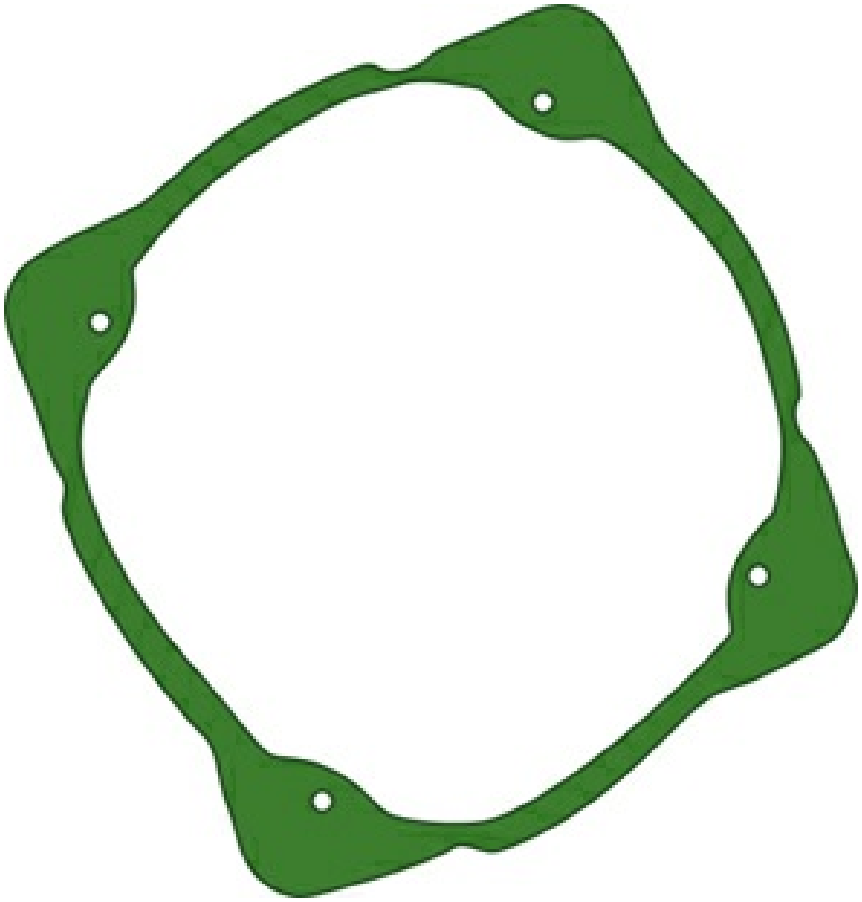

FIGURE 9.4 **I-Ring by Visitec. (Photo was provided courtesy of BVI.)**

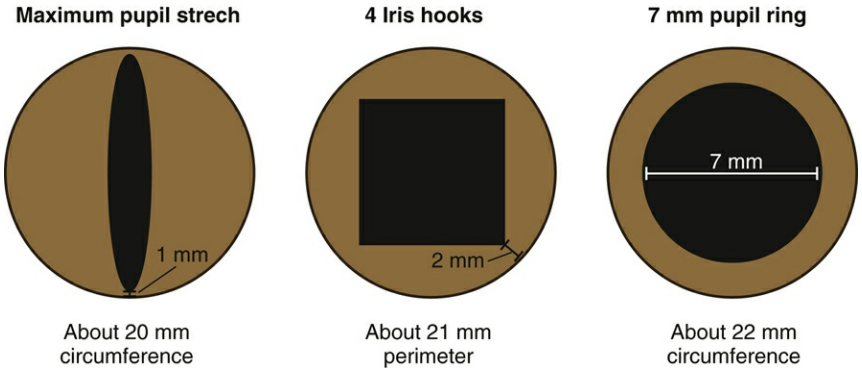

FIGURE 9.5 **Comparison of different types of pupil expansion. (Courtesy of Uday Devgan MD, CataractCoach.com.)**

TECHNIQUES FOR INSERTION OF IRIS EXPANSION DEVICES

Malyugin Ring

- The Malyugin Ring is manufactured in two sizes, 6.25 and 7.0 mm.
- Choose the ring size depending on the elasticity of the iris tissue.
- **Insertion of the Malyugin Ring:** Use the injector to place the distal scroll first followed by the two lateral scrolls (Fig. 9.2). If possible, have distal and lateral scrolls capture the iris tissue upon insertion. If iris tissue is not captured, then use the Malyugin manipulator to position the remaining scrolls and center the ring (Fig. 9.3).
- **Removal of the Malyugin Ring:** Use the Malyugin manipulator to disengage the distal and proximal scrolls and then use the hook on the injector to pull the ring back into the insertion device. The ring can also be removed without the injector and can be removed out of the main incision with the manipulator.

I-Ring

- **Insertion of the I-Ring:** Use the injector to place the entire device in the anterior chamber and then position the ring with a Sinskey hook onto the iris tissue via the four channels.
- **Removal of the I-Ring:** Use a Sinskey hook to disengage the distal channel, followed by the proximal channel and then the two lateral channels. Then use the hook on the injector to pull the ring back into the insertion device.

TECHNIQUES FOR NUCLEUS DISASSEMBLY

- Consider supracapsular nuclear removal if it is difficult to visualize the bag.
- Be comfortable lifting nuclear quadrants with your second instrument toward your phacoemulsification tip as visualization of the anterior capsule and posterior capsule can be challenging through a small pupil.
- Lower the irrigation flow and aspiration rate on the phacoemulsification machine to better control the fluidics in the anterior chamber and reduce chances of iris prolapse.

TIPS FOR IRIS MANAGEMENT

- If the iris prolapses multiple times through your main wound, consider closing this wound with sutures and creating a new, more stable wound. In addition, suture all wounds at the end of the case if the wound is not watertight.

Oftentimes, an iris hook can be inserted right under the main incision to help stabilize the iris tissue and avoid it from prolapsing through the main incision.

When the iris prolapses through the main wound, do not immediately attempt to reposit it into the main incision. Decrease pressure in the anterior chamber by burping a paracentesis. This will often redistribute the pressure in the anterior chamber and reduce the degree of iris prolapse. Then use either a cannula or cyclodialysis spatula to carefully sweep the iris tissue out of the main wound. This reduces the degree of trauma to the iris tissue. Constant manipulation can cause transillumination defects that can be visually debilitating for the patient.

POSTOPERATIVE CONSIDERATIONS

- There can be more postoperative inflammation and pain.
- Consider a long topical steroid taper and/or topical NSAIDs.
- Have a plan of attack for the fellow eye if IFIS was encountered in the first eye.

CHAPTER 10

Intraoperative Management of Zonular Weakness

Brad P. Barnett, MD, PhD, Christopher W. Heichel, MD, FACS

PREOPERATIVE CONSIDERATIONS

Zonular support has become increasingly more important to maintain long-term visual success. Therefore, appropriately assessing the integrity of the zonules is of tantamount interest. Today's case of undertreating zonular laxity will eventually become tomorrow's case of a dislocated IOL. A few simple and straightforward steps can help prevent or at the least delay lens-related issues in the future.

- Every preoperative cataract evaluation requires a detailed slit-lamp examination to identify lenticular malposition, phacodonesis, iris transillumination defects, and pseudoexfoliative material on the lens capsule.[1] The density of the lens can also be suggestive of underlying zonulopathy, especially with mature-white cataracts or ultra-brunescent cataracts.
- In addition to careful slit-lamp examination, a thorough history to identify causes of zonulopathy, including trauma, iatrogenic zonulysis (prior pars plana vitrectomy, repeat intravitreal injections, or history of glaucoma surgery), retinitis pigmentosa, aniridia, advanced age, intraocular neoplasm, pseudoexfoliation syndrome, high myopia, Marfan syndrome, homocystinuria, Weill-Marchesani syndrome, sulfite oxidase deficiency, scleroderma, porphyria, and hyperlysinemia is essential.[2]

- Through slit lamp, corneal topography or tomography, AS-OCT (Fig. 10.1), or UBM, it is important to attempt to identify or approximate the number of clock hours of zonular weakness in order to choose the optimal approach to surgical repair.[1]

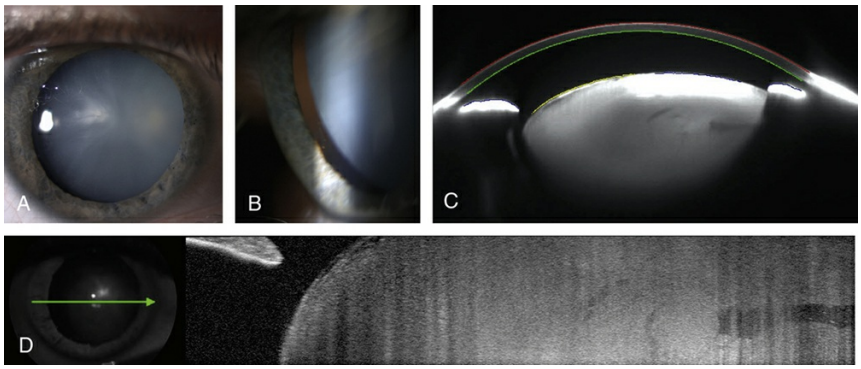

FIGURE 10.1 **Preoperative assessment of zonular weakness. Slit lamp photo of a traumatic cataract demonstrating greater than 8 hours of zonular weakness temporally (A and B). AS-OCT demonstrating tilted intumescent lens with absence of temporal zonules (C and D).**

As the degree of zonular weakness is not always appreciated preoperatively, it is important to ensure a backup surgical approach and necessary supplies are available in the operating room. Having an appropriate power three-piece IOL or sutured IOL as a backup for sulcus placement with or without optic capture, iris fixation, or scleral fixation (Yamane, glued-IOL, or sutured lens techniques) is critical in the event the primary in-the-bag one piece IOL with capsular support device approach is not successful.

SURGICAL PROCEDURE

Intraoperative Signs of Zonular Weakness

Recognizing the signs of zonulopathy from the obvious to the sublime

can be challenging. As previously mentioned, hopefully a detailed history and examination will elicit common risk factors such as prior trauma, pseudoexfoliation syndrome, or phacodonesis. However, occasionally the presence of zonular weakness will only become apparent once in the OR. Here are a few subtle or not-so-subtle signs commonly encountered during surgery:

- Chamber instability. A dynamic chamber with a trampolining lens diaphragm can indicate zonular compromise.
- Difficulty with creation of the capsulorhexis or wrinkling of anterior capsule when attempting to create the rhexis flap.
- Difficulty with cortical stripping.

Capsulorhexis

- As zonulopathy results in abnormal vector forces, the rhexis should be initiated away from a region of intact zonules. A second instrument may also be of benefit to provide a point of fixation on the central lens capsule. This technique allows initiating a rhexis in the area of maximal counter traction.[3,4]
- To combat the increased risk of radialization of the rhexis, sufficient viscoelastic should be used to counterbalance the outward forces on the anterior capsule and vigilance should be maintained to perform the Little capsulorhexis tear-out recuse maneuver early to redirect the rhexis.[5]
- Finally, although a smaller rhexis may be necessary to safely remove the cataract, care should be taken to avoid leaving the rhexis too small (<4.5 mm). In cases of significant zonular weakness, accentuated capsular phimosis can occur further increasing zonular laxity and the risk of late IOL dislocation.

Hydrodissection

- To minimize stress on zonular fibers during lens rotation and nuclear disassembly, complete cortical cleaving hydrodissection

is essential.

- The use of capsular hooks prior to attempting nuclear disassembly is advised if significant zonulopathy is present.

Nuclear Disassembly

- Care should be taken to utilize a surgical technique that minimizes lens manipulation and rotation.
- The Zero-Min-Spin technique, a rotationless horizontal chop technique, is ideal.[6] In brief, a standard horizontal chop is used to create two hemilens fragments followed by a second perpendicular chop in which the second instrument is placed over the phaco instrument to form an “X.” The hemilens is then bisected by a cross-chop in which the second instrument is drawn back perpendicularly toward the phaco instrument, ie, the center of the previously formed “X.”
- Other techniques to reduce zonular stress include the use of nuclear dissection tools such as Akahoshi Combo Prechopper, the Zeiss Mi-Loop,[7] and potentially the use of femtosecond laser lens fragmentation.[8]

Cortical Removal

- Cortical removal should be performed with care to minimize zonular stress. One such method, coined the “hurricane cortical aspiration technique,” involves a tangential stripping force perpendicular to the radial fibers.[9]
- Viscodissection with a cohesive viscoelastic can be helpful in gently separating the cortex from the capsule and elevating it away from the posterior capsule.
- In extreme laxity, a “central cortical cleanup” has been described in which central cortex is stripped to create a clear visual axis but peripheral cortex is left in place. However, this should be avoided when possible as residual cortex can form significant a

Soemmering ring and increase the risk of late dislocation.[10]

Capsular Hooks

- Capsular hooks are similar to nylon iris hooks with a looped shape that distributes the force over a larger area thereby decreasing the risk of anterior capsule tear. If these are not available, standard iris hooks can also be carefully employed and passed through standard perilimbal paracentesis incisions until they hook the anterior capsule, thereby substantially stabling the capsule. Care should be taken to avoid aggressive capsule retraction with capsular or iris hooks as this can cause tears in the anterior capsule.[11]

Capsular Tension Rings

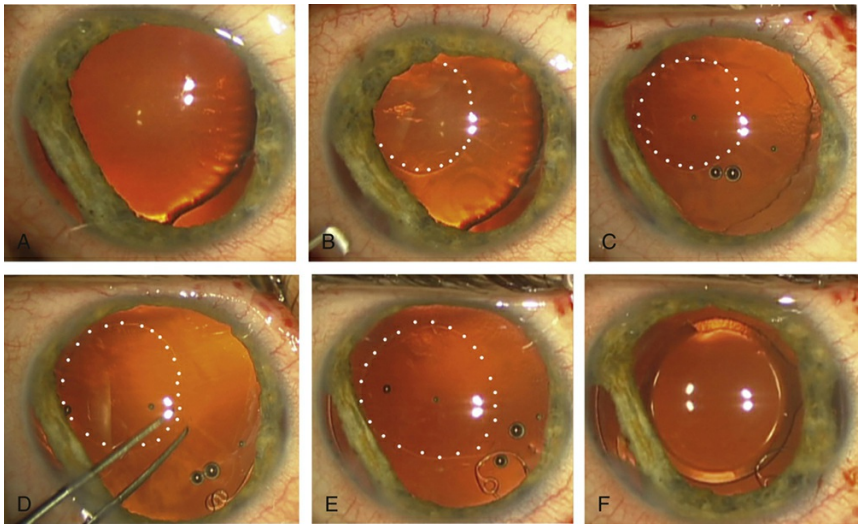

FIGURE 10.2 AND VIDEO 10.1 CE/PCIOL with use of capsular tension support. Seven clock hours of zonular loss was identified in this patient (A). Care was taken to begin the rhexis with forces directed toward the area of zonular weakness. The rhexis (highlighted with dotted white line) was performed in capsular center instead of pupillary center to ensure once recentered the rhexis was positioned centrally (B). After lens extraction the capsular bag remained decentered (C). A CTR was carefully inserted to better stabilize the bag. Although the capsule is distended, it

remains malpositioned (D). Next an Ahmed segment was inserted (E) followed by one-piece IOL implantation in the capsular bag. The sutures to the Ahmed segment were then tied at the appropriate tension to achieve capsular centration (F). (Credit: Christopher Heichel, MD.)

- A CTR is a loop of PMMA that can be utilized to distribute zonular strain more evenly when placed in the capsular bag. The use of a CTR in the setting of anterior or posterior capsular tear is contraindicated as it will likely extend the capsular rent and potentially dislocate.
- CTRs are available in a variety of formats including an open-ring CTR with eyelets on either end that range in size from 12 to 14.5 mm diameter. The Cionni CTR is a modification of this standard CTR with one or more fixation eyelets on angled hooks that protrude over the anterior rhexis that can be utilized for sutured scleral fixation without violation of the capsular bag.
- Both the standard CTR and the Cionni CTR can be inserted with a standard CTR inserter or with a hand-over-hand technique (Fig. 10.2 and Video 10.1).
- Timing of CTR insertion should be carefully considered in order to provide enough support to facilitate lens removal while not violating the capsule or further compromising zonular support. These sentiments are eloquently summarized in the words of Dr Kenneth Rosenthal who advocates “to insert the ring as late as possible—but as early as necessary.”
- If early CTR placement is necessary, the use of a Henderson CTR with multiple loops that create space for cortical cleanup may be preferable.
- When placing a CTR after the use of capsular hooks, take care to lift the capsular hooks anteriorly while inserting the CTR to avoid entrapment of the hooks by the CTR loop or eyelet as this can render capsular hooks removal very challenging.

Capsular Tension Segments

- The CTS introduced by Ike Ahmed has the advantage of ease of insertion in the capsular bag prior to crystalline lens removal. The CTS covers 120 degrees of the capsular fornix and has an anteriorly placed fixation eyelet. In the setting of pre phaco insertion, an iris hook can be inserted through this eyelet to provide capsular support. Once the lens is removed this eyelet can be employed for sutured scleral fixation (Video 10.1).

  A rule of thumb commonly practiced is:

- With zonular weakness of 2 to 3 clock hours, a CTR is recommended in the setting of a one-piece IOL in the bag to enable future scleral fixation of the CTR supported bag complex if necessary.
- With zonular weakness of 3 to 5 clock hours, a CTR is essential and is usually sufficient to support the lens-capsule complex.
- With zonular weakness of 5 to 7 clock hours, a CTR alone is generally insufficient and a scleral fixated CTS should be considered in concert with the CTR. Alternatively, a Cionni ring can be fixated to the sclera. If a CTS or Cionni ring are not available at the time of the initial procedure, a CTR in the bag can later be fixated to the sclera in an ab externo approach once the capsule has adequately fibrosed (>6 to 12 months).
- Dialysis of >7 clock hours can be quite challenging and will usually require capsule support hooks temporarily followed by a CTR and scleral fixation of one to two CTS segments or a Cionni ring with two eyelets fixated to the sclera. If this cannot safely be accomplished, then it may require complete lensectomy, capsulectomy, and implantation of scleral or iris fixated IOL or AC-IOL combined or staged.

POSTOPERATIVE CONSIDERATIONS

All eyes will experience some degree of zonular loss both intraoperatively and postoperatively. In the words of Benjamin Franklin, "an ounce of prevention is worth a pound of cure." To this end, the use of capsular tension support and/or a three-piece IOL for all persons with any identified zonulopathy is recommended. The judicious use of these devices not only decreases the likelihood of lens dislocation but also enables a means of secondary fixation without the morbidity of secondary lens exchange.

References

1. Hasanee K, Ahmed IIK. Capsular tension rings: update on endocapsular support devices. *Ophthalmol Clin North Am*. 2006;19:507-519.
2. Conway RM, Schlotzer-Schrehardt U, Kuchle M, Naumann GO. Pseudoexfoliation syndrome: pathological manifestations of relevance to intraocular surgery. *Clin Exp Ophthalmol*. 2004;32(2):199-210.
3. Blecher MH, Kirk MR. Surgical strategies for the management of zonular compromise. *Curr Opin Ophthalmol*. 2008;19:31-35.
4. Por YM, Lavin MJ. Techniques of intraocular lens suspension in the absence of capsular/zonular support. *Surv Ophthalmol*. 2005;50:429-462.
5. Little BC, Smith JH, Packer M. Little capsulorhexis tear-out rescue. *J Cataract Refract Surg*. 2006;32:1420-1422.
6. Kim DB. Cross chop: modified rotationless horizonal chop technique for weak zonules. *J Cataract Refract Surg*. 2009;35:1335-1337.
7. Ianchulev T, Chang DF, Koo E, et al. Microinterventional endocapsular nucleus disassembly: novel technique and results of first-in-human randomised controlled study. *Br J Ophthalmol*. 2019;103:176-180.
8. Crema AS, Walsh A, Yamane IS, Ventura BV, Santhiago MR. Femtosecond laser-assisted cataract surgery in patients with marfan syndrome and subluxated lens. *J Refract Surg*. 2015;31:338-341.
9. Nakano CT, Motta AF, Hida WT, et al. Hurricane cortical aspiration technique: one-step continuous circular aspiration maneuver. *J Cataract Refract Surg*. 2014;40:514-516.
10. Mansour AM, Antonios RS, Ahmed IIK. Central cortical cleanup and zonular deficiency. *Clin Ophthalmol*. 2016;10:1919-1923.
11. Sati A, Shankar S, Gurunadh VS, Sangwan VS. Iris retractors: the saviours in cataract surgery for cataract in lens coloboma. *BMJ Case Rep*. 2013;2013:bcr2013201955.

CHAPTER 11

Pediatric Cataract Surgery: Special Considerations

Austin R. Meeker, MD, Lucas Bonafede, MD

PREOPERATIVE CONSIDERATIONS

Patient Selection and Timing

- Infants with visually significant congenital cataracts should have surgery by age 6 weeks for those with unilateral cataract and by 8 weeks for those with bilateral cataracts to minimize the impact of vision deprivation on the maturation of visual pathways.[1 - 3]

  Note: In the setting of bilateral cataracts, surgery of the second eye should be performed quickly after the first to avoid the potential for development of amblyopia.[3]

  Note: The timing may need to be altered in premature infants and those with significant systemic comorbidities. Sequential bilateral cataract surgery may be considered in special scenarios where there is a high risk to anesthesia.

- For toddlers and older children, cataract surgery should be considered for any visually significant lens changes limiting best visual acuity to a level that inhibits their daily activities.[3]

- An extensive discussion should be had with the family and patient regarding the risks and potential alternatives to cataract surgery, as well as the need for refractive correction with bifocal lenses and the necessity for long-term follow-up and rehabilitation.

- Visual potential should be discussed on an individual basis with consideration of associated comorbidities and preoperative evaluation.
- Underlying reversible refractive errors and amblyopia should be treated and may delay the need for surgery in select cases.
    - Nonsurgical management with refractive correction, occlusion therapy, and/or mydriasis may be appropriate in select cases.

Preoperative Examination

- A complete ophthalmic examination should be performed, including vision assessment in an age-appropriate manner and pupillary evaluation.
- Undilated and dilated evaluation of the size, location, and morphology of the cataract can help determine a possible underlying cause, the visual significance, and the appropriate treatment.
    - Slit-lamp examination can identify anomalies associated with anterior segmental dysgenesis, glaucoma, uveitis, or systemic disease, which may help to unveil underlying systemic causes of cataract development.
    - In children with unilateral cataract, slit-lamp examination is important to rule out signs of trauma, which may help in the preparation for potential zonular weakness or capsular instability during surgery.
    - Cycloplegic retinoscopic evaluation should be performed and can aid to determine the visual significance of the cataract.
    - The morphology of the cataract may have implications for the surgical plan as well as the need for systemic evaluation.[3] , [4]

- Posterior examination should be performed, including B scan ultrasonography when the view to the posterior segment is obscured by the lens. Comorbid pathology such as persistent fetal vasculature or tumors should be identified preoperatively.
    - The clarity of the view of the posterior pole can also serve as an indicator of the visual significance of the cataract.
- Careful evaluation of the ocular motility and alignment are important to discover associated strabismus and nystagmus.
- Consider evaluation of patients with bilateral cataract and no significant family history for underlying systemic infectious, metabolic, and genetic conditions.[3] ,[a]

Measurements

- When unable to measure axial length and keratometry values in the preoperative setting owing to age or cooperativity, intraoperative measurements should be performed if an IOL is planned as discussed below.

SURGICAL CONSIDERATIONS[A]

Examination Under Anesthesia

- A thorough examination under anesthesia of both eyes should be considered in all pediatric cataract cases.

Traction Suture

- Placement of a superior rectus traction suture should be considered, especially in infants and younger children.

Surgical Incisions

- A superior approach with the use of limbal incisions and a scleral

tunnel when IOL implantation is planned is often preferred in younger patients. Conjunctival closure over the incision may provide additional wound coverage.

Note: A clear corneal incision is preferred by some physicians and may be utilized.

Note: The sideport incision width should be matched to the size of the instrumentation in order to prevent leakage. An MVR blade may be used to facilitate this process.

- Sutured closure of the surgical incisions should be performed. The use of absorbable suture should be considered.

Anterior Capsulotomy

- The anterior capsule is typically approached with the use of a CCC or a vitrectorrhexis.

Continuous Curvilinear Capsulorhexis

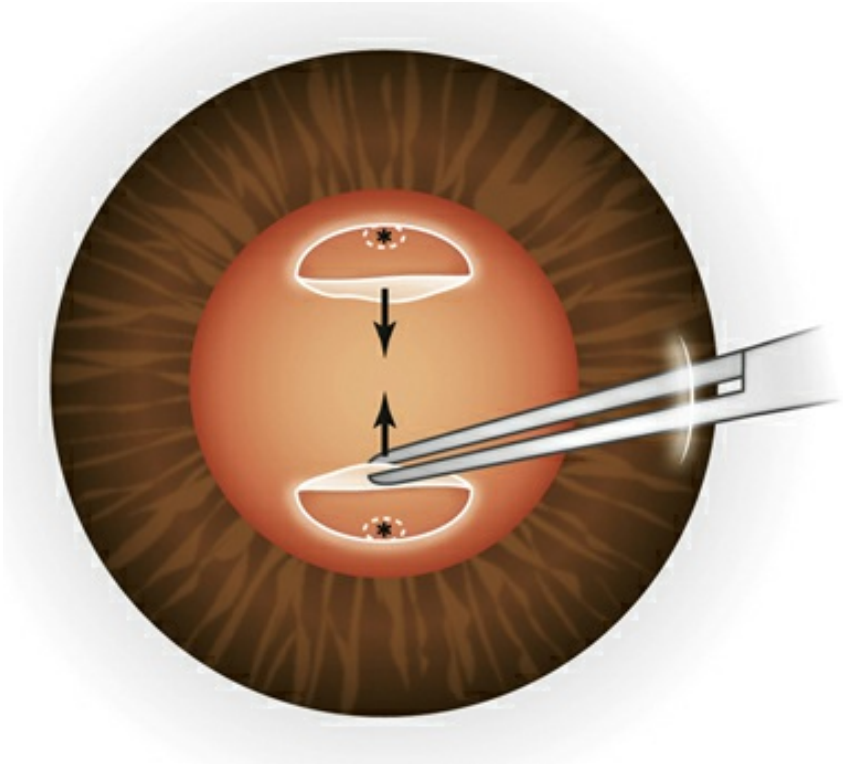

FIGURE 11.1 **The two-incision push-pull technique for capsulorhexis. The stab incisions (*) are made 4 to 5 mm apart at the proximal and distal ends of the desired capsulorhexis. The flaps are pulled toward the center to create 180 degrees of the capsulorhexis at a time.**

- Unlike the anterior capsule of adults, which is prone to tear into a CCC, the pediatric capsule is more elastic, making it difficult to perform a CCC, particularly in children younger than 2 years.
- Pulling perpendicular to the site of the initial capsular tear may aid in performing this maneuver.
- Multiple techniques for CCC creation have been described, including the two-incision push-pull technique wherein two stab incisions are made with an MVR blade separated by 180 degrees and the width of the desired CCC diameter. The distal and proximal flaps are pulled and pushed, respectively, toward the center of the lens until the leading edges meet to create a CCC (Fig. 11.1).[5]

Vitrectorrhexis

- The vitrector may be used to create an opening in the anterior capsule and enlarge it to the desired size.
    - A vitrectorrhexis may be preferred in the setting of a lensectomy without IOL implantation as the entire procedure can be performed without the need to change instruments.

Trypan Blue

- Trypan blue may be useful for visualization in specific circumstances.

Nucleus Removal

- The nuclear material of the pediatric cataract is typically soft without dense nuclear sclerosis found in adult cataracts.
- The vitrector or bimanual aspiration/irrigation is typically sufficient to remove the lens.

Intraocular Lenses

- The decision of whether to insert an IOL at the time of cataract extraction in infants remains controversial. The Infant Aphakia Treatment Study demonstrated higher rates of intraoperative complications and additional intraocular surgeries for infants undergoing cataract extraction with primary IOL implantation versus those left aphakic, although there was no significant difference in corrected visual acuity 10 years postoperatively between the two groups.[6]
- Typically, IOL implantation is performed after the age of 2 years, considered on a case-by-case basis between 7 months and 2 years, and avoided in patients less than 7 months of age.[7, 8]
- Both traditional PMMA and foldable acrylic lenses have been

utilized. In children with significant posterior segment pathology, silicone lenses should be avoided in case the child needs silicone oil in the posterior segment in the future.

- In children who have not completed their growth, the refractive aim must be considered with the expected myopic shift, compliance with therapy and optical correction, and the refractive state of the other eye in mind.
- Patients who are emmetropic postoperatively will become more myopic as they age, and their axial length increases. Conversely, those left hyperopic postoperatively who will be closer to emmetropic after they mature will need strong hyperopic correction with glasses or contact lenses after surgery.
- A common approach to IOL power selection commonly referred to as the Enyedi Rule of Seven recommends a postoperative refractive goal determined by subtracting the age of the patient from 7 (eg, refractive goal of +6 for a 1-year-old, +5 for a 2-year-old, +4 for a 3-year-old).[9, 10]
    - Other strategies exist and may be preferred by individual surgeons.[11, 12, a]

Posterior Capsulotomy

- Visually significant PCO will occur in the vast majority of pediatric eyes with an intact posterior capsule within 18 to 24 months of cataract extraction.
- Although many children older than 5 years of age may cooperate for a YAG capsulotomy, the decision should be made preoperatively on a case-by-case basis depending on the patient's cooperativity and maturity as to whether a primary posterior capsulotomy should be performed at the time of cataract extraction.
- The primary posterior capsulotomy may be performed in several ways:

- In patients planned for aphakia, a posterior capsulotomy may be performed with the vitrector from an anterior approach or as a manual posterior CCC after removal of the lens material. Anterior vitrectomy may be subsequently performed through the posterior capsular opening.
- In patients planned for IOL insertion, the posterior capsulotomy may be made prior to lens implantation. However, if this is the case, care must be taken not to place the haptics and/or optic through the posterior capsular opening during IOL insertion. Alternatively, the posterior capsulotomy may be performed through a pars plana approach where an MVR blade is used to make a pars plana incision through which the vitrector may be inserted. Via the pars plana, a generous anterior vitrectomy and a posterior capsulotomy may be achieved from a posterior approach.

Anterior Vitrectomy

- Anterior vitrectomy at the time of cataract surgery is recommended during posterior capsulotomy for infants and young children to prevent opacification of the visual axis, which can occur along the anterior vitreous face following cataract extraction.[13]

Special Considerations

- A small filtered air bubble may be placed in the anterior chamber at the conclusion of the case to help maintain the anterior chamber and facilitate evaluation of the anterior chamber depth on the first postoperative day.
- Miotic medications can be utilized to constrict the pupil and should be considered following sulcus lens implantation.
- Use of intracameral or subconjunctival antibiotics and subconjunctival steroids should be considered at the completion

of the case.

- Consider intravenous (IV) acetazolamide if there is concern for concurrent glaucoma or if an ophthalmic viscosurgical device was utilized during the case.
- Consider IV steroids if there is concern for an exuberant inflammatory response.
- Consider soft restraints to avoid the child from injuring the eye.

POSTOPERATIVE CONSIDERATIONS[A]

Medications

- Postoperative medication regimens vary between surgeons but include topical steroids, antibiotics, and cycloplegia.[3, 4]
- The need for postoperative oral steroids should be determined on a case-by-case basis.
- IOP management may be required with topical and oral medication.

Visual Axis and Posterior Capsular Opacification

- YAG capsulotomy should be performed for visually significant PCO; as above, the decision of whether to perform a primary posterior capsulotomy intraoperatively depends on the cooperativeness of the patients and their estimated ability to sit for a YAG laser. Although many children older than 5 years may cooperate, consideration should be given to each patient on a case-by-case basis.
- Higher than expected laser power may be required for YAG capsulotomy.
- A dense anterior or posterior membrane may require

intraoperative removal.

Amblyopia

- Close follow-up is needed postoperatively to continue to treat amblyopia with vision correction via spectacles or contact lens, as well as with patching or penalization to the contralateral eye when appropriate.
- In patients with bilateral visually significant cataracts, the second eye should have surgery within 1 to 2 weeks of the first eye cataract extraction to limit the risk of amblyopia.
- The refractive state of the patient must be monitored closely and the spectacle or contact lens prescription adjusted as the patient ages and the eye elongates, creating a shift toward a more myopic state.
    - If a child is left aphakic, the refractive state and optical correction with contact lenses or aphakic glasses should be performed as soon as possible following surgery.
- Bifocals should be prescribed to aid in visual rehabilitation. In patients unable to tolerate bifocals, a mild myopic state after vision correction may be ideal as most of their interactive world is within the near range.

Glaucoma

- Glaucoma following cataract surgery has a high incidence and requires close follow-up to monitor for elevated IOP and optic nerve damage.

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References

1. Birch EE, Stager DR. The critical period for surgical treatment of dense congenital unilateral cataract. *Invest Ophthalmol Vis Sci*. 1996;37(8):1532-1538.
2. Lambert SR, Lynn MJ, Reeves R, Plager DA, Buckley EG, Wilson ME. Is there a latent period for the surgical treatment of children with dense bilateral congenital cataracts? *J AAPOS*. 2006;10(1):30-36.
3. Lambert SR. Childhood cataracts. In: Lambert SR, Lyons CJ, eds. *Taylor and Hoyt's Pediatric Ophthalmology and Strabismus*. 5th ed. Elsevier; 2016:346-361.
4. Enyedi L , Yanovitch T , Gandhi N. The Duke Manual of Pediatric Ophthalmology and Strabismus Surgery. *Wolters Kluwer*; 2021.
5. Nischal KK. Two-incision push-pull capsulorhexis for pediatric cataract surgery. *J Cataract Refract Surg*. 2002;28(4):593-595.
6. Plager DA, Lynn MJ, Buckley EG, Wilson ME, Lambert SR; Infant Aphakia Treatment Study Group. Complications, adverse events, and additional intraocular surgery 1 year after cataract surgery in the infant Aphakia Treatment Study. *Ophthalmology*. 2011;118(12):2330-2334.
7. Wilson ME, Bartholomew LR, Trivedi RH. Pediatric cataract surgery and intraocular lens implantation: practice styles and preferences of the 2001 ASCRS and AAPOS memberships. *J Cataract Refract Surg*. 2003;29(9):1811-1820.
8. Struck MC. Long-term results of pediatric cataract surgery and primary intraocular lens implantation from 7 to 22 months of life. *JAMA Ophthalmol*. 2015;133(10):1180-1183.
9. Enyedi LB, Peterseim MW, Freedman SF, Buckley EG. Refractive changes after pediatric intraocular lens implantation. *Am J Ophthalmol*. 1998;126(6):772-781.
10. Sachdeva V, Katukuri S, Kekunnaya R, Fernandes M, Ali MH. Validation of guidelines for undercorrection of intraocular lens power in children. *Am J Ophthalmol*. 2017;174:17-22.
11. Serafino M, Trivedi RH, Levin AV, et al. Use of the Delphi process in paediatric cataract management. *Br J Ophthalmol*. 2016;100(5):611-615.
12. Dahan E, Drusedau MU. Choice of lens and dioptric power in pediatric pseudophakia. *J Cataract Refract Surg*. 1997;23(suppl 1):618-623.
13. Vasavada AR, Nihalani BR. Pediatric cataract surgery. *Curr Opin Ophthalmol*. 2006;17(1):54-61.

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[a]The topic of pediatric cataract is discussed at length in *the Duke Manual of Pediatric Ophthalmology and Strabismus Surgery*.[4] Please refer to the pediatric cataract chapters for extensive discussion regarding specifics on laboratory workup, step-by-step instructions for the surgical technique, strategies for IOL calculations, postoperative medical regiments, and evaluation and management of surgical complications.

CHAPTER 12

Management of Postoperative Complications of Cataract Surgery

Matias Soifer, MD

Several complications can occur after cataract surgery. It is critical for the cataract surgeon to be able to identify these conditions and treat them correctly. In this chapter, we review some of the common complications encountered in the postoperative period.

RETAINED LENS FRAGMENT

Definition

This condition is a rare occurrence that occurs when a small portion of the lens nucleus or cortex remains inadvertently in the AC or angle after cataract surgery.

Risk Factors

Risk factors include myopic eyes, corneal arcus, light iris pigmentation, complicated surgeries (ie, poor pupillary dilation, zonular laxity, capsular rupture, dense cataracts), and inexperienced surgeons.

Presentation

Presentation includes isolated, focal corneal edema (usually inferior), persistent AC inflammation, ocular hypertension, visible retained lens fragment on slip-lamp biomicroscopy or on gonioscopy, and rarely

macular edema.

Diagnosis

Usually, the lens fragment is visible upon clinical examination on the slit lamp. Fragments are usually located inferiorly, but at times, they can be lodged in the angle and can only be identified by gonioscopy. When it is not seen on clinical examination, UBM or AS-OCT can be performed. With the combination of a thorough clinical examination and ancillary imaging, it is highly likely that the fragment will be found.

Management

We strongly encourage surgical intervention to solve this condition. Oftentimes, differentiation of whether the fragment is nuclear or cortical matter is challenging. Nuclear material is less likely to dissolve with the use of exclusive medical management. Expeditious surgery can also allow for rapid resolution of corneal edema and improvement in visual acuity. Prior to surgery, administer a miotic agent to the eye (ie, pilocarpine 1%), to avoid movements of the lens fragment through the pupil.

Surgical Technique

Enter the eye through the previously made paracentesis or main wound. Inject viscoelastic to protect the cornea and isolate the lens fragment in a particular quadrant of the eye. Consider using the irrigation and aspiration devices in a bimanual technique to remove the lens fragment. Use slow-motion fluidics to prevent excessive movement of the lens fragment throughout the AC. If the lens fragment is large, the phacoemulsification probe may be required. Utilize intraoperative gonioscopy to analyze the angle for any residual fragments.

ENDOPHTHALMITIS

Definition

Endophthalmitis is intraocular inflammation as a result of an infection of the vitreous and/or the aqueous humor, due to entry of a microorganism intraoperatively or postoperatively. Presentation can be acute or chronic, and typically the etiology is secondary to a bacteria.

Risk Factors

Risk factors include a poorly sealed corneal incision, posterior capsule rupture, complex surgery, eyelid or conjunctival diseases (ie, blepharitis), immunosuppression, age > 85 years, use of silicone IOLs.[1]

Presentation

Most commonly, patients present within the first 3 to 5 days after surgery and 77% present within the first 2 weeks. A red, painful eye with diminished visual acuity is the key presenting feature. On slit-lamp examination, there is increased AC inflammation with hypopyon or fibrin formation in the AC. Vitritis can be seen as well, and membranes can be detected with ultrasonography.

Diagnosis

The diagnosis is largely clinical, and patients present with the signs and symptoms stated above. The differential diagnosis can include TASS or a flare of an underlying uveitic disorder. A trial of topical corticosteroids can be attempted if there is reason to believe these other etiologies are more likely; however, if there is no response, the possibility of endophthalmitis has to be seriously considered. When there is significant media opacity to fully assess the posterior segment, an ultrasound has to be performed. Asymmetric chorioretinal thickening and diffuse vitreous opacities with membranes are findings highly suggestive of endophthalmitis. The gold standard for diagnosis is culture of an intraocular sample, ideally the vitreous gel, since it has a higher yield of positive cultures. This can be done with a

vitreous needle tap or during vitrectomy with a cutting/aspirating probe.

Management

There are two acceptable options for management: Pars plana vitrectomy or vitreous tap and injection of intracameral antibiotics ± antifungals and steroids. According to the Endophthalmitis Vitrectomy Study,[2] that decision-making process for intervention is largely guided by the patient's visual acuity.

Only LP Vision

Patients with LP vision had a significant chance of improving vision after immediate pars plana vitrectomy as compared with vitreous tap and injection.

HM Visual Acuity or Better

Patients with HM vision or better did not show significant differences in final visual acuity when treated with either pars plana vitrectomy or vitreous tap and injection.

Pars Plana Vitrectomy

The standard technique involves a standard three-port setup. A vitreous sample of 0.2 to 0.5 mL is first obtained without infusion using gentle manual aspiration into a syringe with a high cutting rate. After this, the infusion is initiated and a core vitrectomy performed. Intravitreal medications are injected at the conclusion of the case.

Vitreous Tap and Injection

Empirical therapy covers only bacteria, the main etiologic agent. Regardless, every case must be analyzed based on the patient's risk factors and clinical presentation, and intravitreal steroids (ie, dexamethasone) and/or antifungals (ie, amphotericin or voriconazole) can be considered. The usual antibiotics used are vancomycin

1.0 mg/0.1 mL and ceftazidime 2.25 mg/0.1 mL. The vitreous needle tap is achieved by inserting a 23G, 25G, or 27G needle attached to a tuberculin syringe into the vitreous cavity through the pars plana. First, a controlled aspiration is done. If no fluid vitreous can be obtained with a needle tap, a vitreous biopsy must be performed instead to avoid aspirating the formed vitreous. AC samples can also be obtained if the vitreous sample is inadequate. Afterward, the antibiotics are injected into the vitreous cavity.

TOXIC ANTERIOR SEGMENT SYNDROME

Definition

This syndrome involves sterile inflammation of the AC after cataract surgery.

Etiology

- Intraocular irrigating solutions with additives or conservants, with incorrect pH (<6.5 or >8.5) or abnormal osmolarity (<200 to >400 mOsm).
- Denatured viscoelastic.
- Intraocular medications (antibiotics or mydriatics).
- Inadequate sterilization of surgical instruments and tubing can maintain residual detergents, bacterial endotoxins, or metallic precipitates.
- Preservatives.
- High friction between instruments during surgery may release metallic elements into the AC.

Presentation

The condition has an acute onset, typically within 24 hours after

cataract surgery. Classic signs include diffuse corneal edema (limbus to limbus), hypopyon or fibrin formation, and pupillary mydriasis. There is no significant pain or conjunctival hyperemia, and the inflammation is restricted to the anterior segment. The inflammation typically has a good response to topical steroids administered at high frequencies (ie, every hour).

Diagnosis

Diagnosing this condition means excluding the possibility of infectious endophthalmitis. Patients with endophthalmitis typically have pain, later onset of intraocular inflammation, and involvement of the posterior pole with minimal response to steroid therapy. The ophthalmologist must have a low threshold to perform vitreous and AC taps for culture. These have to be considered according to the severity of the case and the response to topical steroids every hour.

Management

TASS is treated with topical corticosteroid of high penetrance (ie, 1% prednisolone acetate) every hour or difluprednate 0.05% 4 to 6 times a day. The response to steroid therapy is usually rapid, but the healing process may take several weeks. Mild cases may resolve within a few weeks, but moderate and severe presentations will likely take months to resolve and even need systemic corticosteroids to alleviate the inflammation. These cases may develop long-standing damage, such as persistent corneal damage needing keratoplasties, macular edema, or glaucoma secondary to trabecular meshwork damage. Patients should be monitored closely, especially in the early management period to assess their response. Prevention is the fundamental aspect to avoid the occurrence of the syndrome. The American Society of Cataract and Refractive Surgery has assessed and established protocols for the prevention of TASS.[3]

WOUND BURN

Definition

Wound burn is the incisional thermal damage due to increased exposure to high temperature causing collagen denaturalization. This leads to wound closure failure, stromal and endothelial damage, delayed corneal healing and edema, as well as increased corneal astigmatism.

Risk Factors

- Patient anatomic features: Prominent orbital border or sunken eye.
- Dense cataract.
- Narrow and long tunnel corneal incision.
- Significant tip angulation and friction movement during surgery.
- Phacoemulsification technique, prolonged tip occlusions, and amount of energy delivered.
- Infusion failure.
- AC blockage due to abundant viscoelastic.

Presentation

Presentation includes failure to close the incision, corneal edema, haze, and striae typically directed toward the wound. Posteriorly it can present with corneal scarring and even corneal melt.

Prevention

- Know the patient's predisposing factors and act accordingly. In a patient with a prominent orbital ridge, perform a temporal clear corneal incision. If a superior approach is taken, secure the patient's head to avoid forced maneuvers.
- Make sure there is enough irrigation and flow along the surgery.

- Avoid incisions that are tight and with excessive intrastromal tunnel length. It is safer to seal the first wrong incision and create a second one than to have a wound burn.
- Perform viscoelastic aspiration before beginning with phacoemulsification.
- Avoid significant tip angulations. A temporal and well-constructed incision will support this.
- Avoid prolonged occlusion of the tip.
- Use appropriate forms of energy delivery, such as pulse or burst or torsional modes of phacoemulsification.
- Use chop techniques as much as possible.
- When irrigating the cornea, the assistant points specifically to the incision.

Management

First, stop phacoemulsification and remove the probe. Immediate closure of the wound is imperative to prevent further complications. Ideally, closure with interrupted 10-0 nylon sutures would suffice, but that is not always the case. When the lesion has a "fish mouth" appearance (ie, the anterior lip of the incision is curve shaped and distant to the posterior corneal incision lip), performing a radial "classical" suture will not seal the incision and may even complicate the closure owing to opposing corneal forces. In those cases, a perpendicular suture or gape suture above the opening of the incision has to be made, such that the anterior and posterior parts of the tunnel are first secured. Then, radial or crossed sutures can be placed. The use of tissue adhesive or bandage contact lens can be of great utility. Perform Seidel testing with a fluorescein strip to ensure no leakage is present.

DESCEMET MEMBRANE DETACHMENT

Definition

- It is the separation of the Descemet membrane and endothelium during cataract surgery, which leads to localized corneal edema in the area of detachment.

Risk Factors

- Shallow AC.
- Use of blunt instruments or dull blades.
- Inadvertent insertion of instruments or solutions between the corneal stroma and Descemet membrane.
- Injury to the Descemet membrane during any point of surgery.
- Surgeon immaturity.

Presentation

Localized or diffuse corneal edema with stromal swelling and epithelial bullae, commonly over the area of DMD.

Diagnosis

Slit-lamp examination can be enough to diagnose DMD. In cases of moderate to severe corneal edema, topical glycerin can be applied to dehydrate the cornea and have better visualization. UBM is a useful tool to detect DMD, but AS-OCT is considered the most effective tool for diagnosis, especially in cases of significant corneal opacification and poor visualization.

Management

The extension, height, and location relative to the pupil are the usual determinants of the choice for management for DMD. In general,

small, peripheral, simple DMDs are treated conservatively. In contrast, large, central, complex DMDs require surgical management.

Conservative Management

According to the HELP protocol described by Kumar et al,[4] conservative management can be applied to certain scenarios: DMD less than 1.0 mm in length and less than 100 mm in height in any part of the cornea, DMD up to 2.0 mm in length and up to 300 mm in height in the paracentral and peripheral cornea, and DMD longer than 2.0 mm and higher than 300 mm in the peripheral cornea. Conservative management can be observation or topical medications, such as hyperosmotic agents (sodium chloride 5% eye drops) or topical corticosteroids (prednisolone acetate 1% or dexamethasone 0.1%). In these scenarios, the reattachment rate is close to 97%.

Surgical Management

The aforementioned algorithm reserves surgical treatment for DMDs in the central cornea of 1 to 2 mm length with a height of 100 to 300 mm, and in the paracentral or peripheral cornea, when longer than 2 mm and higher than 300 mm. The most common surgical technique is descemetopexy with long-lasting gases, such as 15% to 20% SF6 and 12% to 14% perfluoropropane (C3F8). This modality has a reattachment rate of 95.8%. Prior to operating, the localization of DMD has to be determined on slit lamp or AS-OCT. Once localized, a paracentesis is created in the cornea where the Descemet membrane is still attached and gas is injected with a 27G or 30G needle to create a bubble that traverses under the DMD that attaches the disconnected membrane. To drain the liquid between the reattached Descemet membrane and the corneal stroma, venting incisions can be created or fluid can be aspirated with a needle in the pre-descemetic space. To avoid pupillary block, cycloplegics, laser iridotomy, or antiglaucoma medications can be considered.

References

1. Bainbridge JWB, Teimory M, Tabandeh H, et al. Intraocular lens implants and risk of endophthalmitis. *Br J Ophthalmol*. 1998;82(11):1312-1315. doi:10.1136/bjo.82.11.1312
2. Endophthalmitis Vitrectomy Study Group. Results of the Endophthalmitis Vitrectomy Study. A randomized trial of immediate vitrectomy and of intravenous antibiotics for the treatment of postoperative bacterial endophthalmitis. *Arch Ophthalmol*. 1995;113:1479-1496.
3. *TASS Registry Background*. ASCRS. Accessed August 1, 2020. https://ascrs.org/tools/tass-registry.
4. Kumar DA, Agarwal A, Sivanganam S, Chandrasekar R. Height-, extent-, length-, and pupil-based (HELP) algorithm to manage post-phacoemulsification Descemet membrane detachment. *J Cataract Refract Surg*. 2015;41(9):1945-1953. doi:10.1016/j.jcrs.2015.01.020

Section 3

Posterior Capsular Rupture and Vitrectomy

CHAPTER 13

Causes and Signs of Posterior Capsular Rupture

Andrew Rollin Davis, MD

PREOPERATIVE CONSIDERATIONS

It is important to consider the major risk factors for PCR. These include:

- Prior penetrating trauma with resultant zonulopathy or an already compromised anterior or posterior capsule.
- Poorly dilating pupil secondary to posterior synechiae or iris atrophy from prior episodes of intraocular inflammation chronic miotic agent use.
- Floppy iris in the setting of medication or supplements use (ie, tamsulosin and other alpha-1 antagonists, finasteride, saw palmetto).
- Pseudoexfoliation[1] causing poor dilation and zonulopathy.
- Dense lens.
- Shallow AC.
- High myopia with a large eye and axial length.
- Corneal haze impairing visualization.
- Previous lens dislocation.
- Posterior polar cataract.

- Previous vitrectomy[2] or previous intravitreal injection use that can cause preexisiting posterior capsular compromise.
- Neurologic or mental disorders that can generate involuntary movements during surgery.
- Obesity that can cause increased vitreous pressure during surgery.

POSTERIOR CAPSULAR RUPTURE

When recognizing a PCR intraoperatively, it is important to pause and reflect on why this occurred.

Questions to ask yourself include:

- Did the patient have preoperative risk factors that you did not consider?
- Did you notice cardinal signs of PCR, such as a sudden dilation of the iris or deepening of the AC?
- Did any of the nuclear fragments appear to be moving posteriorly during the course of the case and not reaching your phacoemulsification tip?[3]
- Are there any retained lens fragments that may not have been removed that require an additional surgery?
- Did the patient not receive adequate anesthesia? Would a retrobulbar block or general anesthesia have been advisable if the patient was known to move more frequently than other patients?

Signs of PCR include (Fig. 13.1):

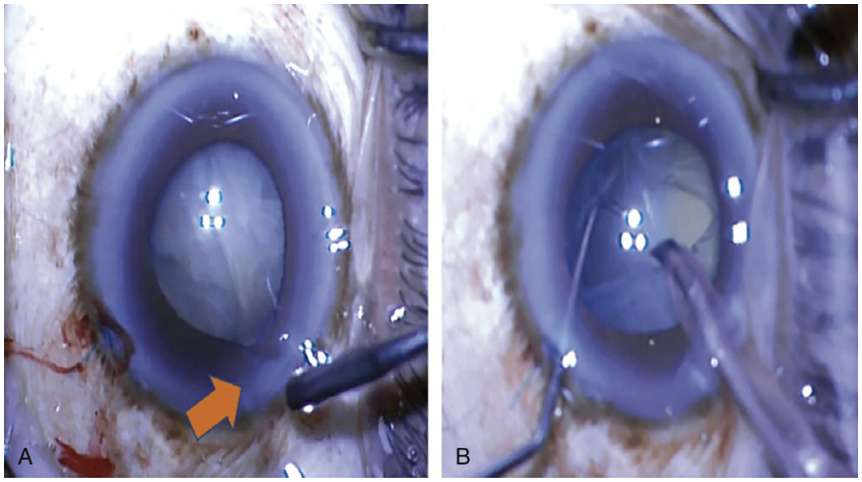

FIGURE 13.1 **A. Momentary pupillary dilation with iris prolapse out of the main wound (orange arrow) after hydrodissection. B. Soon after in the case, a complete PCR was noted with posterior dislocation of the entire lens nucleus. (Courtesy of Nandini Venkateswaran, MD.)**

- Sudden pupillary dilation.
- Sudden deepening of the AC.
- Posterior dislocation of the nucleus.[2]
- Vitreous in the AC that is being aspirated by the phacoemulsification time.
- An anterior capsular tear that may have occurred during capsulorhexis creation or during nucleus disassembly that extended posteriorly.
- Frank posterior capsular tear that is visualized as the case proceeds.

SURGICAL PLANNING

Prior to your operating room day, it is important to identify the patients on your surgical list who may have underlying risk factors for a complex surgery or a PCR. Inform your operating room team of the need for additional supplies or time during this case in the event

of a complication.

Let the OR team know you may need

- Anterior vitrector—bimanual setup.
- Dilute preservative free triamcinolone to "stain" the vitreous (5 mg/mL).[4]
- Miochol to constrict the pupil.
- 10-0 nylon to suture the wound.
- More sedation from the anesthesia team as the patient will likely have prolonged surgery that may be uncomfortable.

Please see Chapter 14 on Anterior Vitrectomy for further details on the anterior vitrectomy procedure.

References

1. Kohnen T, Wang L, Friedman N, Koch D. Complications of cataract surgery. In: Yanoff M, Duker JS, eds. Ophthalmology. 5th ed. Elsevier; 2017:402–409:5.16.
2. Alberto Castro M. Intraoperative signs of posterior capsular rupture. EyeWiki. Published 2019. Accessed August 30, 2020. eyewiki.aao.org. https://eyewiki.aao.org/Intraoperative_signs_of_posterior_capsular_rupture
3. Devgan U. How to perform an anterior vitrectomy. EyeNet Magazine. 2006:2. Accessed April 8, 2020. https://www.aao.org/eyenet/article/how-to-perform-anterior-vitrectomy
4. Reeves SW, Kim T. How to perform an anterior vitrectomy. American Academy of Ophtalmology. EyeNet Magazine. Published 2006. Accessed April 8, 2020. https://www.healio.com/ophthalmology/cataract-surgery/news/print/ocular-surgery-news/%7Bd135bc8e-c768-43c9-9946-b4cf9b72b617%7D/how-to-perform-an-anterior-vitrectomy

CHAPTER 14

Anterior Vitrectomy—Surgical Approach and Settings

Clayton L. Falknor, MD

PREOPERATIVE CONSIDERATIONS

In situations when vitreous is encountered during cataract surgery, it is important to avoid the following:

- Causing any further vitreous prolapse beyond what has already occurred.
- Manipulating the vitreous in ways that may cause traction and risk formation of a retinal tear.
- Losing any additional lens fragments to the posterior segment.
- Worsening capsular damage that may preclude IOL implantation in the most suitable location possible.

Prevent Causing More Vitreous Prolapse

- Vitreous flows like a liquid from high to low pressure along a gradient.
- Do not allow the AC to decompress or collapse, especially when instruments are removed from the AC.
- Prevent wound leaks during and after the vitrectomy procedure. Suture wounds closed, and make new ones if necessary.
- Work through water-tight incisions only, and know gauge of instruments you will use for vitrectomy when making new

incisions.

- Be liberal in placing dispersive OVD to hold vitreous back at the capsule rupture site.

Avoid Manipulation of the Prolapsed Vitreous

- Pulling on vitreous strands in the AC has a distant site of traction on the retina.
- Once vitreous prolapse has occurred, do not sweep instruments across the AC that may pull on the vitreous strands.
- Do not use Weck spears to pull vitreous strands out of the incisions, and cut with scissors if you already know there is vitreous present in the AC. You want to remove the strands as far posteriorly as possible to avoid traction.

Take Measures to Prevent Loss of Lens Fragments Into the Posterior Segment

- Use the OVD to elevate free-floating lens fragments from the capsular bag into the AC.
- Use the vitrector to remove the lens fragments rather than continuing to use the phaco handpiece.
- Be slow and deliberate in removing the lens fragments, using initially the ICA setting to remove the surrounding vitreous and later the IAC settings to allow for removal of the lens fragments.

Avoid Worsening Any Capsular Damage

- Be sure not to accidently worsen the posterior capsule rupture or rent.
- More importantly, do not accidently cause damage to an intact anterior capsule rim. So long as this remains intact, your lens placement options are better, particularly for sulcus lens

placement or optic capture.

- A posterior capsular rent may be extended into a circular capsulorhexis after vitreous clean-up is completed if needed.

SURGICAL PROCEDURE: ANTERIOR VITRECTOMY

- Stop active maneuvers in the anterior segment but do not remove phaco handpiece from the main incision at this point. Keep in foot pedal 1, or keep continuous irrigation active.
- Have your surgical assistant lower the bottle height on the phaco machine to approximately 50 cm.
- Through a paracentesis using the other hand, inject dispersive OVD (ie, Healon Endocoat, VisCoat, OcuCoat). Inject over the location of vitreous prolapse, such as over a capsule rupture site or area of zonular dialysis. Do not overinflate, as increased pressure here can expand a capsular rent. I like to inject near the main incision internally, as well, to reduce fluid leak when I remove the phaco handpiece.
- Remove the phaco handpiece.
- Suture the main incision closed with 10-0 nylon and bury the knot. A wound leak could lead to additional vitreous prolapse into the AC or out the wound.
- Ask your surgical assistant to prepare for vitrectomy. There should always be a vitrectomy pack in the operating room, often within your phaco machine's drawers or bays.
- Ask the circulator to obtain additional OVD, preservative-free triamcinolone (ie, Triessence), or prepare your own by filtering preservative from Kenalog, as well as a miotic agent (ie, Miostat or Miochol).

Reassure the patient. If your patient is lightly sedated and under topical anesthesia, ask your anesthesia provider to increase their intravenous sedation since the case will be lengthier and the patient may be concerned if there is suddenly more room movement and talking during the procedure. You may also place a small sub-Tenon block if you prefer.

- Make a second, and possibly a third, paracentesis through which to perform bimanual vitrectomy. Consider a 20G (~0.9 mm) or 23G MVR blade (~0.65 mm), which will allow your 20G or 23G sleeveless vitrector to fit in a water-tight manner. Some phaco machines allow for 25G vitrectomy, as well.

Although most devices now offer bimanual vitrectomy handpieces, there are coaxial setups, as well. Avoid using coaxial vitrectomy if at all possible, as the wound must be larger and flow is directed in the same plane as the vitreous cutting.

- Ensure proper settings on the phaco machine for vitrectomy. Start with the ICA mode, so that cutting starts before aspiration. Increase the cut rate to maximum possible. Older machines may have a maximum cutting speed of 400 to 800 cpm (cuts per minute) or less, whereas newer machines usually cut much faster (2,500 to 7,500 cpm). Lower the bottle height to 50 cm initially, but adjust to keep it high enough to maintain a formed chamber based on the flow rate (or reduce the IOP on Alcon Centurion to ~25 mm Hg). Reduce vacuum (150 to 200 mm Hg) and flow rates (15 to 20 mL/min) so that movement is slower in the AC. Use a peristaltic pump if available on your machine rather than venturi.

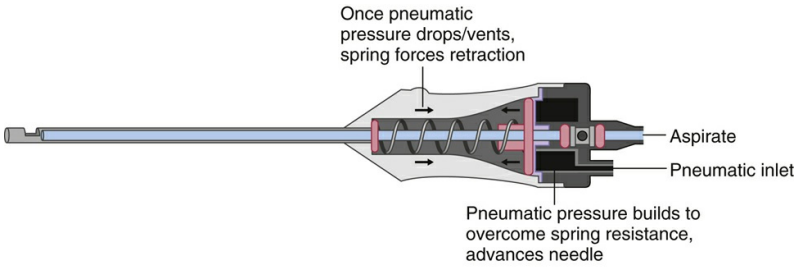

FIGURE 14.1 **Guillotine-style vitrector diagram.**

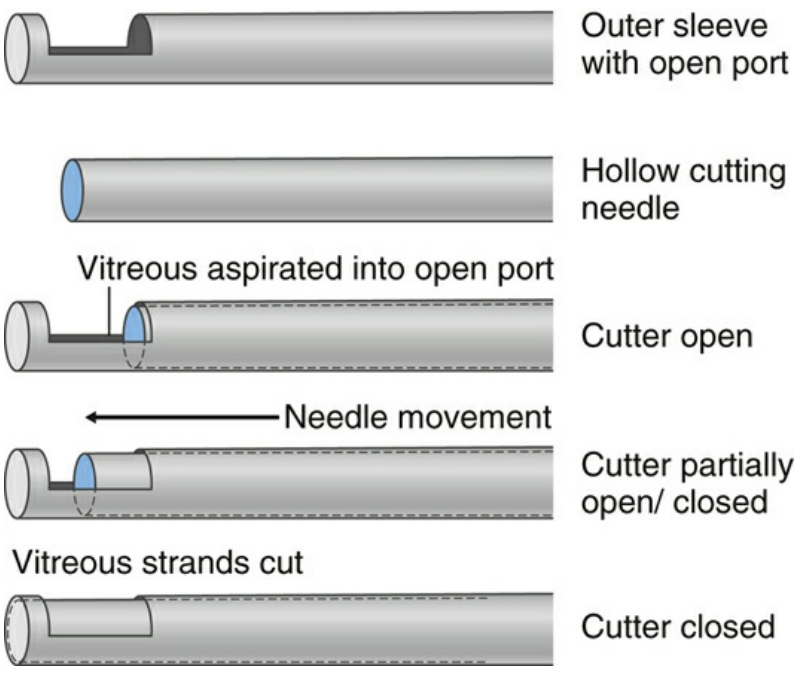

FIGURE 14.2 **The typical guillotine pneumatic vitrector uses a hollow needle within a sleeve with an opening near the tip. Aspiration causes the vitreous to enter the port, and the needle is propelled forward within the sleeve by air or gas pulses to sever the vitreous entering the port into small fragments. A spring action pushes the needle back and reopens the port after each cut. These vitreous fragments are aspirated through the cutter's needle. The faster the cutting speed, the smaller the quantity of vitreous that enters the port before being cut, reducing the tractional forces on the vitreous.**

Maximum cut rate settings: AMO Whitestar Signature Pro allows up to 2,500 cpm with 20G, 23G, or 25G. Alcon Centurion allows up to 4,000 cpm using 23G only. B&L Stellaris Elite allows up to 7,500 cpm for 20G, 23G, 25G.

- Irrigate high and cut low. Keep irrigation anterior (directed above the iris plane into the angle) and cutter deep to go after vitreous from where it presents (start cutting before aspiration, start within the capsular bag, and direct posterior to capsule through rent before aspiration) (Figs. 14.1 and 14.2).
- Infusion can be via an irrigation handpiece or an AC maintainer (such as 20G or 23G Lewicky AC maintainer). I like using the irrigation handpiece for additional control of the eye position and stability by oar-locking in the paracentesis wound.
- Always keep the vitrector port facing the vitreous centrally, and always be able to visualize the tip. Stay away from the pupil margin and the anterior capsule.
- Go slowly and deliberately while you perform the vitrectomy, as the flow rate is low, and do not move higher in the AC until vitreous is fully removed at the capsular defect region.
- Do not move the vitrector tip quickly or while cutting is off to avoid traction on vitreous strands. Continue cutting, but stop aspiration when removing the vitrector from the eye.
- Inject a small amount of preservative-free triamcinolone into the AC, and then gently irrigate with BSS to stain vitreous strands in the AC and incarcerated in wounds. Do not overinject. Then repeat vitrectomy until all stained vitreous is removed.
- When no more vitreous is seen (reinject triamcinolone to confirm), switch the vitrectomy mode to IAC and keep in foot pedal position 2 to aspirate any residual lens fragments or cortex from the capsular bag, then use position 3 to remove the larger pieces. Engage the cutter in position 3 if you suspect any vitreous has

presented.

- You can also use a 23G Simcoe I/A cannula (or a separate J-cannula if using an AC maintainer) to remove the cortex.
- Inject cohesive OVD and inject the IOL, with the site depending on the capsule status. If placing a three-piece IOL in the ciliary sulcus, try to capture the optic posteriorly through the anterior capsulotomy to maintain centration and a two-chamber eye).
- Following placement of the IOL, inject miotic (Miochol or Miostat) and watch for peaking of pupil to suggest more vitreous prolapse into the AC.
- If a peripheral iridotomy is needed, use the vitrector for this (IAC, reduce cut speed significantly, often to a cut rate of 100 cpm).
- Use the vitrector in IAC mode to aspirate the OVD from the AC at the conclusion of the case.
- Strongly consider intracameral antibiotic injection (such as preservative-free moxifloxacin) to reduce postoperative endophthalmitis risk. The benefit is especially pronounced in cases of capsule rupture and vitreous prolapse.
- Recheck the wounds with Weck spears and suture any leaking wounds.
- Cover the eye with a shield or patch if any block was given.

ALTERNATIVE APPROACH: PARS PLANA ANTERIOR VITRECTOMY

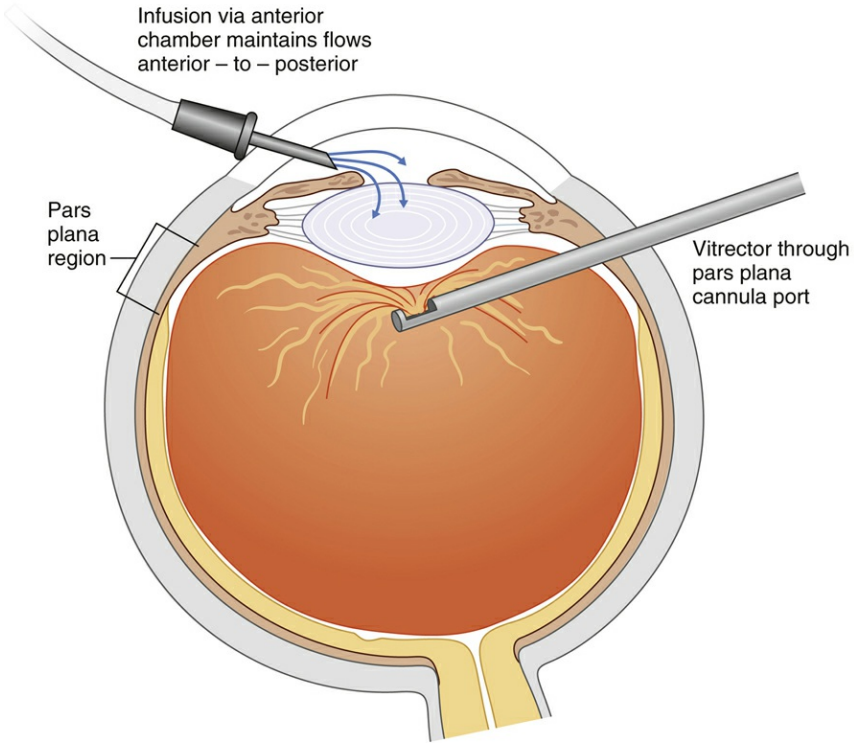

FIGURE 14.3 **Cutting and aspiration occurs posterior to the capsular rent, truncating vitreous strands behind the site of anterior vitreous prolapse. This advantageous position from which to perform anterior vitrectomy may reduce tractional forces on the vitreous base and allow for more complete vitreous removal than from a limbal incision.**

- An alternative method to anterior vitrectomy is via a more posterior wound through the pars plana, rather than the anterior wound at the limbus. This affords an advantageous direction from which to remove anteriorly prolapsed vitreous and may reduce the risk of retinal traction during the vitrectomy (Fig. 14.3).
- Ensure the eye is moderately pressurized with sealed or sutured limbal incisions.
- If there is communication between the anterior and posterior segments (ie, a capsular or zonular defect), then infusion can be placed anteriorly or posteriorly. An AC maintainer, as mentioned above, allows for flow to move anterior to posterior, helping prevent more anterior prolapse of vitreous or hydration of the

vitreous.

- Use a valved trocar cannula system to penetrate the sclera in a beveled fashion at the level of the pars plana, typically between 3 and 4 mm posterior to the limbus. This should usually be placed inferotemporally or superotemporally based on the operative eye and handedness of the surgeon to allow a comfortable angle to approach the vitreous prolapse with the vitrector.
- Using forceps or a cotton-tipped applicator, gently slide the conjunctiva overlying the site of the sclerotomy a few millimeters to one side so that the penetration of the conjunctiva does not lay directly over the sclerotomy later.
- Make a biplanar sclerotomy incision by initially inserting the trocar blade at a 30- to 45-degree angle to the sclera to tunnel 1 to 2 mm before lifting the trocar handle to penetrate straight into the posterior segment space. Use trocar port grasping forceps to hold the port while removing the bladed handle.
- Insert the vitrector through the cannula port and direct the tip centrally and posterior to the posterior capsule with the port opening facing anteriorly.
- Perform the vitrectomy slowly and deliberately to pull the anteriorly prolapsed vitreous back posteriorly through capsular or zonular defect, still using the ICA setting and maximum cutter speed as noted previously. Take care to avoid contacting the posterior capsule inadvertently.
- If retained nuclear fragments are encountered, reduce the cut speed significantly to enable the fragments to be cut and aspirated with the vitrector.
- Confirm completion of the anterior vitrectomy with a conservative reinjection of the preservative-free triamcinolone in the AC.
- When removing the ports, gently massage the conjunctiva overlying the sclerotomy with a cotton-tipped applicator. If a

persistent wound leak is noted, suture the wound closed through both the conjunctiva and sclerotomy with a 7-0 or 8-0 interrupted Vicryl suture.

POSTOPERATIVE CONSIDERATIONS

- After successful clean-up of the vitreous, be sure to do careful dilated fundus examinations for peripheral retinal tears at regular intervals. Have a low threshold to refer to a retina specialist for consultation to inspect the peripheral retina.
- IOP spikes are more common after ruptures in the capsule during cataract surgery.
- Conversely, hypotony due to wound leaks need to be addressed promptly if found.
- Give the patient careful instructions to report retinal tear or detachment symptoms, as well as endophthalmitis symptoms, as their risk is significantly elevated.
- If an IOL was not placed during the procedure, consider timing and techniques for secondary IOL placement later.
- Plan to use topical steroids and NSAIDs for a longer period of time, such as 6 weeks.

ACKNOWLEDGMENTS

Assistance with illustrations provided by Lori Falknor.

Section 4

IOL Considerations

CHAPTER 15

Toric Intraocular Lenses

Preeya K. Gupta, MD

Corneal astigmatism is common among patients undergoing cataract surgery. Toric IOLs are a commonly used tool to correct astigmatism at the time of cataract surgery.

CONSIDERATIONS FOR A TORIC IOL

- **Corneal astigmatism magnitude**—generally patients with with-the-rule astigmatism greater than 1.5 D and against-the-rule astigmatism greater than 1 D are candidates for toric IOL.
- **Topography** is necessary to rule out irregular astigmatism.
- **Ocular surface conditions** such as anterior basement membrane dystrophy, pterygium, and dry eye can create irregular astigmatism, and as such patients should be screened for this prior to surgery.
- **Consistency of magnitude and axis of corneal astigmatism** is critical for success—consider performing more than one set of biometry and topography measurements prior to choosing a toric IOL implant.

SURGICAL TECHNIQUE

- Mark the cornea with horizontal and vertical marks using a preoperative marking device while the patient is upright in the preoperative or operative area to avoid placement error induced

by cyclotorsion.

- Intraoperatively, mark the intended axis of astigmatism.
- Perform cataract surgery with standard technique.
- Insert the desired toric IOL and then remove any viscoelastic from behind the IOL.
- Align the IOL within 30 degrees of the intended axis (often counterclockwise from the intended axis of placement as it is easier to rotate the lens clockwise) and continue to remove viscoelastic from the anterior chamber.
- Gradually move the IOL to properly align with the axis of astigmatism.
- Be sure that the primary and secondary incisions are watertight, and secure to avoid postoperative shallowing of the chamber, which may lead to toric IOL rotation.

ADDITIONAL CONSIDERATIONS

- If using the femtosecond laser, the arcuate incision feature can be used to mark the cornea or capsule (depending upon laser type) to aid in alignment of the toric IOL.
    - If marking the cornea, create an incision at 30% corneal depth with small-degree arcs (~15 degrees) along the intended axis of toric IOL placement.
- Intraoperative aberrometry can be helpful in determining both the toric IOL power and optimal axis alignment.
- Modern formulas such as the Barrett Toric formula and Barrett TK formulas (total keratometry available on swept source OCT biometry platforms such as the IOL master 700) provide most optimal outcomes.

POSTOPERATIVE COMPLICATIONS

- IOL rotation is uncommon but can occur in the early postoperative period.
- Toric IOLs can be rerotated with or without placement with a CTR.
- www.astigmatismfix.com is a useful tool for planning IOL rotation. It will help determine the amount of IOL rotation and the expected residual refractive error after rotation.
- Consider CTR insertion for patients with longer axial lengths and larger capsules to allow for greater IOL-capsule contact in attempts to minimize risk of postoperative rotation. Laser vision correction (PRK or LASIK) can be used to enhance residual refractive error that is not amenable to full correction via IOL rerotation.

For every 1 degree of axis rotation, there will be a 3.3% reduction in effective cylinder correction of the toric IOL. As such, if a toric IOL rotates or is misplaced by 30 degrees, the toric IOL is essentially ineffectual.

For astigmatismfix.com, the surgeon will need to know the following points of information in order to use the online tool for IOL rotation planning:

- Current postoperative uncorrected and best corrected visual acuity.
- Most recent postoperative manifest refraction.
- Model and power of implanted toric IOL.
- Current axis of toric IOL.
- Originally calculated IOL axis.

CHAPTER 16

Extended Depth of Focus Intraocular Lenses

Jeehee Kim, MD

PREOPERATIVE CONSIDERATIONS

- Patient's age, needs, and expectations for postoperative glasses use.
- Manifest refraction and eye dominance.
- History: Contact lens wearer? History of monovision or multifocal contact lens use? History of refractive surgery such as LASIK or PRK? History of glaucoma or amblyopia?
- Slit-lamp examination: Look for Fuch corneal dystrophy, anterior basement membrane dystrophy, corneal scars, corneal ectasia, and ocular surface disease such as dry eye syndrome.
- Computed corneal topography: Look for irregular corneal astigmatism and keratoconus.
- Use OCT to detect retinal pathology such as macular drusen, macular holes, or ERM.
- IOL calculations: Use third-generation formula such as SRK/T or fourth-generation formula such as the Barrett Universal Formula to choose the IOL.
- Intraoperative: The Alcon ORA system can be used to finalize IOL power for postrefractive corneas and patients with difficult IOL calculations.

HISTORY

- The Tecnis Symfony IOL (Johnson & Johnson) is currently the only FDA-approved EDOF IOL in the United States.

LENS DESIGN

- One-piece hydrophobic acrylic platform with index of refraction of 1.47.
- Overall diameter of 13.0 mm with optical zone of 6.0 mm.
- Available in powers ranging from +5.0 to +34.0 diopters (D).
- UV light-absorbing filter and diffractive optic.
- Biconvex anterior aspherical surface and posterior achromatic diffractive surface with an echelette design.
- Proprietary diffractive echelette design on the posterior surface creates a pattern of light diffraction that elongates the focus, extending the range of vision by 1.50 D.
- The nine echelettes on Symfony IOL are taller than other Tecnis Multifocal IOLs (MFIOLs), and they are slightly angled. The echelettes elongate the focus area rather than split the light and create a second focal point as in the other MFIOL platforms.
- Correction of chromatic aberrations by allowing less chromatic dispersion. Contrast sensitivity is similar to that of monofocal IOLs, and there is an increased IOL decentration tolerance.
- Also comes in a Toric version, which expands patient pool in whom this lens can be used.

TORIC EDOF IOL

- Postoperative residual astigmatism tolerance is better than the MFIOLs: 1.0 D in EDOF IOL versus 0.75 D in MFIOL.
- Greater tolerance of induced astigmatic defocus compared with trifocal IOLs and MFIOLs.

QUALITY OF VISION

- Excellent distance vision that is comparable with that of monofocal IOLs.
- Excellent intermediate vision at 20 in.
- Trifocal and MFIOLs typically provide better near vision than EDOF IOL.
- Reduction of night vision symptoms as compared with MFIOLs.
- Less chromatic aberration with improved contrast sensitivity.
- Fewer dysphotopsias than MFIOLs.
- Chromatic aberration correction in EDOF IOLs makes this IOL platform a more attractive alternative in some patients whose pathology prevents their receiving traditional MFIOLs: postrefractive patients, early and well-controlled glaucoma, or mild cases of ERM.

CONTRAINDICATIONS

- Patients with pathology in the macula, optic nerve, or cornea are not ideal candidates for EDOF IOLs.
- In patients who are not candidates for EDOF lenses, alternative lens correction options include:
    - Monofocal IOL implantation set for distance or near vision

and use of glasses as needed.

- Monovision (aim nondominant eye −1.50 to −2.00) or mini-monovision (aim nondominant eye −0.75 to −1.00).

CHAPTER 17

Multifocal Intraocular Lenses

Kyle A. Kirkland, DO

MfIOLs are presbyopia-correcting IOLs that give patients the ability to have multiple points of focus to reduce the need for spectacle correction after cataract surgery. Multifocal IOLs can be further broken down into diffractive (Alcon ReSTOR or AMO Tecnis diffractive MfIOL) or refractive lenses (AMO ReZoom).[1]

LENS DESIGN

- Diffractive MfIOL: a central distance-focused area is surrounded by concentric rings of decreasing heights (apodization) to diffract both near and distant targets. There are multiple different near add powers available in both lenses (ReSTOR +2.5 D, +3 D, +4 D and Tecnis +2.75 D, +3.25 D, +4 D).
- Refractive MfIOL: uses five concentric zones of alternating near- and distance-focusing rings (ReZoom lens no long available).[2]

Considerations for an MfIOL

- Patient motivation—although the optics and technology are greatly improved, MfIOLs can cause glare, halos, and other optical aberrations; therefore, a patient who is willing to tolerate these optical phenomena in order to reduce spectacle correction is imperative when considering patient selection.
- Ocular surface conditions: patients with dry eye syndrome or anterior basement membrane disease that could cause irregular

astigmatism or alter preoperative biometry measurements should be aggressively treated prior to IOL measurements and selection for an MfIOL.

- Patients with ocular comorbidities such as macular degeneration, diabetic retinopathy, uveitis, progressive glaucoma, or other chronic ocular surface disorders are likely poor candidates for an MfIOL.
- Pupil size and abnormalities: A patient with a small pupil (<2.5 mm) or large pupil (>5.5 mm) may have less than desirable outcomes with the ReSTOR or ReZoom lenses. Corectopia or other decentration of the pupil will also affect the centration and thereby effectiveness of the lens.

SURGICAL TECHNIQUE

- Perform cataract surgery with standard technique.
- Ensure capsulorhexis size of 5 to 5.5 mm using a manual technique or femtosecond laser-assisted technique to ensure IOL centration and prevent optic tilt or prolapse out of the bag.
- Intraoperative aberrometry can be useful in determining lens power.
- Take care to fold the lens gently and properly into the cartridge to avoid damage to the optic.
- Insert the lens into the bag in the correct orientation and remove any viscoelastic from behind the lens using irrigation and aspiration to allow for better adherence.
- With the patient looking directly ahead, use the Purkinje images to guide the centration of the lens (centered lens alignment will maximize effectiveness of the optics).

Additional Considerations

- A monofocal IOL should be available to the surgeon if an intraoperative complication arises.
- Bifocal diffractive and refractive lenses have suboptimal intermediate distance vision. Consider a slightly myopic target (−0.25 to −0.75 D) in the patient's nondominant eye to enhance intermediate vision.
- A lower add power in the dominant eye can sometimes achieve acceptable intermediate vision.
- Small or large pupils may benefit more from the Tecnis multifocal diffractive lens as its design is less dependent on pupil size.

POSTOPERATIVE COMPLICATIONS

- Posterior capsular opacification, even in mild cases, can lead to visual complaints that are easily addressed with YAG capsulotomy.
- The most common complaint of MfIOLs is glare and halos. Consider YAG capsulotomy if there is visually significant posterior capsular opacification, but an IOL exchange with an MfIOL may ultimately be required.
- Inferior decentration of the IOL can occur in high myopes.[3]

References

1. Buznego C, Trattler WB. Presbyopia-correcting intraocular lenses. *Curr Opin Ophthalmol*. 2009;20(1):13-18. doi:10.1097/ICU.0b013e32831c4cf5
2. Montés-Micó R, Ferrer-Blasco T, Charman WN, Cerviño A, Alfonso JF, Fernández-Vega L. Optical quality of the eye after lens replacement with a pseudoaccommodating intraocular lens. *J Cataract Refract Surg*. 2008;34(5):763-768. doi:10.1016/j.jcrs.2008.01.017
3. Alio JL, Plaza-Puche AB, Férnandez-Buenaga R, Pikkel J, Maldonado M. Multifocal intraocular lenses: an overview. *Surv Ophthalmol*. 2017;62(5):611-634. doi:10.1016/j.survophthal.2017.03.005

CHAPTER 18

Trifocal Intraocular Lenses

Patrick C. Tso, MD

The trifocal IOL is a presbyopia-correcting IOL category offered to patients wishing to have relative freedom from glasses for their near vision in addition to distance vision after cataract surgery. This type of lens focuses light from far, intermediate, and near sources onto the retina.

TYPES OF TRIFOCAL INTRAOCULAR LENSES

- PhysIOL, first trifocal lens developed by Fine Vision.
- AT LISA, developed by Zeiss.
- Panoptix, developed by Alcon, first diffractive trifocal lens to receive FDA approval in the United States.
    - Offered in a toric trifocal version that corrects up to 3.75 D of cylinder correction at the corneal plane.

PREOPERATIVE CONSIDERATIONS

- History: including ocular injury, trauma, medications like tamsulosin or other alpha-1 antagonist, history of prior refractive surgery such as LASIK, PRK, or RK.
- Visual need questionnaire: occupation, activities of daily living, measures of expectations.

- Complete ocular examination:
  - Distance and near vision.
  - Pupillary examination, tonometry.
  - Manifest refraction.
  - Eye dominance testing.
  - Tear function testing: consider Schirmer test, TBUT, vital dye staining, osmolarity, and/or MMP-9 testing.
  - Slit-lamp examination: detailed examination to rule out ocular surface disease, dry eyes, cornea pathologies (ie, ABMD, Fuchs dystrophy, or scars), pseudoexfoliation syndrome, and herpetic eye disease, in addition to assessing the type and degree of cataract severity.
  - Dilated eye examination and macula OCT testing: important to check for glaucoma, ARMD, macular pucker, vascular retinopathy, and diabetic retinopathy.
- Biometric measurement: Lenstar or IOL master with IOL selection based on fourth-generation formulas like Barrett, Olsen, or Hill RBF.
- Corneal tomography (Pentacam, Orbscan) or corneal topography (Zeiss Atlas): evaluate for magnitude, location, type of cornea astigmatism, corneal thickness, and HOA.

SURGICAL PLANNING

- Manage patient expectations: discussion of IOL options with patient based upon patients' needs, history, examination, and testing results.
- Inform patients with certain ocular comorbidities like glaucoma, macula pucker, ARMD, or significant retinopathies that they may

not be good candidates for presbyopia-correcting lenses. Ocular surface diseases like dry eyes, blepharitis, and corneal diseases, like Fuchs corneal dystrophy and anterior basement dystrophy, are relative contraindications.

- Inform the patient that any presbyopia-correcting lens does not guarantee that the patient will not need to use reading glasses, but rather expectation should be set that they will be less dependent.
- Inform patient that diffractive trifocal IOL can have potential side effects such as glare in low-light situations, halos around point sources of light, and/or reduced contrast sensitivity.
- The patient needs to be educated that neuroadaptation to these types of lenses occurs gradually and over the course of several months.

1. Selection of IOL option and informed consent should be based on a thorough history, detailed slit-lamp examination, and discussion matching the functional need of the patient to the appropriate technology.
2. Provide patients with educational handouts, booklets, and websites with lens option details for patient to review.
3. Repeat any testing as needed to establish consistency/repeatability.
4. Give patients ample opportunity to ask any questions or concerns that they may have.

INTRAOPERATIVE CONSIDERATIONS

- IOL centration on the visual axis is critical.
- Capsular polishing can aid in the reduction of PCO and/or facilitate IOL removal in future if needed.

- Intraoperative aberrometry can be considered to optimize spherical IOL selection in addition to alignment of the toric trifocal.

POSTOPERATIVE CONSIDERATIONS

- After successful surgery, discuss with the patient the possibility of PCO formation, which can reduce the effectiveness of the trifocal lens and causes glare, blurry vision, and halos.
    - Patient should be instructed to have follow-up examination if symptoms occur.
    - Consider YAG capsulotomy only if the patient is satisfied with overall vision quality prior to developing PCO as IOL exchange becomes more complicated post capsulotomy.
- Postoperative refraction at 1 month post surgery to assess for any residual refractive error that may need enhancement to provide optimal visual outcomes.
- Reassure patients between eyes that near vision is best when both eyes have the trifocal implant (binocular summation effect).
- Aggressively treat dry eye or other ocular surface disease to allow for greatest visual potential.
- Consider IOL exchange only if the above have been addressed and the patient is persistently unhappy with vision quality.

Please see Video 18.1 showcasing surgical technique for implantation of toric trifocal IOL.

CHAPTER 19

Intraocular Lens Formula Selection for the Cataract Surgeon

Robin Vann, MD, Anthony Kuo, MD

Over the past decade, great strides have been made to improve the efficiency, safety, and stability of outcomes after cataract surgery. With this progress, cataract refractive surgeons can reduce astigmatism and provide spectacle independence better than ever before. To provide these refractive outcomes, surgeons rely on accurate biometric measurements and modern IOL selection formulas. This chapter reviews essential tools for appropriate selection of IOL power.

PREOPERATIVE FORMULA DATA ENTRY

- All IOL calculation formulas need to accurately predict the final IOL position in the eye to recommend the appropriate IOL power for the desired postoperative refraction.
- IOL calculation formulas need preoperative anatomic measurements to predict the appropriate IOL power for the desired postoperative refraction.
- Anatomic measurements that are needed (depending on formula) include AL, K, ACD, LT, and corneal diameter (WTW).
- Sources of error include inaccurate AL measurements (17%), inaccurate K measurements (8%), formula estimated lens position error (38%), and inaccurate postoperative refraction (27%).[1, 2]

- To reduce errors, best practices incorporate multiple measurements with validation and a final screening review prior to entering into formulas.

CAPTURE PHASE AT MACHINE

- Perform multiple captures of all the anatomic measures and ensure there is agreement of measurement samples.
- Confirm small standard deviations of each anatomic measurement captured (ie, all keratometric meridian readings within ±0.25 D).
- For K, ensure good tear film layer with crisp clear reflections of mires/dots projected onto the anterior surface of the cornea.
- Once anatomic measures are captured, there are two additional steps prior to entering into formulas: validation and screening.

Validation

- Are the measurements consistent with the operating parameters of the biometer?
- You can refer to machine manufacturer guidelines to create a validation system of your own.
- Validation guidelines are available for IOL Master 500 or Lenstar LS900 at www.doctor-hill.com.
- Additional resource: Hill WE, Abulafia A, Wang L, Koch DD. *J Cataract Refract Surg*. 2017;43(7):869-870.

Screening

TABLE 19.1 Validation criteria for ultrasound and optical biometry[3,4]

	Ultrasound biometry[a]	Optical biometry[a]
AL	<22 or >25 mm	<21.3 or >26.60 mm
Average corneal power	<40.00 or >47.00 D	<41.00 or >47.00 D Corneal astigmatism >2.50 D
Difference between eyes	Average K reading >1.00 D AL >0.3 mm	Average K reading >0.90 D AL >0.70 mm

[a]Repeat the measurements by a different examiner or on a separate day to confirm their validity.

- After capture and validation, use screening criteria that have been developed for both ultrasound and optical biometry to detect potential errors in gross measurement. Table 19.1 summarizes these criteria.[3, 4] Measurements that fall outside these ranges need to be repeated by a different examiner or on a separate day to confirm validity.

FORMULA ACCURACY

TABLE 19.2 The different categories of AC size versus AL

	Short AL	Normal AL	Long AL
Small AC	Small eye Nanophthalmia	Microcornea	Microcornea and axial myopia
Normal AC	Axial hyperopia	Normal	Axial myopia
Large AC	Megalocornea and axial hyperopia	Megalocornea	Large eye and axial myopia

- There are multiple formulas available, and there is no one single formula that performs best across all axial lengths.
- Third-generation formulas (SRK/T, Holladay 1, Hoffer Q) adjust ELPs using AL and K values. However, they assume AL and AC are linked proportionally, which is incorrect in up to 20% of eyes.[5, 6] See Table 19.2.
- Large-scale studies conclude that third-generation formulas are able to achieve a mean ±0.50 D prediction accuracy between 70% and 80%.[6, 7] Modifications to the formulas or adopting newer-generation formulas that use additional measurement values will improve predictions.

- Newer-generation formulas look beyond just AL and K to better predict the AC size and therefore improve the ELP.
- Newer-generation formulas include Holladay II, Haigis, Olsen Ray Tracing, Barrett Universal II, Kane, RBF, FullMonte, and Ladas super formula.
- These newer-generation formulas have been compared with third-generation formulas and have consistently performed better.[8 - 11] Barrett Universal II and RBF have been well studied and are freely available for use online. See www.rbfcalculator.com or www.apacrs.org.

High Axial Myopia (>26 mm)

- The accuracy of outcomes can be improved by modifying the AL value entered in third-generation formulas. Wang and colleagues stated that highly myopic eyes have much more vitreous liquefaction, which changes the refractive index compared with normal eyes.[6] Unfortunately, current optical biometers use an average refractive index to measure the entire eye. Eyes longer than 26 mm may deviate from this "normal" average refractive index, and as a result, AL measurements in these long eyes can be inaccurate.[6]
- Wang et al developed a nomogram based on their data with a recent modification to adjust the AL measurements to account for the hyperopic drift in these extremely myopic eyes:

  Holladay1 modified optimized AL = 0.817 × Measured AL + 4.7013 [12]

- In a retrospective study by Abulafia et al, eyes with AL greater than 26 mm and where an IOL power <6.00 D was used, the Barrett Universal II, AL-adjusted Haigis, and AL-adjusted Holladay 1 formulas all met benchmark criteria. In this same group, the mean absolute error was the lowest with the Barrett Universal II and all three AL-adjusted formulas (not statistically significantly different).[7]

Hyperopic Eyes (AL < 22 mm)

- These eyes require high-power IOLs and so are more likely to have ELP prediction errors.
- Gocke et al, compared 86 eyes measured with optical biometry and AL < 22 mm and found when personalized A constant across all axial lengths: Holladay 1, Holladay 2, and Hill RBF were the best performers.[13]

CONCLUSION

- No single formula has the best prediction error across the varying ranges of AL of eyes on which we perform cataract surgery.
- Table 19.3, based on published data and our personal outcomes, outlines the formulas we typically use and recommend.
- The table is organized into third-generation formulas and the newer formulas that require more data.
- We encourage surgeons to review their own outcomes, optimize/personalize constants and factors, and see which formulas are the most accurate for their practices.

TABLE 19.3 The authors' recommendations for IOL selection formulas based on AL

	Short AL (<22 mm)	Normal AL (22–25.99 mm)	Long AL (>26 mm)
Third-generation formulas	H1	H1	WK-H1 AL adjusted formula
Newer-generation formulas	H2, Hill RBF	Barrett II, Hill RBF	Hill RBF, Barrett II
Additional data points needed for newer-generation formulas	Age, Rx, WTW, ACD, LT	WTW, ACD, LT	WTW, ACD, LT

H1, Holladay 1; H2, Holladay 2; Rx, prescription; WTW, horizontal white to white.

References

1. Olsen T. Sources of error in intraocular lens power calculation. *J Cataract Refract Surg*. 1992;18:125-129.
2. Norrby S. Sources of error in intraocular lens power calculation. *J Cataract Refract Surg*. 2008;34(3):368-376. doi:10.1016/j.jcrs.2007.10.031
3. Holladay JT, Prager TC, Chandler TY, et al. A three-part system for refining intraocular lens power calculations. *J Cataract Refract Surg*. 1988;14:17-24.
4. Knox Cartwright NE, Johnston RL, Jaycock PD, et al. The Cataract National Dataset electronic multicentre audit of 55,567 operations: when should IOLMaster biometric measurements be rechecked? *Eye*. 2010;24(5):894-900.
5. Holladay J. Standardizing constants for ultrasonic biometry, keratometry, and intraocular lens power calculations. *J Cataract Refract Surg*. 1997;23:1356-1370.
6. Wang L, Shirayama M, Ma XJ, Kohnen T, Koch DD. Optimizing intraocular lens power calculations in eyes with axial lengths above 25.0 mm. *J Cataract Refract Surg*. 2011;37(11):2018-2027. doi:10.1016/j.jcrs.2011.05.042
7. Abulafia A, Barrett GD, Rotenberg M, et al. Intraocular lens power calculation for eyes with an axial length greater than 26.0 mm: comparison of formulas and methods. *J Cataract Refract Surg*. 2015;41(3):548-556.
8. Roberts T, Hodge C, Sutton G, Lawless M; contributors to the Vision Eye Institute IOL Outcomes Registry. Comparison of Hill-radial basis function, Barrett Universal and current third generation formulas for the calculation of intraocular lens power during cataract surgery. *Clin Exp Ophthalmol*. 2018;46:240-246. doi:10.1111/ceo.13034
9. Kane J, Heerden A, Atik A, Petsoglou C. Accuracy of 3 new methods for intraocular lens power selection. *J Cataract Refract Surg*. 2017;43(3):333-339. doi:10.1016/j.jcrs.2016.12.021
10. Cooke D, Cooke T. Comparison of 9 intraocular lens power calculation formulas. *J Cataract Refract Surg*. 2016;42(8):1157-1164. doi:10.1016/j.jcrs.2016.06.029
11. Melles R, Holladay J, Chang W. Accuracy of intraocular lens calculation formulas. *Ophthalmology*. 2017;125(2):169-178. doi:10.1016/j.ophtha.2017.08.027
12. Wang L, Koch D. Modified axial length adjustment formulas in long eyes. *J Cataract Refract Surg*. 2018;44(11):1396-1397. doi:10.1016/j.jcrs.2018.07.049

Gökce S, Zeiter J, Weikert M, Koch D, Hill W, Wang L. Intraocular lens power calculations in short eyes using 7 formulas. *J Cataract Refract Surg*. 2017;43(7):892-897. doi:10.1016/j.jcrs.2017.07.004

Section 5

Astigmatism Management

CHAPTER 20

Corneal Topography for the Cataract Surgeon

Anthony N. Kuo, MD, Robin R. Vann, MD

Corneal topography is a diagnostic technology used to assess the curvature (shape) of the front surface of the cornea and its overlying tear film. By color coding the measured curvatures across the front surface of the cornea, one can qualitatively see asymmetries in anterior corneal shape such as regular and irregular astigmatisms or localized areas of curvature flatness/steepness. Corneal topography is closely related technologically to keratometry, which is a key parameter used in intraocular lens calculations. Conceptually, corneal topography can be thought of as a display of all the curvature points across the front of the cornea, whereas keratometry is only an average of a select zone of curvature points. Corneal tomography systems (Scheimpflug photography, OCT) that measure both the front and back surfaces of the cornea are also available and are particularly useful in cataract surgery for post laser refractive surgery calculations.

GENERAL MEASUREMENT CONSIDERATIONS

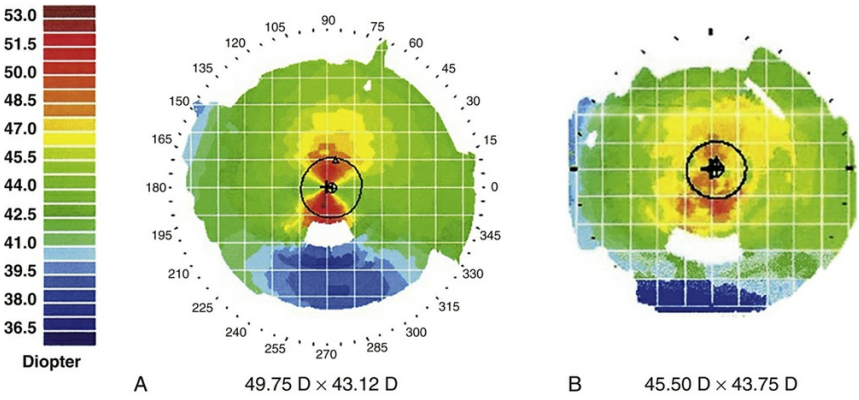

FIGURE 20.1 **Corneal topography OS (left eye) of a patient with severe dry eye before (A) and after (B) dry eye treatment. Treating the dry eyes reduced her corneal topography measured astigmatism from more than 6.5 D to less than 2 D of astigmatism.**

Tear film abnormalities: Because corneal topography (and keratometry) relies on reflections off the precorneal tear film to measure corneal curvature, disruptions of the tear film such as from dry eye affect the quality and reliability of the measurements (Fig. 20.1). Dry eyes can even create keratoconus-like topography patterns that are due to the disrupted tear film, not corneal ectasia.

Misalignments: Corneal topography, specifically the commonly used axial curvature map, assumes that the axis of the topographer is aligned with the center of the imaged cornea. Decentering the cornea relative to the axis of the topographer, as can happen with poor alignment or patient looking elsewhere, will cause decentration of the topography pattern, which will falsely indicate pathology.

Outlier measurements: Corneal topography is usually a single image measurement. Because of this, care must be taken to ensure that the single measure does not incorporate artifacts (like the two discussed above). One way to address this, particularly for quantitative measurements, is to take multiple measurements and perform averaging.

SPECIFIC PATTERNS OF IMPORTANCE IN CATARACT SURGERY

Regular Astigmatism

Regular astigmatisms on corneal topography have the classic dumbbell- or bowtie-shaped pattern (Fig. 20.2A). Of note, there is symmetry in regular astigmatisms: one can draw a straight line through the bowtie and the halves of the cornea on either side of that line and the one 90 degrees apart appear qualitatively similar. The topography image can be used to confirm the steep axis of astigmatism for toric IOL calculations.

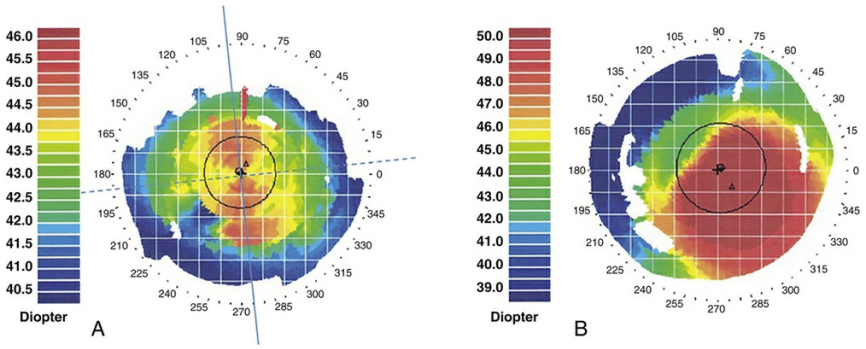

FIGURE 20.2 **Regular (A) and irregular (B) astigmatism on corneal topography. In regular astigmatism (A), the cornea can be divided into symmetric halves as indicated by the added lines. The solid line through the "bowtie" is the steep axis of astigmatism and can be used for toric calculations. In irregular astigmatism (B), there is asymmetry between the superonasal half of this cornea versus the inferotemporal half of this OS with keratoconus.**

Irregular Astigmatism

In irregular astigmatism, there are no two orthogonal lines of symmetry (Fig. 20.2B). Keratoconus typically has offset inferior steepening (the "hot spot") as shown in the figure. Owing to their asymmetric cornea, irregular astigmatisms can be difficult to treat

from a refractive cataract standpoint even with toric IOLs.

Surface Pathologies (eg, Anterior Basement Membrane Dystrophy, Pterygium)

These entities can also cause irregular astigmatisms on corneal topography, although not often as profound as in keratoconus. Treatment of these entities, such as by debridement or excision, will remove the surface pathology and typically regularize the surface and the corneal topography.

POST-LASER REFRACTIVE SURGERY CALCULATIONS

The K values generated by keratometry and corneal topography (via the SimK value) are calculated only from a front corneal surface measurement. Assumptions are made about the contributions of the corneal thickness and posterior cornea to the overall corneal power in a normal eye. Laser refractive surgery (LASIK, PRK) change these assumptions, and compensatory calculations need to be made to the keratometry or topography measurements. Alternatively, corneal tomography platforms can make direct measurements of anterior and posterior corneal surfaces and calculate "total power" measurements. The American Society of Cataract and Refractive Surgery maintains an updated website (http://iolcalc.ascrs.org/) that guides cataract surgeons through the various methods to calculate corneal power for a patient who has previously had laser refractive surgery.

CHAPTER 21

Manual Limbal Relaxing Incisions

Nandini Venkateswaran, MD

BASICS OF ASTIGMATISM

- Astigmatism management is essential to provide the high quality of uncorrected vision that patients seek after refractive cataract surgery.
- Nearly 50% of patients have 0.75 D of astigmatism or greater.
- We recommend LRIs for corneal astigmatism ranging from 0.75 to 1.25 D that is with-the-rule or at an oblique axis.
- For corneal astigmatism < 0.75 D against-the-rule, consider a toric IOL.
- For corneal astigmatism > 1.25 D with-the-rule, consider a toric IOL.

MANUAL LRI PEARLS

- LRIs flatten in the meridians they are created in.
- Manual LRIs are created just within the limbus.
- They are often created at 80% depth of the corneal thickness.
- LRIs can often be paired along the steep axis.
- LRIs can have variable effects depending on corneal thickness, corneal diameter, corneal elasticity, patient age, as well as depth and arc length of the incisions.

NOMOGRAMS

- There are several established nomograms to calculate manual incision length:
  - Gills/Fenzel
  - Nichamin
  - Koch
  - Miller
  - Donnenfeld
- There are also online calculators that can help manual LRI planning.
- www.lricalculator.com
  - Contains the Donnenfeld and NAPA nomogram
- Note that nomograms vary and require surgeons to note the intended depth of the LRI incisions and patient age to guide planning.
- Utilize information from biometry and corneal topography to ensure the degree and axis of astigmatism are consistent through multiple measurements.

AVOID MANUAL LRIS IN CASES OF:

- Prior radial keratotomy or arcuate keratotomy incisions.
- Corneal ectasia (ie, keratoconus, pellucid marginal degeneration, furrow degeneration).
- Corneal opacification.
- Peripheral corneal disease.

SURGICAL PEARLS

- In the preoperative suite, the surgical eye is marked at the 0- and 180-degree locations using a toric marker to account for cyclorotation of the eye once the patient is supine under the femtosecond laser.
- Ideally create manual LRIs at the beginning of the case when the globe is formed. Mark the axis of astigmatism and the arc length of the LRIs with a marking pen. Some surgeons will choose to perform LRIs at the conclusion of the case.
- LRIs can be created with fixed-depth steel blades or adjustable-depth diamond blades. The author uses a disposable 600-µm guarded blade.
- Utilize a fixation ring or forceps to stabilize the globe.
- In a smooth, continuous fashion, use the blade to "glide" along the limbus, taking care to apply equal force throughout the entire incision.
- If using a guarded blade, it is helpful to position the instrument such that the surgeon can visualize the blade at all times.
- Creating manual LRIs is a bit of an art. Inconsistent depth and shape of incisions can lead to over- or undercorrection of astigmatism as well as induction of higher-order aberration.
- Avoid creating LRIs at the location of your main incision and/or paracentesis.
- Avoid LRIs > 50 degrees as larger incisions behave less predictably.
- We recommend using a topical antibiotic as prophylaxis for 1 week to avoid infection risk.

CHAPTER 22

Femtosecond Laser-Assisted Limbal Relaxing Incisions

Nandini Venkateswaran, MD

Please refer to principles of astigmatism in the Limbal Relaxing Incisions–Manual Incisions chapter for basics on astigmatism management.

FEMTOSECOND LASER PRINCIPLES

- The incision made with the laser is **photodisruptive**; therefore, tissue is removed from the incision site at the time of creation.
- The incision is made in a **precise and continuous** fashion, and the laser allows the surgeon to control the **exact depth, width, length, and symmetry** of the incisions.
- OCT imaging measures the exact depth of the cornea in real time at the micrometer level to allow the laser to create the LRI at **80% depth of cornea** and within the **9-mm optical zone.**

AVOID FEMTOSECOND LRIS IN CASES OF

- Prior radial keratotomy or arcuate keratotomy incisions.
- Corneal ectasia (ie, keratoconus).
- Corneal opacification.

NOMOGRAMS

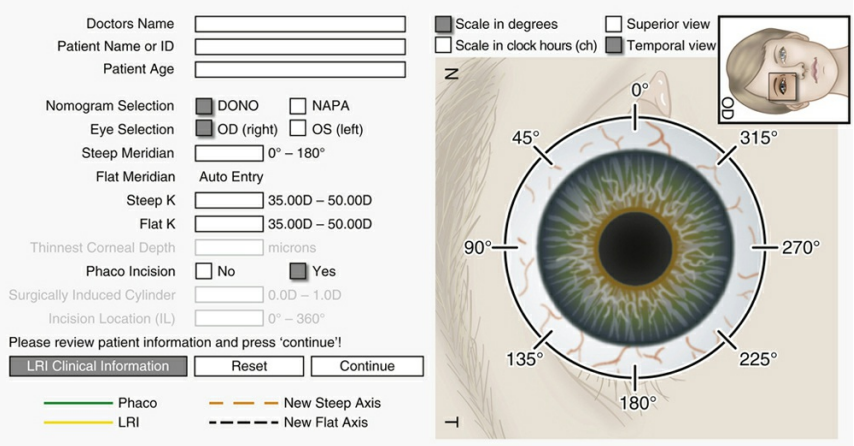

FIGURE 22.1 **Donnenfeld nomogram on www.lricalculator.com.**

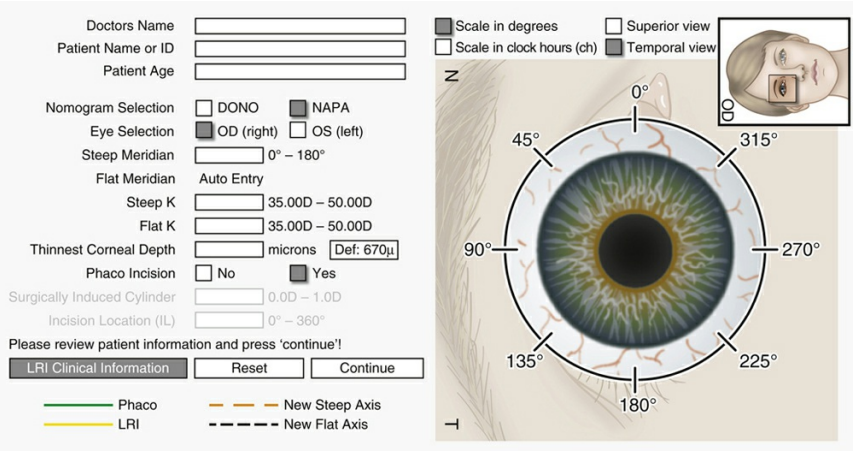

FIGURE 22.2 **NAPA nomogram on www.lricalculator.com.**

- Keratometry readings should be taken from **intraocular lens biometry** measurements to input into these nomograms.
- The nomograms are **easy to access online** and should be done **prior to surgery** such that the information can be programmed in the laser. They allow the surgeon to **plan the degree and location of LRIs.**

- Available nomograms include:
  - www.laserarcs.com—created by Dr Michael Jones.
  - www.lricalculator.com—note that this website is not intended for femtosecond laser-created incisions and modifications (see below) should be made when using laser—Figures 22.1 and 22.2.
    - WTR incisions calculated from this site should be reduced by 30% when using the laser.
    - ATR incisions calculated from this site should be reduced by 20% when using the laser.
    - www.lricalc.com.
    - Contains Wortz-Gupta formula.

SURGICAL PEARLS

- In the laser suite, the surgical eye is marked at 0, 180, and 270 locations using a toric marker to account for cyclorotation of the eye once the patient is supine under the femtosecond laser.
- Ensure the LRI calculations (incision length and location) are programmed correctly into the laser—always check this, and verify left versus right eye. Avoid creating LRIs at the location of your main incision and/or paracentesis.
  - If the LRI coincides with the main incision, move it 180 degrees away (typically most surgeons operate temporally, so move the LRI 180 degrees to the nasal location).
- Avoid LRIs greater than 50 degrees as larger incisions behave less predictably.
- Intraoperative aberrometry can be used to determine if LRIs need to be opened.

- LRIs can be opened using a Sinskey hook intraoperatively or even postoperatively.
- We recommend using a topical antibiotic as prophylaxis for 1 week to avoid infection risk.

Section 6

Secondary Intraocular Placement

CHAPTER 23

Anterior Chamber Intraocular Lens Placement

Nandini Venkateswaran, MD

CONSIDERATIONS FOR AN ACIOL

An ACIOL can be utilized if:

- There is inadequate posterior capsular support and adequate iris tissue support.
- There is adequate anterior chamber depth.

An ACIOL should be avoided if the patient has:

- Preexisting corneal endothelial disease that may require a corneal transplant in the future.
- A prior corneal transplant.
- A history of comorbid uveitis or glaucoma that can cause formation of peripheral anterior synechiae that will prevent positioning of the ACIOL.

SURGICAL PLANNING

- Obtain intraocular lens biometry.
- Since an ACIOL is placed more anteriorly than a posterior chamber IOL, it will require less power (typically ~3 D less than the power of the IOL for the capsular bag).

- The A-constant of an ACIOL will account for this when various IOLs are calculated with biometry values on the biometry printout.

PREOPERATIVE STEPS

- Pay attention to the WTW measurement on biometry. In the operating room, take the corneal WTW measurement with calipers on the axis of IOL placement (if a temporal incision is used, measure the horizontal WTW; if a superior incision is used, measure the vertical WTW).
- Add 1 mm to the manual WTW measurement to determine the sizing of the ACIOL.
    - WTW on biometry and manual WTW measurements can vary.
    - See Table 23.1 for a sizing chart used for the Alcon platform ACIOL measurements.

TABLE 23.1 Chart for Alcon ACIOL lenses

White-to-white	Lens size diameter (mm)	Corresponding model designation
11.0–11.4	12.0	MTA2U0
11.5–11.9	12.5	MTA3U0
12.0–12.4	13.0	MTA4U0
12.5–12.9	13.5	MTA5U0
13.0–13.4	14.0	MTA6U0
13.5–13.9	14.5	MTA7U0

ACIOL Sizing Guide

Determine the location of your incision.

- First, assess the patient's visual potential and look at the IOL biometry to determine if the patient has WTR or ATR astigmatism.
- A temporal clear corneal incision is often the most comfortable;

however, the corneal wound needs to be extended to 6 mm to accommodate ACIOL insertion, which can worsen the existing ATR astigmatism. In these cases with ATR astigmatism, a superior scleral tunnel can be created to avoid creating a large temporal corneal wound.

- If the patient has WTR astigmatism, this can be neutralized with a 6-mm superior clear corneal incision.
- In general, superiorly placed wounds have the advantage of being covered and protected by the upper eyelid.

SURGICAL STEPS

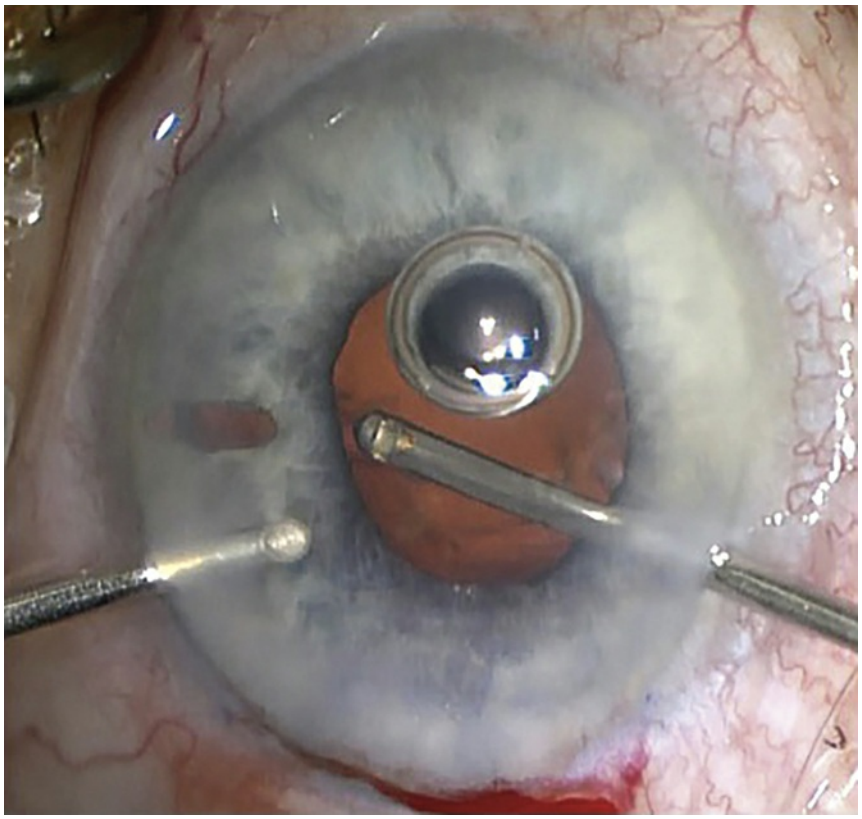

FIGURE 23.1 **Creation of an inferior peripheral iridotomy using a vitreous cutter.**

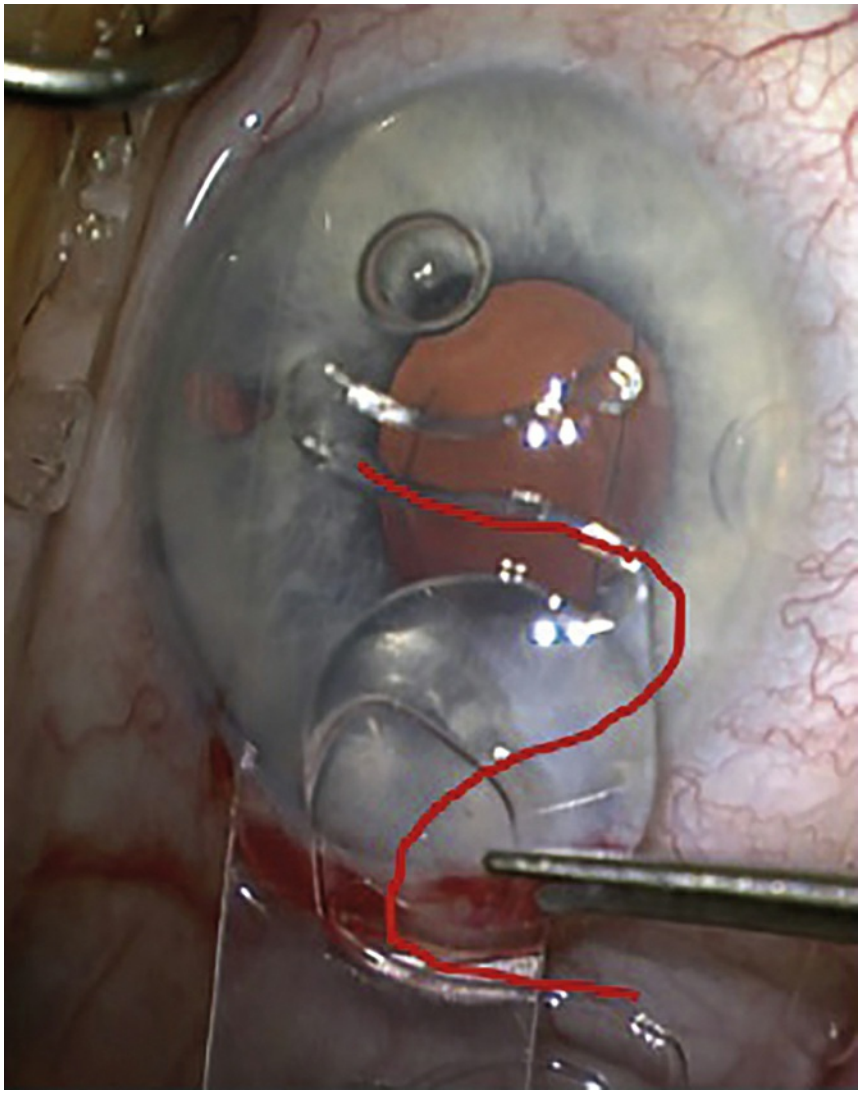

FIGURE 23.2 **Proper orientation of the ACIOL. Ensure proximal haptics are in a "reverse S" configuration.**

- Measure the corneal WTW diameter (vertical or horizontal) and determine the size of the ACIOL.
- Determine if a clear corneal incision or scleral tunnel will be created and where it will be created.
- If a posterior capsular rupture occurs or a previous IOL is explanted, perform a thorough anterior vitrectomy to ensure removal of all vitreous in the AC through two sideport incisions.

- Scleral tunnel:
    - Create a 7-mm conjunctival peritomy in the location of the tunnel.
    - Use electrocautery to achieve hemostasis.
    - Mark a 6-mm scleral tunnel with calipers 1 mm posterior to the limbus.
    - Make a partial-thickness scleral incision with a bent crescent blade and tunnel the scleral incision toward the cornea until you are 1 to 2 mm into clear cornea.
    - Extend the edges of the tunnel laterally to achieve a 6-mm-diameter wound.
    - Use a keratome to enter the AC and extend the internal wound laterally using the keratome.
- Clear corneal incision:
    - Measure a 6-mm corneal wound with calipers.
    - Enter the AC with a keratome and extend the lateral edges of the wound to 6 mm diameter using the keratome.
- Inject Miostat (carbachol intraocular solution) or Miochol (acetylcholine intraocular solution) to achieve pupillary miosis.
- Inject dispersive viscoelastic to protect the corneal endothelium and to form the AC. Cohesive viscoelastic can be retained in the eye and cause a postoperative IOP spike.
- Place the mouth of the vitreous cutter under peripheral iris tissue (typically inferiorly) to create a peripheral iridotomy. The cutter should be in IAC mode with a low cut rate (ie, 100 cpm). The haptics of the ACIOL should be positioned away from inferior iridotomy such that the haptics do not get incarcerated in the iridotomy. For example, if the PI is made inferiorly, the ACIOL haptics should be positioned at 3 and 9 o'clock (Fig. 23.1).

- Position a sheets glide over the iris and pupil. A sheets glide is not mandatory but can be helpful to prevent posterior dislocation of the ACIOL.
- Ensure the ACIOL is in the correct orientation. Please look at the PROXIMAL haptics and ensure they are not in an "S" configuration but rather in a "reverse S" configuration (Fig. 23.2).
- Hold the ACIOL by the trailing haptic using angled McPherson or Kellman forceps. Insert the leading haptic of the ACIOL through the corneal or scleral wound over the sheets glide keeping the IOL optic and haptics parallel to the iris plane.
- Remove the sheets glide carefully and position the proximal haptic under the lip of the wound.
- Close the scleral tunnel with interrupted 10-0 nylon sutures (usually 2 to 3 sutures).
- Close the clear corneal wound with interrupted 10-0 nylon sutures (usually 2 to 3 sutures).
- Using a Sinskey or Kuglen hook, carefully manipulate the distal haptics of the ACIOL to rotate the IOL and position the haptics in the angle. This is done by grasping the distal aspect of the haptic and pulling centrally and anteriorly and "walking" the ACIOL along the angle on each side. Ensure the ACIOL does not incarcerate any iris tissue. If there is any peaking of the pupil, this may indicate residual vitreous in the AC or capture of the iris tissue by the ACIOL.
- Use the vitreous cutter to aspirate any remaining viscoelastic in the AC or to remove any residual vitreous.
- Ensure all wounds are watertight and rotate and bury the knots. Ensure good suture tension to minimize astigmatism.
- Close the conjunctival peritomy with 7-0 or 8-0 Vicryl suture if a scleral tunnel was created.

- An air bubble can be injected at the conclusion of the case over the IOL to keep the ACIOL optic in position.

Reference

1. Carter PC, Oetting TA. *Anterior Chamber Intraocular Lens Placement Technique*: A Tutorial. EyeRounds.org; 2016. Accessed September 1, 2020. http://EyeRounds.org/tutorials/AC-IOL-Placement.htm

CHAPTER 24

Iris-Sutured Intraocular Lenses

Nicole Fuerst, MD

PREOPERATIVE CONSIDERATIONS

An iris-sutured IOL is an excellent technique for secondary IOL fixation. This technique is often used in cases where the IOL can be placed in the sulcus but there is inadequate anterior capsular support to keep the lens secure. Other scenarios in which this technique is used include cases with significant zonular weakness or dislocation of a previously placed IOL (either a dislocated sulcus lens or late in-the-bag IOL dislocation) as well as in aphakic patients without any capsular support.

Important Preoperative Considerations

Some important things to note on pre-operative ocular examination include:

- the status of the iris tissue—look carefully for iris tissue atrophy, transillumination defects, or iridodenesis, as all of these factors can influence the ability to suture iris tissue and/or stability of the IOL.
- the location and model of the dislocated IOL (if prior dislocation).
- the presence of vitreous in the AC warranting an anterior vitrectomy.
- any concurrent glaucoma or retinal pathology that may limit the secondary lens options.

Good candidates for iris-sutured IOLs have:

- adequate iris tissue for IOL support with minimal iridodenesis.
- a pupil that is able to constrict <6 mm (if the iris is dilated beyond 6 mm, it may be hard to obtain iris capture of the optic and the IOL may dislocate into the posterior chamber).

Advantages of Iris-Sutured IOLs

- Smaller incision as compared with ACIOLs.
- No disruption of conjunctiva (important for eyes with glaucoma that may need future surgery).
- Minimally induced astigmatism.
- Reduced risk of suprachoroidal effusion or retinal complications (compared with pars plana scleral suturing).
- Good suture longevity with no externalized sutures.
- IOL is positioned away from cornea leading to less risk of pseudophakic bullous keratopathy.
- Reproducible, relatively easy surgical technique for beginner and advanced surgeons.

Disadvantages of Iris-Sutured IOLs

- May cause ovalization of the pupil ("cat eye").
- Some patients may develop iris chafing and pigment dispersion.[1]
- Inability to correct astigmatism with the IOL chosen (typically a three-piece IOL).

SURGICAL PLANNING

- Manage patient expectations about the difficulty of IOL calculations and the possible need for glasses after surgery, especially if there is a significant amount of astigmatism.
- IOL choice:
    - Any three-piece IOL can be iris-sutured (this is an off-label use of the implant) as most modern three-piece lenses have posterior angulation, which keeps the optic away from the iris.
    - At Duke, our first choice is the Alcon MA60AC lens.
    - We recommend using a lens that is 0.5 to 1 D less in power than indicated for a posterior chamber IOL, following the bag-to-sulcus conversion table created by Dr Hill.[2] This compensates for the anterior position of the lens following iris suturing.
- For secondary lens placement in an aphakic patient, we do not recommend pre-op dilation or miotic drops. Lidocaine with epinephrine is enough to dilate the pupil intraoperatively. If suturing an existing three-piece lens, the pupil can be dilated to prolapse the optic anterior to the iris and Miochol (acetylcholine chloride) or Miostat (carbachol) can then be used to maintain optic capture. If performing an IOL exchange, it is best to dilate the pupil to remove the existing lens and to use Miochol or Miostat to constrict the pupil after the existing lens is removed.
- Let the OR team know you need these special tools:
    - Dispersive viscoelastic.
    - Intracameral miotics (Miochol or Miostat).
    - Seibel folding forceps.
    - 10-0 polypropylene suture on a CIF-4 (tapered/spatulated) needle or CTC-6 (cutting) needle.

- MST Condon snare (if your institution does not have a Condon snare, you can use a Kuglen hook or Sinsky hook).
- Docking 25G, 26G, or 27G needle or cannulas.
- MST scissors.
- Anterior vitrector setup.

SURGICAL PROCEDURE

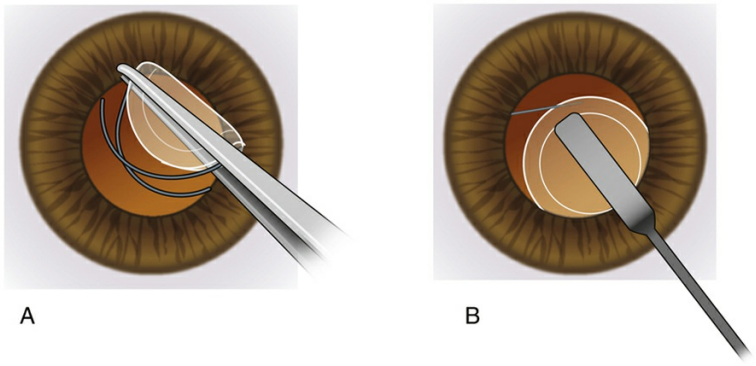

FIGURE 24.1 **A. The folded three-piece IOL is folded with overlapping haptics before insertion. B. The optic is temporarily stabilized with an iris spatula as it is unfolded.**

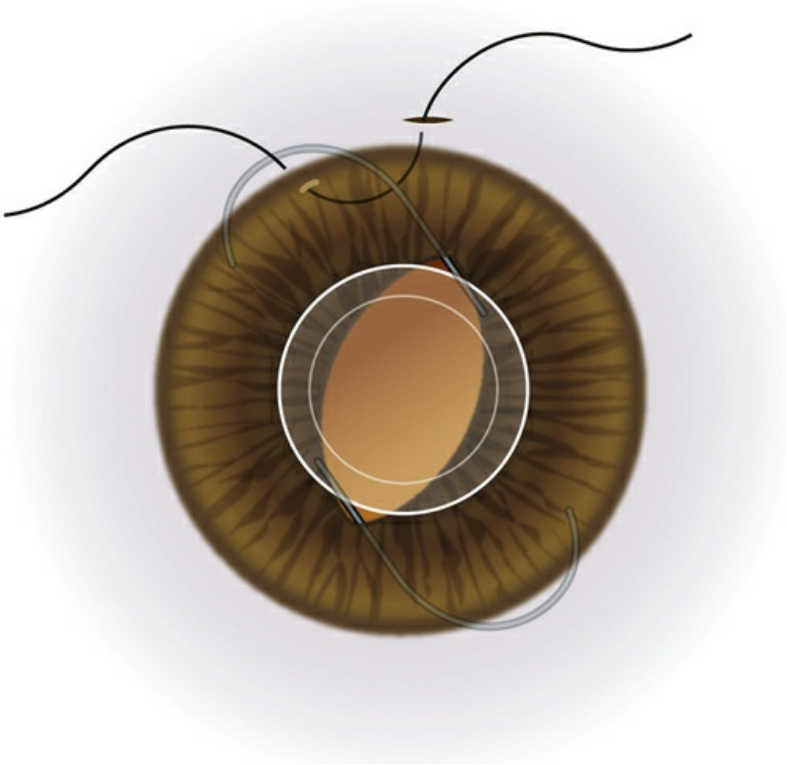

FIGURE 24.2 **A 10-0 Prolene suture is passed through the distal paracentesis, under the iris tissue and haptic and out through the iris and distal paracentesis.**

- If the IOL is dislocated in the vitreous, partner with a retina colleague to bring the IOL to the AC.
- If vitreous is present in the AC, perform an anterior vitrectomy.
- Fill the AC with a dispersive OVD.
- Create a keratome incision (recommend superior approach) and widen to ~4 mm.
- Place adequate intracameral miotic agents to constrict the pupil adequately.
- Use lens-folding forceps to fold the three-piece IOL optic with the haptics crossed and pointing downward. It is easiest to grab the optic at the 12- and 6-o'clock positions and slowly close the forceps to fold the optic.

- Insert the lens into the eye with lens-folding forceps (Fig. 24.1):
    - Turn the lens clockwise sideways to insert it into the wound and tuck the trailing haptic with forceps to help get the lens in the eye.
    - Once in the eye, rotate the lens counterclockwise so the haptics are again facing down.
    - Place the haptics through the pupil and slowly let go of the lens to allow the lens to unfold with the haptics below the iris and the optic captured in the pupil anterior to the iris.
- Make paracentesis wounds facing each peripheral haptic (you can use your original paracentesis or create two additional paracenteses; do not hesitate to create additional paracenteses that will maximize ease of suturing). Different from cataract surgery, the paracentesis is directed almost tangential to the limbus, pointing toward the haptic that you would like to suture.
- Cut the 10-0 Prolene suture in half.
- Holding the needle toward the back one-third of the needle with the needle driver, place the needle through the paracentesis. Moving side to side can help ensure that you are within the paracentesis and not caught in the cornea.
- The 10-0 Prolene suture is then passed through the iris tissue, under the haptic, and out through the iris again. Use the tip of the needle to catch the peripheral aspect of the haptic with as little bite of iris tissue as possible (Fig. 24.2).

FIGURE 24.3 **A diagram of a three-piece IOL. The lines show the position where the sutures should be placed to avoid iris and pupil distortion.**

The best way to avoid ovalization of the pupil is to place the suture more toward the peripheral iris than toward the pupillary margin. Using a Sinskey hook or another second instrument, push up on the optic to help visualize the haptics behind the iris.

- Push the needle out through limbal clear cornea (the exit wound does not need an incision). Another option is to create a paracentesis where you will exit with the suture needle and use a needle or cannula to dock the suture needle and externalize it out of the paracentesis.
- Now that the haptic is fixated, the suture can be tied using a variety of methods (Fig. 24.3). Options include a modified Siepser knot or a McCannel suture. At Duke, we strongly advocate the use of a modified Siepser sliding knot to prevent haptic slippage.[3]

Modified Siepser Knot

- Use a Sinskey or Kuglen hook or Condon snare, grab the distal end of the suture, and pull it through the paracentesis from which you entered with the suture needle.
- Make a large loop with the distal suture you pulled through. The loose end (the end NOT attached to the iris) on the loop should

be AWAY from you and the tight end (the end ATTACHED to the iris) should be TOWARD you.

- Place the proximal tail close so that it is easy to grab.
- The suture can be tied down with a 2-1-1 knot in opposite directions.
- An excellent video demonstration can be found on eyetube.net.[4]
- The second haptic is fixated in the same manner as the first, repeating the same steps above.
- Once both haptics are fixated, the optic is positioned behind the iris into the posterior chamber using a Sinsky hook. Perform this step with caution as to not disengage your sutures.
- The sutures are cut with MST scissors to leave a 1- to 2-mm tail.
- The irrigation/aspiration unit is used to remove the remaining OVD.
- Hydrate all incisions with BSS and return the eye to physiologic pressure.

POSTOPERATIVE CONSIDERATIONS

- It is best to avoid dilation of the pupil for a few months after surgery to prevent haptic slippage.
- Assess for any postoperative AC inflammation or iris chafing by looking for AC pigment, cell, or flare, as well as transillumination defects. Also carefully monitor postoperative IOP to ensure there are no elevations in the setting of pigment dispersion.

References

1. Duchene M, Iscar C, Muraine M, Gueudry J. Characteristics and management of Uveitis-Glaucoma-Hyphema syndrome. Article in French. *J Fr Ophtalmol*. 2020;43(3):205-210.

2. https://www.doctor-hill.com/iol-main/bag-sulcus.htm
3. Siepser SB. The closed chamber slipping suture technique for iris repair. *Ann Ophthalmol*. 1994;26(3):71-72.
4. https://eyetube.net/collection/residents-fellows/siepser-sliding-knot-demo/#

CHAPTER 25

Glued Intraocular Lens Technique

Andrew Rollin Davis, MD, Melissa B. Daluvoy, MD

PREOPERATIVE CONSIDERATIONS

For secondary IOL cases, consider which technique is best for your patient. Some older patients with good endothelial cell counts may do well with a straight forward ACIOL.[1] An iris sutured lens may be appropriate in patients with a low risk of CME.[2] A younger patient who has many more years to develop complications from an AC or iris sutured lens may be better suited with a scleral fixated IOL.

There are several different ways to scleral fixate an IOL.[3 - 8] The glued technique provides excellent scleral fixation; however, it may be inappropriate for patients needing glaucoma surgery in the future or with preexisting conjunctival scarring. In these cases, the Yamane technique is preferable to prevent conjunctival scarring from the peritomies required in the glued technique.

SURGICAL PLANNING

- Manage patient expectations.
- Determine if the patient has had a previous vitrectomy. If not, consider an anterior vitrectomy at the time of surgery.
- Let the operating room team know you will need:
    - Zeiss CT Lucia, Alcon MA60AC lens, or Johnson & Johnson ZA9003 three-piece IOL

- 23G MVR blade
- 23G MST set
- AC maintainer

- If combining your case with a retina surgeon, explain the importance of reducing chemosis, which can obstruct the view for the subsequent steps of the surgery.

SURGICAL PROCEDURE: GLUED INTRAOCULAR LENS (FIG. 25.1)

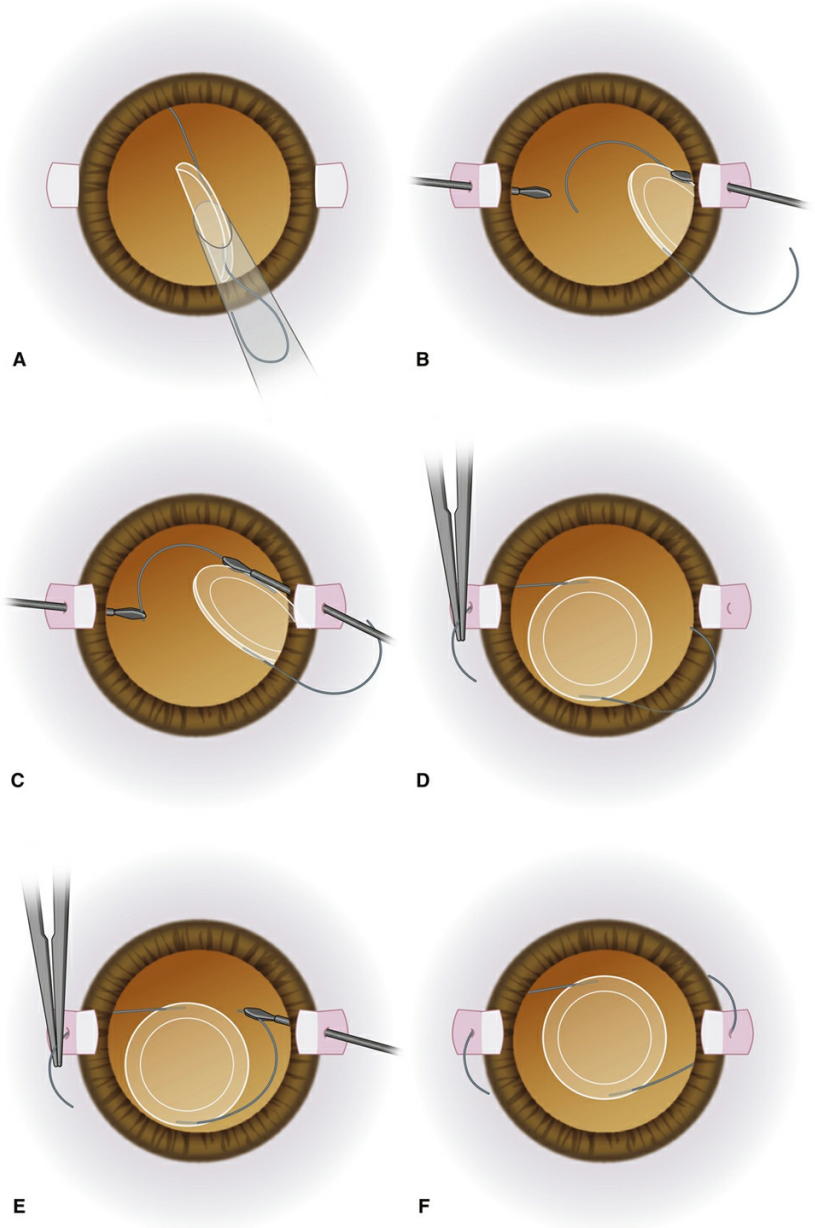

FIGURE 25.1 **Steps of the glued-IOL procedure. A. The three-piece IOL is injected into the AC. The two scleral flaps are created 180 degrees apart, and sclerotomies have been fashioned underneath the flaps. B. Micro forceps are passed through the opposite sclerotomy site while the second set of forceps are ready to receive the leading haptic. C. The leading haptic is grasped with the micro forceps. D. One haptic is externalized and the assistant holds the haptic. E. The trailing haptic is then grasped with the other set of micro forceps through the sclerotomy site. F. Both haptics are externalized under the scleral flaps and then tucked into the scleral tunnels created at the edges of the scleral flaps.**

- We prefer to sit temporally to avoid limiting maneuverability over the brow and nose; however, the surgeon can also sit superiorly..

> The vertical corneal diameter is typically smaller than the horizontal corneal diameter, so a temporal approach will likely give you more haptic length to work with.

- Create two paracenteses 45 degrees away from the main wound.
- Create your main wound with a keratome.
- Create another paracentesis port on the opposite side of your main incision. Place an AC maintainer, or skip this step if there is already an infusion trocar placed by the retina service.
- If sitting temporally, at roughly the 6- and 12-o'clock positions, place marks 2.5 mm posterior from the limbus (further from the limbus in large eyes, closer in shorter eyes). Alternatively, these marks can be made at the 3- and 9-o'clock positions if sitting superiorly.

> Take care to place your marks exactly 180 degrees apart to avoid IOL tilt or decentration. This can be done with a toric marker or an inked cyclodialysis spatula across the center of the cornea.

- Perform localized peritomies overlying these areas.
- Use a crescent blade to first outline a partial-thickness scleral flap 2 to 3 mm in width centered on your previous marks, starting 1 mm posterior to your marks and extending to the limbus. Do not incise on the limbal side.
- After you have created your outlines, use the crescent blade to create a partial-thickness flap.

To create a nice partial-thickness scleral flap, place downward pressure with the bottom of the crescent blade and move side to side in a “wax on, wax off” fashion. Remember, the blade cuts with the top and side components and not the bottom. Keep the heel of the blade down so as not to unintentionally create a full-thickness flap by angulating the cutting toe edge into the eye.

- Reflect your flaps. Again, mark the scleral ~2.5 mm back from the limbus.
- Use the 23G MVR blade to create a sclerotomy at this mark.
- Insert the MST forceps through the sclerotomies to make sure the sclerotomies are large enough for the instruments. Check the forceps and make sure that their tips come together.
- Inject the lens through the main incision. If the injector is a screwing mechanism, you may need to have your assistant do this as you stabilize the injector.
- With your other hand, insert the MST forceps through the sclerotomy and grasp the leading haptic as it comes forward out of the injector. Leave the trailing haptic out of the main wound as you remove your injector.
- Externalize the leading haptic with the MST forceps. Note: If an assistant is available, they can fixate the externalized leading haptic to be sure it does not slide back into the eye. The eyelet of an iris hook can also be used to secure the haptic to the conjunctiva.
- Now, you have a trailing haptic in the main wound. Take a pair of MST forceps and grasp the trailing haptic. Take another pair of MST forceps in your opposite hand and place them through a paracentesis port on that side. “Handshake” the trailing haptic to the opposite MST forceps through the main wound.

- Through the opposite sclerotomy, place the MST forceps, grasp the haptic, and externalize.
- When grasping the edge of the haptics with the MST forceps, take care to not regrab multiple times to avoid crimping the haptic edges as they can bend or break off, which can render tunneling of the haptics into the sclera (described below) more difficult.
- Check the position and centration of the lens. Minor adjustments can be made by tilting the haptics prior to tunneling them in the sclera. Use a 27G needle to create a scleral tunnel counterclockwise from the sclerotomy. Note: inking the tip of the needle will mark the entry point, which can facilitate finding the opening to feed the haptic.
- Tuck the haptics into the tunnels.
- Close the flaps and conjunctiva using fibrin glue.
- Hydrate all wounds, check for leaks, and consider suturing the main wound.
- Consider suturing the sclerotomies if there is concern there may be leakage.

Alternatively, if you want to avoid creating a scleral flap, a modified technique is proposed by the authors as detailed below.

- Mark the sclerotomy points as previously described.
- Perform a peritomy.
- Create your sclerotomies with an MVR blade and orient the incision perpendicular to the limbus.
- Then, perform the above steps and externalize both of the haptics. Next, starting from a position around 0.5 to 1 mm posterior and 1 to 2 mm counterclockwise from the furthest

posterior extension of the sclerotomy (oriented perpendicular to the limbus), use a bent 27G or 30G TSK needle to tunnel into the sclera to the furthest posterior extension of the sclerotomy, dock the haptic in the TSK needle, pull the haptic through the sclera, melt the haptic as in the Yamane technique, and bury the mushroom capped haptic into the sclera.

- At this point, you may consider suturing the sclerotomy.
- Finally, close the overlying conjunctiva. In this proposed technique, the angulation of the TSK needles may be challenging, but in comparison with the traditional technique and others proposed, you avoid creating scleral flaps, create a smaller peritomy, and allow for better closure of the sclerotomy, and no additional equipment is needed besides readily available TSK needles.

POSTOPERATIVE CONSIDERATIONS

- Increase topical steroids if you suspect the patient will have corneal edema and taper according to clinical improvement.
- Consider an NSAID to reduce inflammation and CME.
- Postoperative hemorrhage can occur if there is any disruption of the iris or ciliary body at the time of sclerotomy creation. These tend to resolve over a few weeks, and vitreous hemorrhage precautions should be instituted along with increased topical steroids.
- Postoperative hypotony can occur if the sclerotomies leak. As such, ERR on the side of suturing the sclerotomies closed if there is any concern about leakage. A 7-0 or 8-0 Vicryl suture can be used to suture the sclerotomies.

References

1. Walters RF, McGill JI, Batterbury M, Williams JD. Complications of anterior chamber lens implants and their effects on the endothelium. *Eye (Lond)*. 1989;3(6):690-695. doi:10.1038/eye.1989.106
2. Dzhaber D, Mustafa OM, Tian J, Cox JT, Daoud YJ. Outcomes and complications of iris-fixated intraocular lenses in cases with inadequate capsular support and complex ophthalmic history. *Eye (Lond)*. 2020;34(10):1875-1882. doi:10.1038/s41433-019-0759-6
3. Stem MS, Todorich B, Woodward MA, Hsu J, Wolfe JD. Scleral-fixated intraocular lenses. *J Vitreoretin Dis*. 2017;1(2):144-152. doi:10.1177/2474126417690650
4. Gabor SGB, Pavlidis MM. Sutureless intrascleral posterior chamber intraocular lens fixation. *J Cataract Refract Surg*. 2007;33(11):1851-1854. doi:10.1016/j.jcrs.2007.07.013
5. Agarwal A, Kumar DA, Jacob S, Baid C, Agarwal A, Srinivasan S. Fibrin glue-assisted sutureless posterior chamber intraocular lens implantation in eyes with deficient posterior capsules. *J Cataract Refract Surg*. 2008;34(9):1433-1438. doi:10.1016/j.jcrs.2008.04.040
6. Ganekal S, Venkataratnam S, Dorairaj S, Jhanji V. Comparative evaluation of suture-assisted and fibrin glue-assisted scleral fixated intraocular lens implantation. *J Refract Surg*. 2012;28(4):249-252. doi:10.3928/1081597X-20120221-01
7. Maggi R, Maggi C. Sutureless scleral fixation of intraocular lenses. *J Cataract Refract Surg*. 1997;23(9):1289-1294. https://journals.lww.com/jcrs
8. Nudleman E, Yonekawa Y, Prenner JL. Sutureless transscleral fixation of secondary intraocular lenses. *Curr Opin Ophthalmol*. 2018;29(3):210-216. doi:10.1097/ICU.0000000000000474

CHAPTER 26

Sutureless Scleral Intraocular Lens Fixation Techniques: Yamane Technique

Lloyd Williams, MD, PhD

There are many techniques for scleral fixation for IOLs. One of the most recent is the Yamane technique developed by Shin Yamane and published in 2017.[1] I have found this to be a very effective and quick way to scleral fixate lenses and have had good success with this technique. When using the correct instrumentation and technique, it can seem quite easy, but the learning curve can be very steep and when difficulties arise, they can be quite complex, so this technique should not be underestimated. That said, the Yamane technique is my most common approach to fixating an IOL in a patient with no capsular bag or capsular support.

The original Yamane technique, as described in the journal *Ophthalmology* in 2017, is as follows:[1]

- A 25G or 27G pars plana vitrectomy is performed under retrobulbar anesthesia.
- A three-piece IOL is inserted (X-70 [Santen], Tecnis ZA9003 [Johnson & Johnson], or MA60AC lens [Alcon]) into the AC with the trailing haptic left outside.
- At 2 mm back from the limbus, an angled sclerotomy is made with a 30G thin-walled TSK needle.
- The leading haptic is threaded into the TSK needle.

- A second angled sclerotomy is made 180 degrees away and facing the opposite direction with a second TSK needle.
- The trailing haptic is threaded into this needle.
- Both needles are withdrawn simultaneously with a "double-needle technique."
- The ends of both of the haptics are cauterized to make a 0.3-mm flange and then pushed into the scleral tunnels.

In this study, the results showed no cases of late IOL dislocation with a follow-up of up to 36 months. Complications included iris capture of the IOL (8%), vitreous hemorrhage (5%), elevated IOP (3%), postoperative hypotony (2%), corneal edema (1%), and CME (1%).

Since its first description, many variations have been described, including threading of the trailing haptic as opposed to the leading haptic first into the TSK needle, externalizing haptics one at a time, open-sky technique during a PKP, and refixation of lens inside the eye.[2] I personally frequently externalize haptics one at a time but otherwise find the other aspects of the original description of the Yamane technique to work well for me. Figure 26.1 is a drawing of how I do the technique when using the double-needle pull out method.

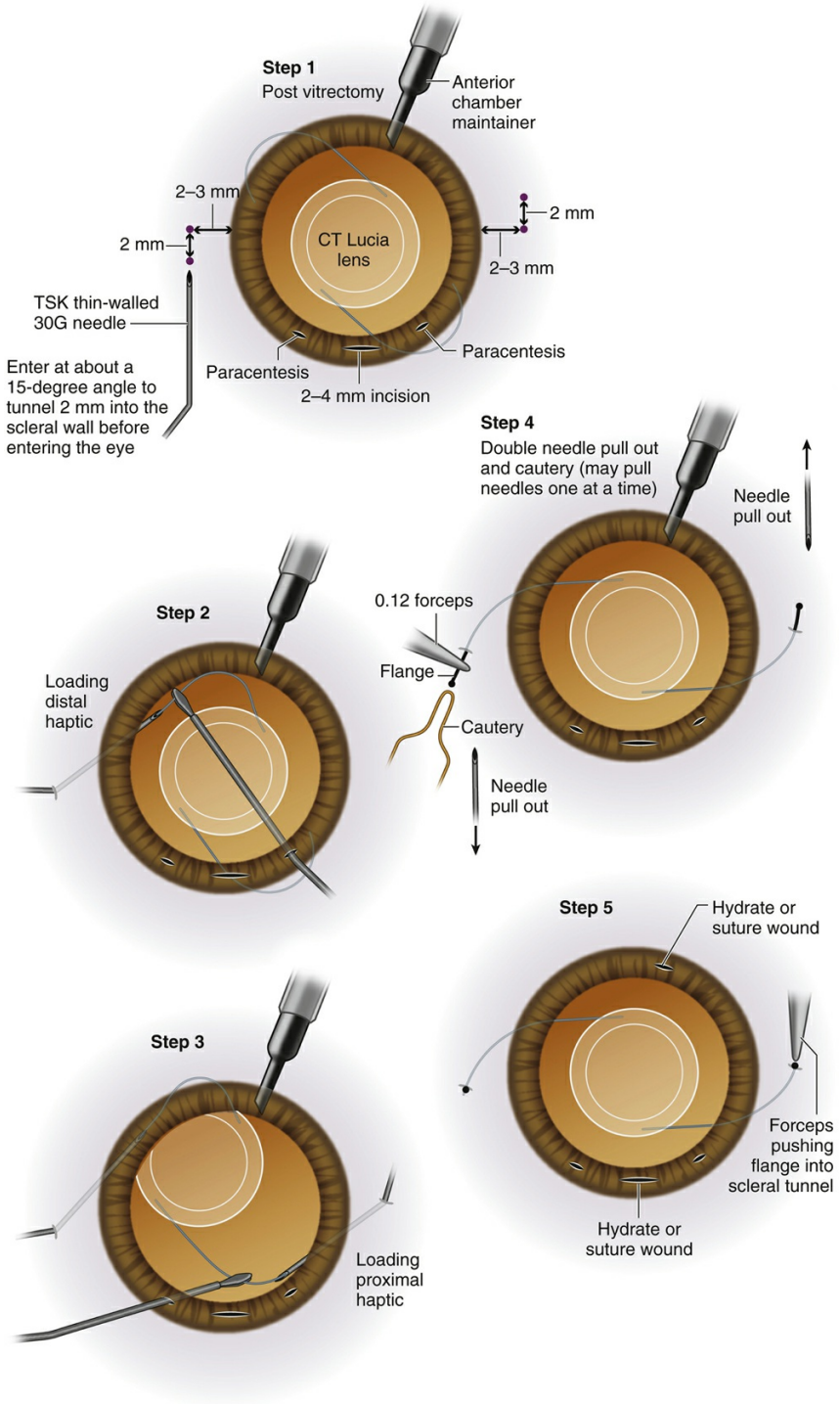

FIGURE 26.1 **Schematic outlining the step-by-step surgical approach for the Yamane intrascleral haptic fixation technique.**

Some of the key principles that I have found in my work with the technique include:

- IOL choice: The Zeiss CT Lucia lens has polyvinylidene fluoride haptics, which are quite flexible and can be bent without crimping. In addition, they seem to be slightly thinner than the MA60AC haptics, which I often find difficult to feed into the TSK needle, even when perfectly positioned. The MA60AC haptics can be easily broken or permanently crimped. Overall, when available, the CT Lucia lens will make the Yamane technique much easier with greater chances of success.
- Needle choice: Use the TSK needle or the thin-walled 30G needle from the MicroSurgical technology (MST) Yamane kit. The TSK needle is necessary if using a 30G needle. A regular 30G needle will not accept the haptic into the lumen. If TSK needles are not available, consider using a 27G needle as has been described in the literature as well. Because of the difficulty I have had in loading the MA60AC haptics into the TSK needle, I plan to use 27G needles if I am using an MA60AC lens.
- AC maintainer: Although a few cases may be able to be performed under viscoelastic, because of vitrectomy, most cases will require stabilization of the AC with an AC maintainer and use of one is essential to having proper visualization and stability. Visibility should be maintained, and it is very difficult and inadvisable to pass a needle through the sclera in a hypotonous eye. If combined with pars plana vitrectomy, the infusion from the pars plana vitrectomy may be used instead of an AC maintainer.
- Intraocular instruments: I use the MST forceps for manipulating the haptics and lens. This allows for movements through a paracentesis wound and main wound that can be oriented at the perfect angle for loading the haptics into each needle. Other fine intraocular instruments exist and should be selected by surgeon preference.
- Proper angling and position of the needle sclerotomy: Sclerotomies should be 1.5 to 2.5 mm from the limbus, created at

a 15-degree angle, oriented tangentially, and the sclera should be at 180 degrees apart from each other. If the pass into the eye is too vertical or different between the two sclerotomies, it will become impossible to prevent lens tilt as the optic position is governed by the sclerotomy position. In addition, if the entrance into the eye is not very nearly or exactly 180 degrees apart, centration of the optic may be impossible.

- Ensuring IOL centration: After externalization of the haptics and using cautery to bulb the ends, the haptics can be manipulated to determine optimal centration of the IOL. Sometimes, ideal centration requires amputation of one or both of the haptics by 1 to 1.5 mm and recauterizing the ends. The ends can then be pushed into the scleral tunnels to confirm position and centration of the IOL.

Although other methods of IOL fixation exist, such as ACIOLs, iris-sutured IOLs, scleral-sutured IOLs, and modifications of these, the Yamane technique for sutureless scleral fixation of IOLs deserves to be considered in cases with inadequate capsular bag support.

Please see Video 26.1 for a view of this technique. In this video, a subluxed crystalline lens in a patient with Marfan syndrome is removed and a CT Lucia IOL is fixated to the sclera with the Yamane technique.

References

1. Yamane S, Sato S, Maruyama-Inoue M, Kadonosono K. Flanged intrascleral intraocular lens fixation with double-needle technique. *Ophthalmology*. 2017;124(8):1136-1142.
2. Pugazhendhi S, Ambati B, Hunter AA. Double-needle Yamane repositioning of a previous Yamane fixation. *Case Rep Ophthalmol*. 2019;10(3):431-437.

Section 7

Corneal Surgery

CHAPTER 27

Penetrating Keratoplasty

Ashiyana Nariani, MD, MPH, Sanjay V. Patel, MD, FRCOphth, Mark A. Terry, MD

INDICATIONS FOR PENETRATING KERATOPLASTY[1,2]

Optical Indications

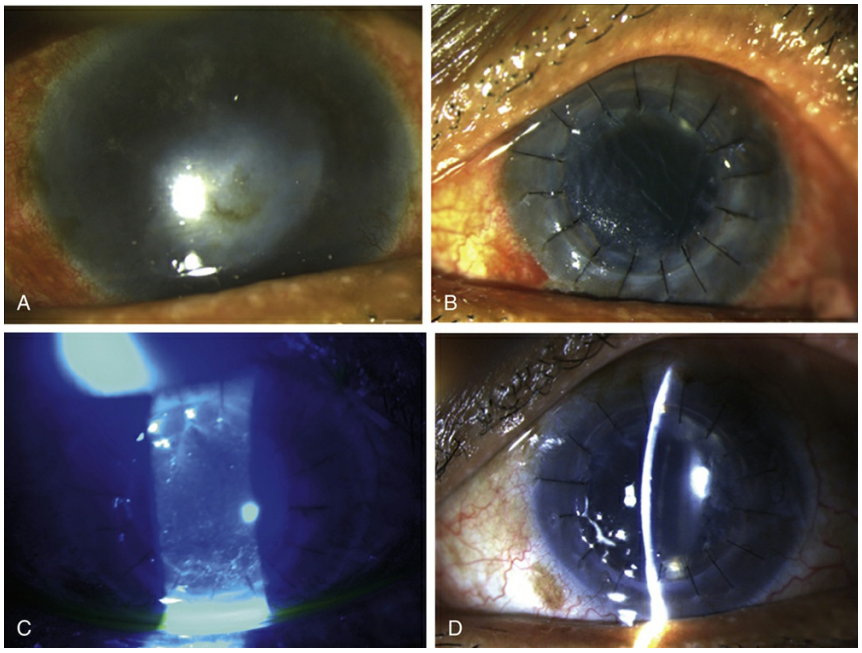

FIGURE 27.1 **Slit-lamp photographs of a scarred cornea post viral keratitis before and after optical PKP. A. Preoperative photograph of left eye with central corneal scar. B. Two days post PKP with stromal edema. C. Eight weeks post-op PKP with fluorescein stain revealing punctuate epithelial erosions. D. Ten weeks post-op PKP with normal epithelium and no stromal edema.**

- Corneal scar (Figure 27.1).
- Keratoconus or other ectasias.
- Corneal dystrophy extending to DM.
- Endothelial failure with significant stromal scarring.
- Failed penetrating graft with high or irregular astigmatism.

Therapeutic Indications

- Microbial keratitis unresponsive to medical therapy.
- Microbial keratitis close to limbus or at risk of scleral involvement.
- Endothelial keratoplasty interface infection.

Tectonic Indications

- Corneal perforation or descemetocele not amenable to lamellar keratoplasty.

PREOPERATIVE CONSIDERATIONS

- Rule out the possibility of improvement with medical therapy, RGP or scleral lens, DALK, or EK prior to electing for a full-thickness PKP.[3]
- If minimal view of the posterior segment and eye is Seidel negative, perform a B-scan to rule out posterior segment pathology.
- Know the status of the lens. If a cataract is present, consider PKP with cataract extraction and IOL implantation (triple procedure). Use biometry measurements from the contralateral eye (if normal) to help with IOL power calculations. Alternatively, use

common average keratometry values of $K = 45$ or $K = 46$.

- Measure the horizontal and vertical corneal diameters at the slit lamp. Determine if the pathology can be encompassed by a certain diameter of trephine or if trephination will need to be eccentric. Be prepared with various corneal trephine sizes in the OR.
- Assess for risk factors that will influence the suture technique.
- Take a detailed medical history including risk factors for posterior pressure, such as hypertension, respiratory disease, coughing, and body mass index.
- Donor considerations: Tissue should meet EBAA standards.[4 - 7]

SURGICAL PLANNING[1]

TABLE 27.1 Complications of PKP

Intraoperative	Expulsive suprachoroidal hemorrhage
	Trephination of iris and/or lens
	Hyphema
Early postoperative	Nonhealing epithelial defect
	Wound leak
	Ocular hypertension
	Eyelid ptosis
	Cataract formation/progression
	Suture-related infiltrates (sterile or infectious)
	Endophthalmitis
Late postoperative	Ocular surface disease (tear film, neurotrophic)
	Wound dehiscence (spontaneous, traumatic)
	Suture-related infection
	Cataract formation/progression
	Glaucoma
	Graft rejection
	Graft failure
	High and/or irregular astigmatism requiring RGP/scleral lens

- Anesthesia considerations: If the eye is Seidel-negative, anesthesia options include retrobulbar or peribulbar block with or without concomitant intravenous sedatives for comfort. Consider general

anesthesia for cases of perforated cornea and avoid retrobulbar/peribulbar block because of increased posterior pressure and the risk of expulsive suprachoroidal hemorrhage.

- Preoperatively, use of topical antibiotics, and in combination with oral antibiotics in some cases, is advised. Instill topical pilocarpine 1% (unless combined with cataract or posterior chamber lens procedure in which case dilation is required) to avoid lens expulsion and touch.
- Obtain detailed informed consent including possible complications (Table 27.1), long-term follow-up, need for staged suture removal, and the possible need for an RGP or scleral lens for visual improvement. Discuss visual prognosis and length of recovery, and try to manage patient expectations.
- Posterior pressure management is critical to avoid an expulsive suprachoroidal hemorrhage. The most common source of posterior pressure is the lid speculum pressing on the sclera, so adjust accordingly. Consider using intravenous mannitol prior to or at the time of surgery (weight-based dosing). Plan for a reverse Trendelenburg position of the patient on the OR table. If general anesthesia is used, the addition of complete muscle paralysis medications prevents inadvertent patient movement.

SURGICAL PROCEDURE: PENETRATING KERATOPLASTY (FIG. 27.2)

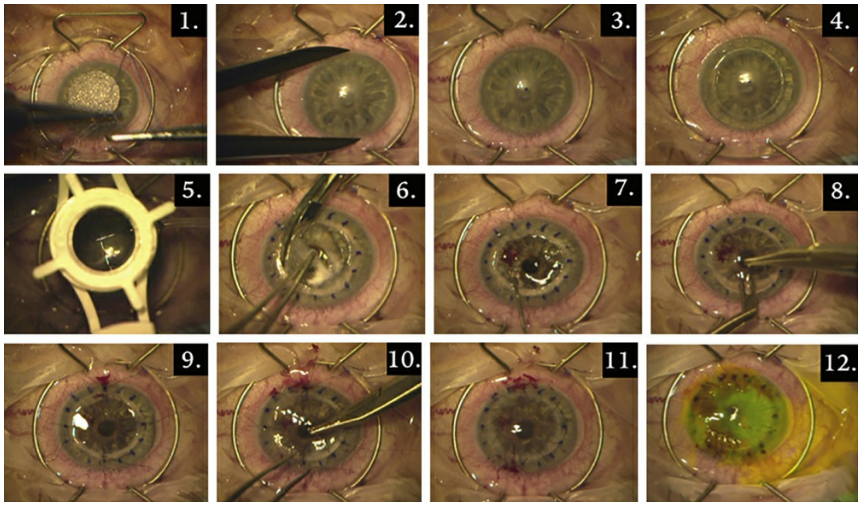

FIGURE 27.2 **Step-by-step surgical technique of PKP 1. Suture Flieringa ring with 6-0 or 7-0 Vicryl suture.2. Measure horizontal and vertical dimensions of the cornea.3. Mark and ink the center of the cornea.4. Place initial trephine indent onto host cornea and check centration.5. After successful donor cornea trephination, trephine host cornea.6. Inject viscoelastic into the AC and trim the wound edge of host cornea rim 360 degrees.7. After ensuring a smooth, full-thickness edge, place viscoelastic into the AC8. Place the first cardinal suture at 12:00 with 10-0 or 11-0 nylon suture.9. Secure door cornea with the initial four cardinal sutures.10. Complete PKP using suture technique of choice (Figure 27.3).11. Confirm astigmatism with keratoscope, adjust sutures and bury.12. Check the wound is Seidel negative with external pressure.**

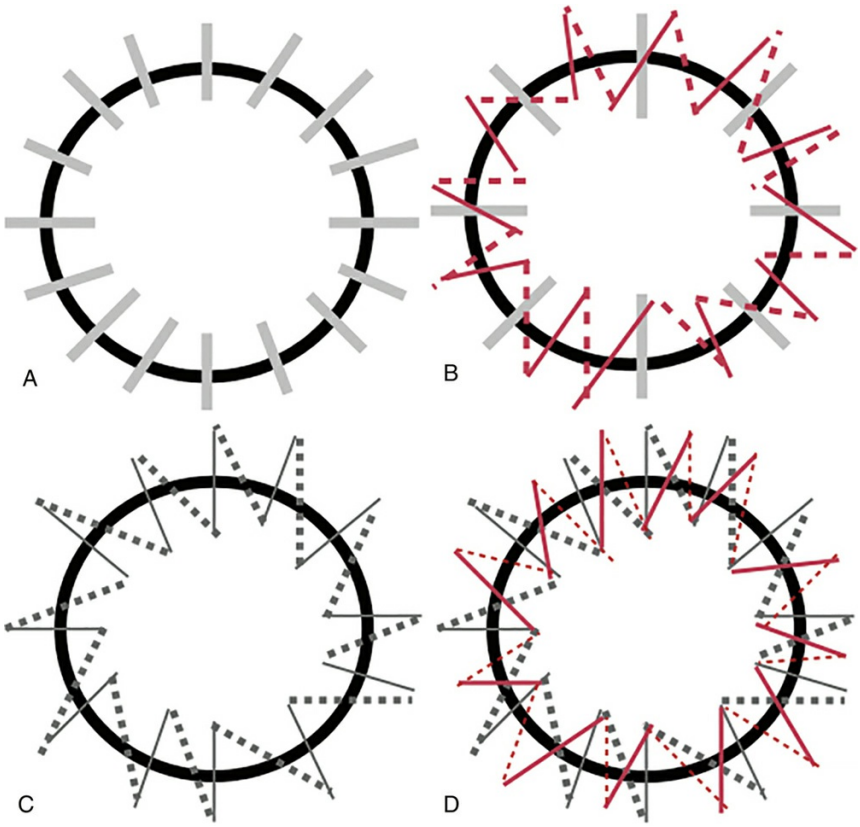

FIGURE 27.3 **Most common PKP suturing techniques. A. Sixteen interrupted sutures. B. Combined interrupted and running. C. Single running. D. Double running.**

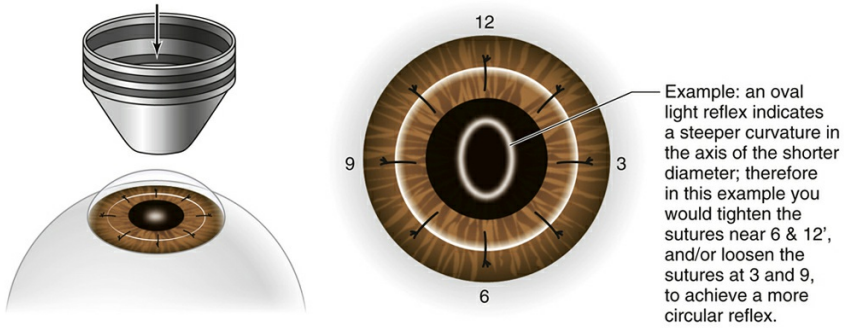

FIGURE 27.4 **A Maloney ring can be used to assess astigmatism during PKP. By observing the light reflex on the cornea, it is possible to adjust the suture tension to reduce the induced astigmatism.**

- If perforated, consider a loose speculum. Avoid a retrobulbar or

peribulbar block in these cases. Avoid periorbital pressure, eg, from tight or heavy drapes.

- Mark the corneal center and measure corneal diameters.
- Consider placing a Flieringa ring, or other scleral support device (eg, McNeil-Goldman blepharostat), particularly in aphakic, pediatric, or combined triple cases, to avoid collapse of the scleral wall.
- Select donor and host trephine sizes. It is deal for the host trephine diameter to be ≥3 mm less than the horizontal corneal diameter to reduce the risk of immunologic rejection where possible. Host and donor trephines can be the same size, or the donor can be oversized (which will induce a myopic shift, so consider limited oversizing or using the same size for keratoconus). Consider oversize in vascularized corneas, inflamed eyes, or eyes at risk of phthisis.
- Donor trephination with a manual punch with the endothelium up (or consider femtosecond laser). Gentle handling of the donor cornea is essential to avoid unnecessary endothelial cell loss.
- Host trephination with a manual handheld trephine or a vacuum trephine (or consider femtosecond laser). Monitor for aqueous egress, and avoid trephination of the iris and lens.
- Inject viscoelastic into the AC. Trim wound edge of the host corneal rim to ensure a smooth full-thickness edge for 360 degrees.
- For a PKP triple procedure, cataract surgery is generally done via an open-sky approach with capsulotomy or phacoemulsification with a capsulorhexis when there is a relatively clear view into the AC. Consider using a viscoadaptive agent or soft-shell technique to minimize run out of the capsulorhexis. Intracameral miotic agents can then be used to secure lens position.
- Consider placing a surgical peripheral iridectomy, particularly if

there are risk factors for or current evidence of glaucoma.

- Place the first four interrupted cardinal sutures using 10-0 nylon. Thereafter, proceed to complete suture placement by your technique of choice: all interrupted sutures, combined interrupted and running suture, single running or double running sutures (Figure 27.3). Avoid running sutures in inflamed eyes and vascularized corneas, as each quadrant can loosen separately, requiring removal of the entire running suture, rather than single suture removal with the all interrupted technique.[8,9]
- Place viscoelastic as needed to maintain the AC during suture placement; evacuate viscoelastic with manual irrigation after suture placement is completed in order to protect the endothelium.
- Tie interrupted sutures to equal tension, or distribute the tension of running sutures guided by a keratoscope while maintaining a sealed wound. Ideal to bury suture knots in the host rim (Figure 27.4).
- Check the wound is Seidel negative with placement of external pressure.
- Inject subconjunctival antibiotics and short-acting steroids unless contraindicated. Alternatively, place a dissolving collagen shield soaked in antibiotics and steroids to deliver antibiotics and steroids to the eye over the ensuing 18 hours of patching.
- Patch the eye.

POSTOPERATIVE CONSIDERATIONS[10,11]

- Use topical antibiotics until the graft is epithelialized. Use topical corticosteroids (unless contraindicated) for postoperative inflammation, with a gradual taper over months.[12] Increase topical corticosteroids if sterile suture-related infiltrates develop

(usually at 2 to 4 weeks postoperative). Consider oral antibiotics and/or steroids if indicated.

- Monitor intraocular pressure regularly. Start topical and/or oral IOP-lowering agents when necessary.[13, 14]
- Loose or broken sutures should be removed immediately to prevent infection and corneal melting; this might require resuturing the wound if early in the postoperative period. Consider removing sutures associated with blood vessel ingrowth.
- Suture removal regimen will vary based on the suture technique performed and per surgeon preference.

References

1. Brightbill FS. *Corneal surgery*: theory, technique and tissue. In: *Section 3*: Penetrating Keratoplasty. 4th ed. Elsevier; 2008:365-553.
2. Krachmer JH, Mannish MJ, Holland EJ. *Cornea*: Fundamentals, Diagnosis and Management. Vol 1. 3rd ed. Elsevier; 2011:1330-1351.
3. Henein C, Nanavaty MA. Systematic review comparing penetrating keratoplasty and deep anterior lamellar keratoplasty for management of keratoconus. *Cont Lens Anterior Eye*. 2017;40(1):3-14.
4. Eye Bank Association of America Medical Standards. https://restoresight.org/what-we-do/publications/medical-standards-procedures-manual/
5. Patel SV, Diehl NN, Hodge DO, Bourne WM. Donor risk factors for graft failure in a 20-year study of penetrating keratoplasty. *Arch Ophthalmol*. 2010;128(4):418-425.
6. Cornea Donor Study Investigator Group; Gal RL, Dontchev M, Beck RW, et al. The effect of donor age on corneal transplantation outcome results of the cornea donor study. *Ophthalmology*. 2008;115(4):620-626.e6.
7. Dunn SP, Stark WJ, Stulting RD, et al; Cornea Donor Study Investigator Group. The effect of ABO blood incompatibility on corneal transplant failure in conditions with low-risk of graft rejection. *Am J Ophthalmol*. 2009;147(3):432-438.e3.
8. Lee RM, Lam FC, Georgiou T, et al. Suturing techniques and postoperative management in penetrating keratoplasty in the United Kingdom. *Clin Ophthalmol*. 2012;6:1335-1340.
9. Kim SJ, Wee WR, Lee JH, Kim MK. The effect of different suturing techniques on astigmatism after penetrating keratoplasty. *J Korean Med Sci*. 2008;23(6):1015-1019.
10. Patel SV, Hodge DO, Bourne WM. Corneal endothelium and postoperative outcomes 15 years after penetrating keratoplasty. *Am J Ophthalmol*. 2005;139:311-319.
11. Alqudah AA, Terry MA, Straiko MD, Greiner MA, Davis-Boozer D. Immediate

endothelial cell loss after penetrating keratoplasty. *Cornea*. 2013;32(12):1587-1590. doi:10.1097/ICO.0b013e3182a73822

12. Shimmura-Tomita M, Shimmura S, Satake Y, et al. Keratoplasty postoperative treatment update. *Cornea*. 2013;32(suppl 1):S60-S64.
13. Zemba M, Stamate A. Glaucoma after penetrating keratoplasty. *Ophthalmol*. 2017;61(3):159-165.
14. Maier AB, Gundlach E, Gonnermann J, et al. Anterior segment analysis and intraocular pressure elevation after penetrating keratoplasty and posterior lamellar endothelial keratoplasty. *Ophthalmic Res*. 2015;53(1):36-47.

CHAPTER 28

Descemet Stripping Automated Endothelial Keratoplasty

Mark Frank Goerlitz-Jessen, MD, Victor L. Perez, MD

PREOPERATIVE CONSIDERATIONS

In eyes requiring corneal transplantation, it is important to consider which layer and/or layers of the cornea is diseased, the type of pathology, lens status (ie, phakic, pseudophakic, or aphakic), condition and anatomy of the AC (ie, presence of AC hardware), and what technique of transplantation will be employed.

DSAEK is one type of EK in which the endothelium, DM, and some posterior stroma are transplanted. The graft is thicker than in DMEK, in which only the endothelium and DM are transplanted.

Cornea

- Which layer of the cornea is diseased determines whether PKP or EK should be performed.
- Mechanism of corneal disease also dictates the type of transplantation.
    - Ectasia and pathology of Bowman layer or anterior stroma requires a DALK or PKP
    - Endothelial, and some posterior stromal, disease may be amenable to EK.
    - Chronic corneal disease may not be suitable for EK owing to extensive stromal scarring.

Lens

- DSAEK may be performed alone or in conjunction with cataract extraction with phacoemulsification. If combined, phacoemulsification should be performed first.
- DSAEK is preferred, rather than DMEK, in aphakia or in the presence of ACIOLs.

Anterior Chamber and Iris

- Prior glaucoma surgery, such as a glaucoma drainage device or a trabeculectomy, can impact graft unfolding, placement, and air bubble management. These eyes are better suited for DSAEK rather than DMEK.
- Understand AC depth prior to surgery. Deeper ACs can render DMEK graft insertion more challenging.
- PAS and iris defects (ie, prior iridectomies) may require simultaneous or prior management. PAS will need to be released using viscoelastic and/or a cyclodialysis spatula prior to insertion of the EK graft. Presence of PAS can increase chances of graft rejection. Iris defects can preclude the air bubble from remaining in the AC to provide adequate tamponade for the EK graft. These defects can be covered with a cohesive viscoelastic or sutured closed prior to air insertion.
- DSAEK requires either an inferior peripheral iridotomy (PI) or cycloplegia to avoid pupillary block from the air bubble. The PI can be created intraoperatively using the anterior vitrector. Cycloplegic drops can be administered preoperatively or intraoperatively after the graft is positioned. In cases with a posterior chamber IOL with an open capsule or an iris or scleral fixated IOL, we recommend dilation in the patient after the graft unfolds as opposed to preoperatively to avoid vitreous prolapse during the course of the procedure.

SURGICAL PROCEDURE

- A variety of techniques exist for insertion of the endothelial graft.
- Some common techniques include (a, b, and c are described in this chapter):
  - Sheets glide
  - Endoserter
  - Suture pull-through
  - Tissue folding with forceps
  - Busin glide pull-through
  - Tan EndoGlide
- A retrobulbar block or topical anesthesia may be used for the procedure.

Technique

- Mark the corneal epithelium with a trephine. Use the same size trephine that will cut the graft tissue. Consider staining the trephine with a surgical marker prior to marking the epithelium for improved visualization.
- Make two 1-mm side-port incisions approximately 90 degrees apart (one inferotemporal and another supratemporal if sitting temporally). Additional side-port incisions can be made depending on surgeon preference.
- Fill the AC with a cohesive viscoelastic.
- Following the previously made corneal mark, score the endothelium and DM 360 degrees with either a 25G bent needle or a reverse Sinskey hook. Using both side-port incisions facilitates scoring of all 360 degrees or scoring can be performed through the main incision.

- Create a main wound with a keratome.
- Strip the DM with a reverse Sinskey hook, Gorovoy stripper, or other stripping instrument and remove all of the tissue at once.
- Remove all viscoelastic with irrigation and aspiration and inject an air bubble into the AC to examine for residual tags of the DM. Use irrigation and aspiration to remove the air bubble and any tags.
- Trephinate the graft to the desired size.
- Enlarge the main wound to between 4 and 5 mm in diameter with a keratome.
- Continue the procedure with one of the aforementioned techniques. Subsequent steps for use of a Sheets glide, the Endoserter, and suture pull-through technique are included below.

One of the keys to a successful DSAEK procedure is the health of the graft's endothelial cells. Regardless of the surgical technique employed, extreme care should always be taken to minimize trauma to these cells.

Sheets Glide (Video 28.1)

- Extend the main wound to 5 mm with a keratome.
- Insert the sheets glide across the AC and place cohesive viscoelastic on the portion remaining outside the eye.
- Bring the cut tissue to the surgical field with a spatula. Free the endothelial graft from the cap with a cannula. Place a small amount of cohesive viscoelastic on the endothelium.
- Fold the endothelial graft with a 60/40 overfold with the endothelium toward the inside of the fold.
- Push the graft into the AC with a 30G needle, and then remove

the sheets glide while holding the graft in place. The edge of the 30G needle can be slightly bent down with a hemostat or needle driver to improve stromal traction when pushing the graft.

- The graft can also be placed onto the sheets glide without a 60/40 overfold and pushed into the AC.
- Close the wound with multiple 10-0 Nylon sutures or another wound sealant.
- Unfold the graft by injecting BSS with a cannula.
- Ensure the graft is correctly oriented with the stamp in the “S” configuration. Center the endothelial graft over the scored stromal bed.
- Instill an air bubble under the endothelial side of the graft and fill the AC. Leave the chamber filled with air for 10 minutes.
- Decrease the bubble to approximately 80% fill.
- Ensure all wounds are water- and airtight.

Endoserter (Video 28.2)

- Extend the main wound to 4.1 mm.
- Bring the cut DSAEK tissue to the surgical field. Free the endothelial graft from the cap with a cannula.
- Load the graft onto the Endoserter with the endothelium face up and align the tissue within the alignment holes. Larger grafts will slightly hang over the edge of the carrier to one side. Note that the graft diameter may not exceed 8.5 mm for this technique.
- Remove excess fluid from the carrier with an absorbent Weck-Cel sponge.
- Place a small amount of cohesive viscoelastic on the endothelium.

- Rotate the blue thumb screw in the direction of the arrow. As the carrier retracts, tuck the overhanging edge under the opposite edge using forceps or a cannula. Continue to rotate the thumb screw until the tissue is completely retracted and the screw spins freely.
- Rotate the device 180 degrees so that the black deployment wheels are face up.
- Hold the deployment wheels firmly in position and remove the black lock guard.
- Begin irrigation as the device is inserted into the AC and continue to hold the deployment wheels firmly. Move the device to the distal side of the stripped stromal bed.
- Roll the deployment wheels forward while holding the device in place. Continue to deploy while holding the device steady until the graft is completely uncovered from the carrier.
- Remove the device and close the wound with 10-0 Nylon sutures or another wound sealant.
- Ensure the graft is correctly oriented with the stamp in the “S” configuration. Center the endothelial graft over the scored stromal bed.
- Instill an air bubble under the endothelial side of the graft and fill the AC. Leave the chamber filled with air for 10 minutes.
- Decrease the bubble to approximately 80% fill.
- Ensure all wounds are water- and airtight.

The suture pull-through technique is particularly useful in aphakic eyes. In these cases, the surgeon does not want the graft to fall to the back of the eye, which is prevented both intra- and postoperatively by the suture. The sheets glide technique can also be used in aphakic eyes to provide a barrier to the posterior

segment during insertion of the DSAEK graft.

Suture Pull-through (Video 28.3)

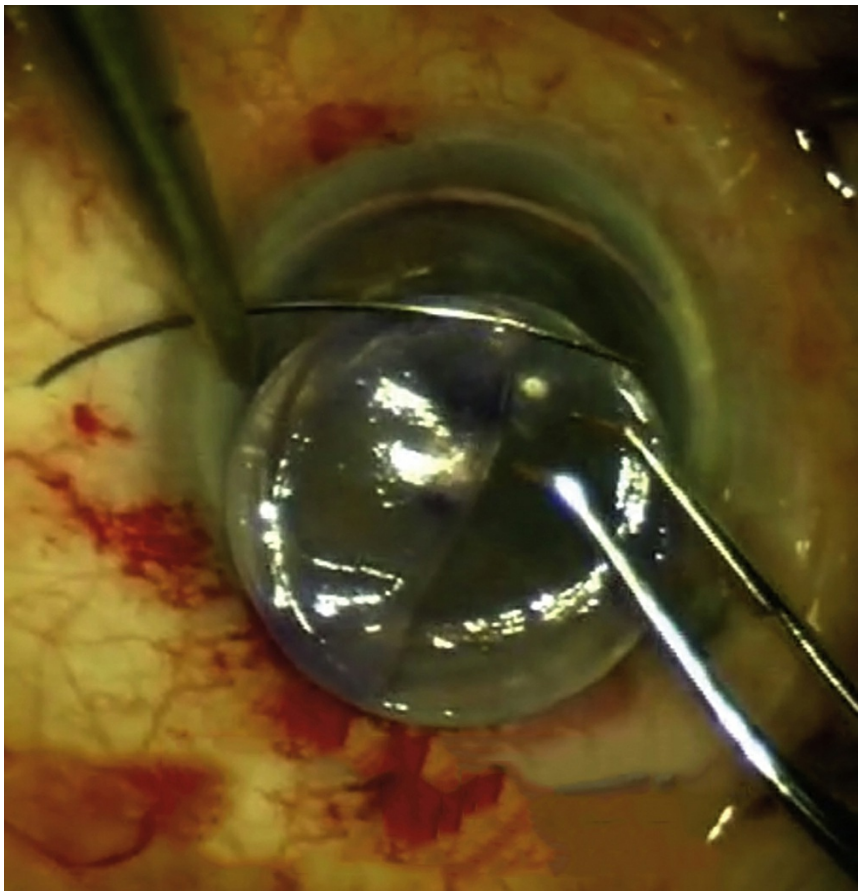

FIGURE 28.1 **A 10-0 polypropylene suture on a CIF-4 needle is passed through the leading edge of the folded graft.**

- Extend the main wound to 4.1 mm.
- Bring the cut DSAEK tissue to the surgical field. Free the endothelial graft from the cap with a cannula.
- Place a small amount of cohesive viscoelastic on the endothelium.
- Fold the endothelial graft with a 60/40 overfold with the

endothelium toward the inside of the fold.

- Pass a double-armed 10-0 polypropylene suture on a CIF-4 needle through the endothelial graft at the leading edge (Fig. 28.1).
- Pass the needle coming from the stromal side of the graft through the main wound, across the AC, and externalize the needle just beyond the scored stromal bed.
- Pass the needle coming from the endothelial side of the graft through the main wound, across the AC, and externalize the needle 1 mm posterior to where the first needle was externalized.
- Approximate the corneal button on the spatula to the main corneal wound. Consider placing some viscoelastic on the conjunctival surface to protect the graft as well. Using the externalized ends of suture, pull the graft off of the corneal cap, through the wound, and into the AC.
- Close the wound with 10-0 Nylon sutures or another wound sealant.
- Unfold the graft by injecting BSS into the fold with a cannula.
- Ensure correct graft orientation with the stamp in the “S” configuration. Center the endothelial graft over the scored stromal bed.
- Instill an air bubble under the endothelial side of the graft and fill the AC.
- Tie the externalized ends of the 10-0 polypropylene suture to secure the endothelial graft in place. Leave the AC filled with air for 10 minutes.
- Decrease the bubble to approximately 80% fill.
- Ensure all wounds are water- and airtight.

Please see Video 28.4 for the folding forceps technique.

POSTOPERATIVE CONSIDERATIONS

In the Recovery Area

- The patient should remain in the supine position for 60 minutes.
- Then, examine the graft to ensure apposition to the stromal bed and adequate centration.
- Verify the air bubble clears the pupillary margin (or PI) and check IOP. If the IOP is over 30, consider decreasing air fill at the slit lamp through one of the paracenteses.
- Place a bandage contact lens if the epithelium was removed at the time of the DSAEK procedure to improve view into the AC.

Air Bubble Management

- The patient should spend as much time in the supine position as possible while an air bubble remains (especially during the first 24 to 48 hours) to ensure apposition of the graft to the stromal bed (at least 45 to 50 minutes of every hour).
- If graft detachment occurs, a "rebubbling" procedure may be performed to place a new air bubble under the graft. Small, peripheral detachments can sometimes be observed.
- If a graft dislocates, the graft can be repositioned using a 27G bent needle with repeat instillation of air. This can be done in the minor procedure room, if necessary.
- The 10-0 polypropylene suture can be removed at postoperative week 1 or later. Do not remove on postoperative day 1 as you may risk dislocation of the graft.

CHAPTER 29

Descemet Membrane Endothelial Keratoplasty

Christopher S. Boelkhe, MD

CLINICAL CONSIDERATIONS

These include endothelial failure/dysfunction and/or visually significant corneal guttae.

RELATIVE CONTRAINDICATIONS

Contraindications include aphakia, ACIOL, history of pars plana vitrectomy (advanced technique involves pars plana infusion to mitigate this), and presence of glaucoma tube shunts/other AC hardware or malformation.

PRESURGICAL CONSIDERATIONS

This procedure needs a patent inferior peripheral iridotomy (PI) to prevent pupillary block related to gas bubble; it is best performed preoperatively with an Nd:YAG laser (3 to 5 mJ) or can be performed intraoperatively with an anterior vitrector or with simultaneous stretching of iris tissue with a bent needle (placed under the iris) and a Sinskey hook (placed above the iris).

Constrict pupil with pilocarpine or intraoperative miotic agents (Miochol or Miostat).

SURGICAL CONSIDERATIONS

Order graft tissue from eye bank: use of tissue that is pretrephined (indicate diameter, 8 mm is typically used), prestripped, prestained with trypan blue, and preloaded into insertion cannula is recommended.

Consider donor age older than 60 years to prevent tightly scrolled tissue

Retrobulbar block versus topical (± intracameral lidocaine)

If DMEK is being performed in conjunction with cataract surgery, intracameral mydriatics will be required initially after which the pupil should be constricted with intraoperative miotic agents.

SURGICAL STEPS

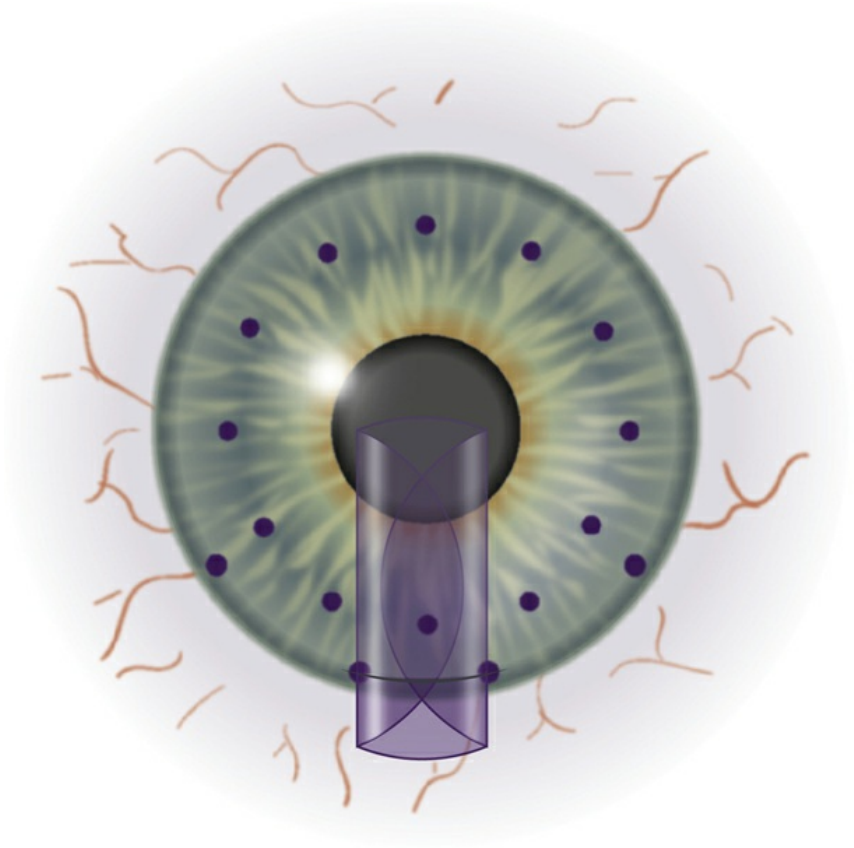

FIGURE 29.1 **Orientation of graft in insertion cannula as it is injected through the temporal clear cornea incision.**

- Use a temporal approach.
- Mark the cornea with an 8 mm–diameter circular marker.
- Create two peripheral paracenteses (superotemporal/inferotemporal). Keep the tunnels short and aimed posteriorly so as to avoid entering within the 8 mm circle (you do not want graft tissue overlapping paracentesis openings).
- Fill the AC with cohesive viscoelastic.
- Create a temporal clear cornea incision 2.2 to 2.8 mm.
- Use a reverse Sinskey hook through superotemporal paracentesis (go posterior to iris) and straight Sinskey hook through temporal cornea incision (anterior to iris) to stretch premade inferior PI and

ensure patency.

- If the PI is performed intraoperatively, take care to not cause hemorrhage into the AC as this can render unscrolling of the graft more challenging.
- Prepare graft tissue. The exact steps will depend on particular eye bank preparation, but generally this involves simple dilution of the storage solution from the insertion cannula. Occasionally, further staining with trypan blue may be required to improve intraoperative visualization. Have a back-up insertion cannula with tubing available in the operating room to reload tissue in the event the original insertion cannula is damaged or the graft escapes from the insertion cannula during tissue preparation or insertion into the eye.
- Strip an 8 mm circle of DM. This can be done with a reverse Sinskey hook or with a bent, bevel-down 25G short needle on a cannula with a slightly roughened edge. First, use a full circumferential movement to score the desired perimeter, then carefully strip the entire 8 mm circle taking care to avoid engaging posterior stroma or causing stromal tags. Consider using a stripper or DMEK forceps to complete stripping.
- If visualization is poor due to advanced bullous keratopathy or epithelial swelling, consider performing a superficial keratectomy and/or using trypan blue in the AC to stain the host DM.
- Submit the DM tissue to pathology for evaluation.
- Use irrigation/aspiration to remove all viscoelastic from the AC.
- Consider placing air bubble into the AC to visualize the area of stripped DM and ensure absence of residual tags of DM (which will inhibit graft adherence), then remove all air/gas and partially fill the AC with BSS (avoid overpressurizing the AC and keep the globe soft as you want the pressure gradient to favor graft insertion).

- Loosen the eyelid speculum to reduce posterior pressure and ease graft insertion.
- Examine the graft tissue in the insertion cannula under the microscope in attempt to ascertain the graft orientation (a scroll-up orientation is preferred if possible).
- Place the insertion cannula into/at the opening of the temporal cornea incision, and with a quick burst of BSS inject graft tissue into the AC. Consider using a BSS cannula to place downward pressure proximal to the main wound when withdrawing the insertion cannula to prevent slippage of the graft out of the eye (Fig. 29.1).
- Inspect tissue orientation and attempt to verify upward/downward scroll; if latter, inject small bursts of BSS to flip the orientation of the graft.
- With 27G cannulas on handles, place posterior pressure on both paracenteses simultaneously to the shallow AC and use swift taps to locate the graft tissue to the center of the host cornea.
- Use tissue manipulation maneuvers to unscroll and center the graft within 8 mm area of the stripped DM.

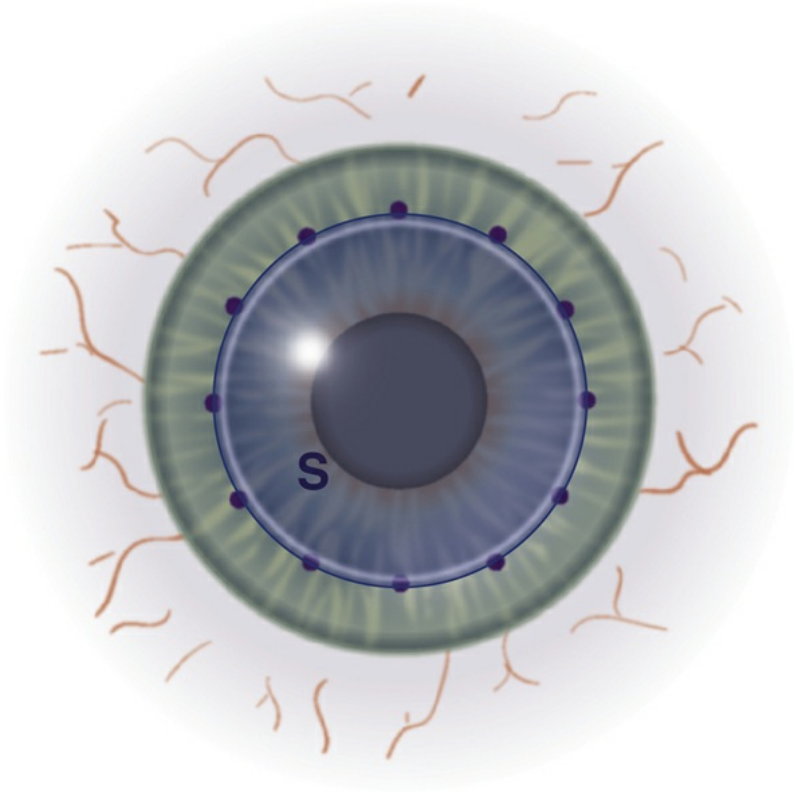

FIGURE 29.2 **DMEK graft unscrolled with S stamp in correct orientation.**

See www.patientready.org for helpful solutions to tissue configurations generally using progressive shallowing of the AC to "trap" tissue in place (you occasionally need to put manual pressure on the equator of the globe to induce AC flattening). Further shallowing of the AC can be achieved by gently burping the main wound. Be mindful that aggressive or prolonged tapping can cause formation of fibrin in the AC. If this occurs, aim to flush out the fibrin with BSS to avoid adherence to the graft, which can inhibit unscrolling of the graft tissue.

- When tissue is unscrolled, oriented (verify alignment of stromal "S" or other orientation marks placed by eye bank), and centered, insert a 30G cannula to the center of the pupil/graft and slowly inject 20% SF6 gas (mix 10 mL of 100% SF6 gas with 50 mL of filtered air) or air to tamponade donor tissue to the host cornea.

Aim for full AC fill with an IOP 40 to 50 mm Hg. Ensure that you are completely under the graft prior to injecting gas or air to avoid rotation or displacement of the graft. If the graft moves or flips, gas or air needs to be removed and injection of BSS along with tapping maneuvers needs to be restarted to reorient and recenter the graft (Fig. 29.2).

- Use BSS on a 30G cannula to hydrate the clear corneal incisions. If there is any doubt about the self-sealing nature of the corneal incision, consider placing one 10-0 nylon stitch or using Resure sealant to seal the wound.
- Consider a full AC gas/air fill for 3 to 5 minutes (avoid having multiple bubbles; goal is one large bubble).
- Reduce the bubble size and replace with BSS aiming to leave IOP at physiologic level with a bubble size of 8 to 9 mm, but be absolutely certain that the inferior edge of the bubble allows for a patent iridotomy to prevent pupillary block.
- Keep the patient supine in the recovery area for 1 hour, and encourage supine positioning at home for approximately 7 days or until the gas bubble disappears (consider bed prism spectacles to allow for reading/TV watching while supine).
- Warn patient that vision will be poor for several days owing to the presence of the air or gas bubble in the AC (Video 29.1).

POSTOPERATIVE CONSIDERATIONS

Cover with antibiotic, steroid, and NSAID (CME is not uncommon especially if performed in conjunction with cataract surgery).

Postoperative Day #1

Verify graft adhesion and orientation, IOP, and bubble that clears iridotomy. If superficial keratectomy was performed or the epithelium

was disrupted during tapping maneuvers, consider bandage contact lens for 1 week.

Postoperative Week 1 or 2

Check vision and IOP, and examine the graft for adhesion (consider anterior segment OCT if unable to visualize graft). If there is greater than one-third graft detachment or the central graft is detached, consider placing a second bubble at the slit lamp or under a minor room microscope. Far peripheral, small detachments can be observed if the central aspect of the graft is attached and clearing.

Postoperative Month 1

Measure new manifest refraction, taper steroid to twice daily, and with time consider further steroid taper to daily or less.

CHAPTER 30

Combined Keratoplasty and Cataract Surgery

Narae Ko, MD

The timing of cataract surgery relative to keratoplasty is dependent on several factors. Cataract surgery alone may improve the vision significantly in patients with mild corneal pathology for which keratoplasty can be deferred. In younger patients with minimal cataract but progressive corneal pathology, keratoplasty can be done first. In these cases, crystalline lens accommodation can be preserved and performing keratoplasty prior to cataract extraction can allow the surgeon to obtain more precise IOL calculations. However, there is an accelerated rate of cataract formation after keratoplasty from surgical trauma and postoperative steroid use along with the risk of graft failure from subsequent intraocular surgery. Owing to the risk and cost of additional surgery, combined keratoplasty and cataract surgery are commonly performed for the appropriate surgical candidates.

PREOPERATIVE CONSIDERATIONS

Combined Endothelial Keratoplasty (EK) and Cataract Surgery

- Adjust the refractive target given the anticipated hyperopic shift when choosing the IOL.
    - Approximately −0.5 D for DMEK and +1.25 to +1.50 D for ultrathin-DSAEK

- Consider using less adrenergic and cycloplegic agents preoperatively owing to the need for rapid miosis prior to performing the DMEK.
- Some surgeons use no preoperative dilating agents and use only a pupil-expanding device during the cataract surgery portion.

> Ensure there is no epinephrine in the solution in the irrigating solution as rapid miosis is needed for the DMEK surgery portion.

- Counsel the patient about the risk of refractive surprise and the need for glasses postoperatively.

Combined Penetrating Keratoplasty (PKP) and Cataract Surgery

- Reduce posterior IOP.
    - After a retrobulbar block is administered, consider using a Honan balloon for 5 minutes.
    - Intravenous mannitol can be given preoperatively.
    - If the patient is undergoing general anesthesia, endotracheal tube with paralytic agent is preferred over laryngeal mask airway (LMA), especially for open-sky cataract extraction.
    - Use a lid speculum that applies the least amount of pressure to the globe, such as Jaffe or Maumenee speculum. Avoid a wire speculum.
- Estimate the power of IOL needed using the anticipated postoperative corneal curvature.
    - A value of 44.5 or 45.0 D is commonly used. Use personalized postoperative keratometric value if possible.
    - Consider a myopic target to avoid a hyperopic surprise given

the limitation of using an estimated postoperative corneal curvature for IOL calculation. Typically aim between −1.00 and −2.00 D.

    - Can use a three-piece IOL design (ie, Alcon MA60AC) as the IOL of choice.

- Assess the view through the compromised cornea; if not adequate, consider open-sky extracapsular cataract extraction.
- Counsel the patient about the need for spectacles and/or contact lens use postoperatively to correct astigmatism and/or refractive surprises.

SURGICAL PROCEDURE

Combined EK and Cataract Surgery

- Consider superficial keratectomy if the view is compromised.
- Create a shorter tunnel for the corneal incisions compared with a routine cataract surgery to avoid overlap of the graft over the incisions.
- Aim paracenteses at a more acute 45-degree angle as opposed to parallel to the iris plane to avoid touching the graft with instrument or cannula entry.
- Use a cohesive viscoelastic to maintain the AC, to flatten the anterior capsule during capsulorhexis and to perform Descemet stripping.
- Have a low threshold to use a pupillary expansion device.
    - If less adrenergic and cycloplegic agents are used preoperatively for DMEK, poor pupillary dilation and floppy iris are more likely to occur during phacoemulsification.
- Trypan blue can facilitate visualization of the anterior capsule

through a hazy cornea.

  - Keep in mind that abnormal endothelium will uptake the dye as well and compromise the corneal clarity. Use the minimal amount of dye necessary, and consider injecting it under cohesive viscoelastic.

- Create a smaller capsulorhexis to prevent IOL prolapse during DMEK, typically 4.5 to 5.0 mm. Avoid creating a capsular tear as it can radialize during unfolding and positioning of the EK graft.
- Achieve miosis using a cholinergic agonist prior to proceeding with DMEK. Perform an inferior iridotomy with an anterior vitrector or a Sinskey hook and a needle. The iridotomy can also be created preoperatively using a Nd:YAG laser.
- In cases of unexpected vitreous prolapse, consider postponing EK.
  - Mechanical manipulation to unfold and center the graft can worsen vitreous prolapse, increasing risk of retinal detachment.

Combined PKP and Open-Sky Extracapsular Extract Extraction

- Assess the intraocular view through the compromised cornea to determine if any steps of cataract surgery can be performed in a closed chamber.

> If possible, perform the capsulorhexis prior to converting to open-sky as the capsulorhexis is often more controlled in a closed AC.

- After the removal of the host corneal button, stain the anterior capsule by applying drops of trypan blue directly. Irrigate excess trypan.

    - It is not uncommon to encounter poorly dilated pupil with posterior synechia in cases with a prior history of infectious keratitis or chronic inflammation. Perform synechiolysis with a cyclodialysis spatula and/or viscoelastic cannula. Utilize a pupil expansion device if needed for pupillary expansion.
- Begin CCC with a cystotome and complete with Utrata forceps.
    - Owing to the posterior pressure, the capsulorhexis tends to extend peripherally. Convert to can-opener technique if needed.
- Express the cataract.
    - Perform a gentle hydrodissection for partial prolapse of the cataract followed by removal with a lens loop. If the cataract tends to fall back into the capsular bag, place viscoelastic behind it. For a dense cataract, a sharp needle tip such as cystotome can be used to impale the center of the nucleus and pull it out of the capsular bag. The phacoemulsification probe can also be used to impale the nucleus and lift it.
    - Look for any sign of anterior capsular tear, especially when a CCC is not performed.
- Remove cortex.
    - Use the irrigation/aspiration handpiece under low-flow setting. Be mindful of the risk of aspiration of the anterior and posterior capsule and zonular dialysis.
    - Consider using a manual irrigation-aspiration system such as Simcoe cannula.
    - A complete removal of cortex is preferred to minimize postoperative inflammation.
- Assess the integrity of the capsular bag. If vitreous loss is noted, perform a thorough anterior vitrectomy. Wipe the pupil and iris with a cellulose sponge to confirm absence of vitreous in the AC.

If any vitreous is noted with a sponge, cut it at the base with Westcott scissors.

- If the capsular bag is intact, fill the capsular bag with viscoelastic and place the IOL in the bag with forceps.
    - If anterior capsular tear is present, expand the sulcus with viscoelastic and place a three-piece IOL.
    - A blunt, second instrument can be used to gently push down on the optic while inserting the IOL with forceps to overcome any posterior pressure.
    - In cases of poor anterior capsular support or diffuse zonulopathy for sulcus IOL, consider leaving the patient aphakic. Secondary IOL placement, such as intrascleral haptic-fixated or sutured IOL, can be considered as a staged surgery.
- Complete PKP in the standard manner.

POSTOPERATIVE CONSIDERATIONS

Management after combined keratoplasty with cataract surgery is similar to keratoplasty alone. In cases of vitreous loss, one should look for presence of vitreous in the AC, such as incarceration of vitreous at the corneal incisions and graft-host junction.

References

1. Steinert R. *Cataract Surgery*. Saunders; 2010.
2. Mannis M, Holland E. *Cornea*. Elsevier; 2017.

CHAPTER 31

Deep Anterior Lamellar Keratoplasty

Melissa B. Daluvoy, MD

PREOPERATIVE CONSIDERATIONS

- DALK removes the anterior layers of the cornea while leaving the host Descemet's membrane (DM) and endothelium intact.
- This provides the advantage of operating on a closed system and reducing the risk of immunologic rejection of the donor tissue when compared with full-thickness penetrating keratoplasty (PKP).
- When evaluating a patient for DALK, the most important criteria is the health of DM and the endothelium.
- DALK is best implemented when the internal layers of the cornea are healthy with no previous breaks in DM and a good endothelial cell count, such as in young patients with keratoconus, anterior stromal scars from trauma or infection, or most corneal dystrophies (excluding macular dystrophy).
- Specular microscopy testing can be helpful in analyzing the endothelial cell count and morphology in patients with a prior history of intraocular inflammation or in older patients.
- Previous Descemet tears as in post-hydrops patients are not an absolute contraindication to DALK but can be challenging and the big bubble technique cannot be used.

SURGICAL PROCEDURE

Entire books have been dedicated to the various techniques for performing DALK. Covering all of the options is beyond the scope and purpose of this chapter. Most surgeons at Duke employ the “big bubble technique.” Thus, key surgical points and main variations of this technique will be described here.

- This surgeon orders traditional PKP tissue from the eye bank and removes endothelium once the DALK is successful. In the case of an unrecoverable tear in Descemet, full-thickness tissue is then available. When attempting a DALK, do not cut donor tissue ahead of time.
- You may place a Flieringa ring if desired.
- Mark the center of the cornea and choose the host trephination size as you would for a full-thickness graft.
- Make a small paracentesis to decompress the anterior chamber (AC) and inject a few small air bubbles; this will help with visualization of the AC and determination if the big bubble was successful.
- Using a suction trephine at your desired size, cut the cornea to ~60% to 80% depth (based on preoperative) peripheral pachymetry. ***Do not enter the AC during trephination*.**
- Using a bent 27G needle attached to a 3-mL syringe filled with air, introduce the needle tip with bevel down deep in the groove, tunnel forward ~3 to 4 mm from the groove aiming slightly off from center (so as to avoid the thinnest area), taking care to not puncture the DM and enter AC.
    - Inking the tip of the needle can help identify your entry point if using a cannula to inject air (see step #7).
    - Air can be forcibly injected at this point using the needle, as this surgeon prefers, or remove the needle and proceed to

step #7.

- Remove the needle and using the same tract insert a DALK canula gradually aiming further to the center of the cornea and forcefully inject air.
    - Corneal emphysema is common at this stage.
- If successful in achieving cleavage of DM from the overlying stroma you will note the small air bubbles you placed in the AC will be spread in the periphery as the inverted DM has pushed them toward the angle.
- Next manually remove the stromal cap with an angled crescent blade.
    - If the big bubble was not successful you can attempt step 6/7 again at this point.
- With the big bubble achieved and stromal cap removed you will need to perform the “brave slash.”
- In this step you are making an opening in the remaining stromal layers and the big bubble will escape so care must be taken to not hit the approaching DM with your blade.
    - The author makes this cut with a super sharp blade using a scratch technique; it can also be done with a keratome.
    - The author covers the area with a dense viscoelastic agent to try to slow the escape of air and gently scratch through layers of anterior stroma until the air escapes.
- Once there is an opening in the stromal layers you can inject some viscoelastic agent to again separate the stroma from DM.
- A specialized DALK spatula (eg, Anwar spatula) can be used at this point to be sure the DM is separated from the peripheral stroma past the original trephination line.
- Using DALK scissors (where the leading edge is rounded and not

sharp) make four radial cuts dividing the anterior stromal portions into four quadrants. Then carefully remove each quadrant.

- At this point you should have an intact clear DM the size of your original trephination with surrounding host tissue.
    - At any point the DM becomes ruptured you can convert to a full-thickness PKP.
    - Small tears in DM can be managed with air bubble management at the end of the case (see step #19).
- Attention is now directed to the donor tissue. Remove the DM and endothelium from your donor tissue (if not already done so by the eye bank).
    - The author's preferred method is to stain with trypan blue, then under balanced salt solution score the far periphery using a sinsky hook, lift an edge of DM/endo, and then peel away using fine tying forceps (similar to preparing DMEK tissue).
- Trephine the donor tissue the same size as your host trephination.
- Secure the graft in place using 16 interrupted 10-0 nylon sutures at 90% depth taking care not to puncture the DM at this point.
    - Be sure the DM is rinsed thoroughly as any retained viscoelastic agent can cause interface haze.
- A moderate air bubble can be instilled into the AC in order to help with adherence of the DM to the new graft tissue. Be sure to dilate the pupil or keep bubble small enough to avoid pupillary block.

POSTOPERATIVE CONSIDERATIONS

- Postoperative day 1 is similar to that of PKP (check IOP, epithelial

defects, etc.) with special attention to identifying a double AC, which occurs when the host DM does not adhere to the donor posterior stroma creating a false AC. This is more common when a perforation or tear had occurred in the DM during the surgery.

- A double AC should be treated with instillation of additional air into the AC to tamponade the detached DM to the graft tissue.
- This author's postoperative drop regimen is the same as with a PKP, high-frequency topical steroids for 1 week then tapering monthly. There is evidence to suggest a quicker taper is possible with DALK. Topical antibiotics are used for 1 week or until all epithelial defects have closed.
- This author begins to remove sutures based on topography at 6 months postoperatively. Sutures can be removed earlier if needed in DALK versus PKP.
- Although DALK eliminates the risk of endothelial rejection, stromal and epithelial rejection can still occur. In the event of rejection, aggressive steroids should be used to try to recover the transplant using techniques similar to those employed with PKP.

Reference

1. Anwar M, Teichmann KD. Big-bubble technique to bare Descemet's membrane in anterior lamellar keratoplasty. *J Cataract Refract Surg*. 2002;28(3):398-403.

CHAPTER 32

Management of Limbal Stem Cell Deficiency

Christine Shieh, MD, Sayan Basu, MBBS, MS, Clara C. Chan, MD, FRCSC, FACS

PREOPERATIVE CONSIDERATIONS

Patient Selection

From the International Limbal Stem Cell Deficiency Working Group[2]

Limbal stem cell deficiency (LSCD) represents a dysfunction in the cornea epithelium's homeostasis. This results in conjunctivalization, where the conjunctival epithelium replaces corneal epithelium. Since the conjunctiva has looser cell-cell attachments, it is significantly more permeable to fluorescein. Therefore, LSCD severe enough to merit consideration of LSCT will demonstrate late fluorescein staining in the periphery of the cornea in a vortex pattern and the central visual axis should be affected; the patient may also have significant pain. LSCT is generally not needed if the central 5 mm visual axis is clear, as these conditions can often be managed with scleral contact lenses or superficial keratectomy with amniotic membrane graft.

Conjunctivalization may be seen in conjunction with other signs of epithelial dysfunction such as

- persistent or recurrent epithelial defects ± neovascularization
- ocular surface inflammation

- cornea scarring

LSCD may present alone or with other comorbid ocular surface abnormalities, especially in either the conjunctiva (ie, cicatrizing conjunctivitis) or the corneal nerves (neurotrophic cornea).

The International Limbal Stem Cell Deficiency Working Group encourages ophthalmologists to perform confirmatory diagnostic testing (in addition to the clinical slit-lamp examination) whenever possible. This may include options such as in vivo imaging (confocal microscopy or AS-OCT) and/or cell sampling from the cornea to detect conjunctival cells. The latter is usually done with impression cytology, which involves nitrocellulose filter paper that is subsequently stained with periodic acid-Schiff and hematoxylin-eosin. Although excisional biopsy of the cornea has been reported to evaluate for goblet cells histologically, this is quite invasive. Superficial keratectomy serves as a less-invasive alternative to an excisional biopsy: the surgeon may remove the conjunctivalized pannus overlying the corneal surface and send the specimen to pathology to confirm the diagnosis. It is important to leave the Bowman membrane intact, as there have been a few reports of detecting ocular surface squamous neoplasia (OSSN) in the setting of limbal stem cell deficiency. OSSN can invade intraocularly if Bowman membrane is breached.

The surgeon may also combine the aforementioned procedures in the table. For example:

- "Cincinnati procedure" = lr-CLAL + KLAL **(living-related donor's limbus and conjunctiva + deceased donor keratolimbal segments).**

OR

- "Modified Cincinnati procedure" (for *unilateral* disease only, NOT for bilateral disease or for patients who do not want their good eye touched): CLAU and KLAL **(fellow eye donor limbus and conjunctiva + deceased donor keratolimbal segments)** allows for decreased antigenic load.1

The authors recommend blood type match for allogenic donor sources. If possible, partial or complete HLA match is also ideal, as it will allow for decreased presence of circulating HLA donor-specific antibodies (DSA) in the recipient.

Anesthesia

For children, general anesthesia is considered mandatory. For adults, limbal biopsy may be harvested from the donor eye under topical anesthesia, but beginner surgeons may prefer a peribulbar or sub-Tenon block. The affected eye in adults requires a peribulbar or retrobulbar block.

Preoperative Eye Drops

To reduce intraoperative bleeding, some surgeons prefer to use two to three preoperative applications of brimonidine tartrate 0.15% and phenylephrine 5% eye drops (alternating) for 5 to 10 minutes before bringing the patient to the operating room.

Indications and Contraindications for All LSCT Procedures

Recipient Eye Indications

Generally, LSCT is reserved for stage IIb, IIc, and III LSCD disease (per Table 32.1).

TABLE 32.1 Limbal stem cell disease staging (based on clinical presentation)[2]

Stage	A	B	C
Stage I			
Normal corneal epithelium within the central 5-mm zone of the cornea	<50% of limbal involvement	≥50% but <100% of limbal involvement	100% limbal involvement
Stage II			
Central 5 mm of the cornea is affected	<50% of limbal involvement	≥50% but <100% of limbal involvement	
Stage III			

Entire corneal surface is affected			

TABLE 32.2 Summary of surgical procedures

Surgical procedure	Donor source	Brief summary of procedure
Simple limbal epithelial transplantation (SLET) [a]	One of below options: • Healthy fellow eye (autologous) • Living relative (allogenic) • Deceased donor (allogenic)	• Small "biopsy" of keratolimbal tissue is divided into smaller pieces and distributed on mid-peripheral cornea circumferentially • Optional conjunctival harvest
Keratolimbal allograft (KLAL) [a]	Deceased donor (allogenic)	• Keratolimbal segments (from 1.5 donor eyes) placed circumferentially around recipient limbus • No conjunctival harvest
Conjunctival limbal autograft (CLAL)	Healthy fellow eye (autologous)	Limbal stem cells on conjunctival carrier tissue placed superiorly and inferiorly
Living related conjunctival limbal allograft (lr-CLAL) [a]	Living relative (allogenic)	Fresh keratolimbal segments + conjunctiva skirt placed superiorly and inferiorly

[a]Systemic immunosuppression is needed whenever the donor source is allogenic.[3]

Recipient Eye Absolute Contraindications

- Dry ocular surface (defined as repeated Schirmer I score with anesthesia of less than 10 mm or presence of corneal or bulbar conjunctival keratinization).
- Uncontrolled glaucoma: this needs to be controlled prior to surgery.
- Presence of uncorrected adnexal pathologies (like lagophthalmos, ectropion, entropion, trichiasis, and dacryocystitis): we recommend this be corrected prior to any LSCTs, and as a separately staged procedure. The patient must have reasonable eyelid apposition without cornea exposure. If it is not feasible for lid correction to be performed separately, then the patient must have a concomitant tarsorrhaphy at the time of LSCT.

- Blind eye without visual potential.
- Eye with disorganized anterior segment (one that is unlikely to have improved vision with transplantation).

Donor Eye: Indications and Contraindications

- Ideal donor eye: healthy contralateral eye without history of LSCD or contact lens wear.
- Contraindications:
    - any signs of LSCD in the donor eye (ie, late fluorescein staining indicating LSCD).
    - donor eye:
        - involvement during the initial injury
        - previous contact lens use or ocular surface surgery
    - if allogenic donor source (living-related donor), serologic testing needs to be performed to rule out HIV I/II as well as hepatitis B and C viruses.

Contraindication to Systemic Immunosuppression

Caution: any allogenic or deceased donor eye source will require systemic immunosuppression (SI) for the grafts to survive long term.

Below are recommended SI contraindications:

- history of malignancy within 5 years
- nonadherence to clinical or laboratory follow-up or to medications
- presence of significant comorbidities, such as:
    - uncontrolled diabetes
    - uncontrolled hypertension

- renal insufficiency
- congestive heart failure
- failure of other organs
- advanced age (suggested to not include patients >80 years)

POSTOPERATIVE CONSIDERATIONS

Suggested Postoperative Followup and Monitoring

- Unless otherwise noted below, most surgeons examine patients at postoperative day 1 and week 1, followed by visits 1 and 3 months after surgery (then at 2- to 3-month intervals).
- Most surgeons use broad-spectrum antibiotic drops at least four times per day for the first week or while a bandage contact lens is in place. Topical steroid eye drops vary but are generally used four to six times per day, then tapered by one drop in frequency every 1 to 2 weeks.
- At each visit, the surgeon should monitor for signs of:
  - delayed epithelial healing or defect
  - microbial keratitis
  - ocular hypertension or glaucoma
- If allogenic LSCT graft, then the surgeon should also monitor for signs of:
  - immune-mediated graft rejection[4]
  - SI side effects or adverse effects

Systemic Immunosuppression

- Details of SI regimens may vary and are outside the scope of this

chapter. The authors largely follow the recent publications from Dr Edward Holland[5] or from this 2020 international review article.[6]

- The authors wish to note that about a third of allogenic LSCT patients suffer immune rejection and that the risk persists long term.[4]
    - Younger patients (younger than 10 years) and those who undergo KLAL alone have higher risk of rejection and should be treated more aggressively with immunosuppression.[4]
- Many surgeons will work with a nephrologist or rheumatologist to help manage SI.

SIMPLE LIMBAL EPITHELIAL TRANSPLANT[7]

SLET-Specific Contraindications

Recipient Eye Contraindications

Given the small amount of harvested tissue needed for SLET (in comparison with other LSCT procedures), the beginner surgeon may be tempted to attempt SLET as a first-line panacea for all LSCD. The authors have found, however, that there are limitations. Below are relative contraindications to SLET:

- increasing severity of symblepharon is correlated with worse outcome
- neurotrophic corneas (with sensation < 2 mm by esthesiometry)
- radiation keratopathy
- lid malpositions (such as lagophthalmos, ectropion/entropion)

Donor Eye Contraindications

Donor eye with LSCD or history of contact lens wear.

- Although it is theoretically feasible to harvest SLET from a donor eye with only partial LSCD, the authors have found that a donor eye with <50% healthy limbal clock hours will in itself become significantly diseased if harvested from its healthy portion. This is true even if the surgeon attempts to perform SLET on the donor eye. First do no harm.

Requests to Eye Bank: Allogenic (Deceased Donor Eye) for SLET

The tissue should

- be fresh (<48 hours from the time of harvest)
- have visibly intact limbal palisades
- have no epithelial sloughing
- be from a donor ≤ 60 years old

SLET Surgical Technique (Video 32.1; **Fig. 32.1**)

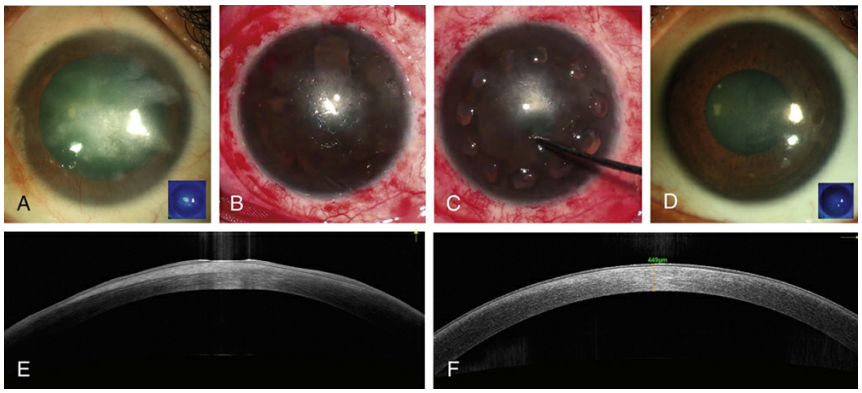

FIGURE 32.1 **Typical postoperative outcome after autologous SLET for unilateral chemical burn–induced limbal stem cell deficiency (LSCD). A. Preoperative appearance showing superficial corneal vascularization and scarring with central epithelial defect (inset: fluorescein-stained photograph); (B) intraoperative image after removal of the fibrotic**

conjunctivalized pannus from the corneal surface; (C) intraoperative image showing the circumferential arrange of limbal transplant pieces being secured to the hAM graft with fibrin glue; (D) at 6 months postoperatively, the corneal surface is stable, avascular, and epithelized (inset: fluorescein-stained photograph); (E) preoperative AS-OCT image showing highly reflective irregular conjunctival epithelium with superficial stromal haze and central epithelial defect; (F) postoperative AS-OCT image showing transparent regular low-reflective corneal epithelium with reduction in stromal haze.

Living Donor Eye (Autologous or Allogeneic): Preparation of Donor Tissue

- One-clock hour or roughly 3.5 to 4 mm is measured with a caliper, and **marking is done slightly behind the limbus** on the conjunctiva. The superior portion is best if available since there are more palisades of Vogt present there.
- Create a conjunctival bleb using a 30G needle on syringe filled with BSS. **Key decision step:** is donor conjunctiva needed to repair symblepharon on recipient eye?
    - If no donor conjunctiva is needed, balloon with fluid just behind the selected area of biopsy (~1 mm peripheral to limbus). Start the subconjunctival dissection 1 mm peripheral to limbus (with Vannas scissors) to undermine a flap of conjunctiva. Continue the dissection until the limbus is reached.
    - If donor conjunctiva is needed, modify the technique to take a larger area of conjunctiva peripheral to the limbus. This may be used to graft the bulbar sclera when the symblepharon is released from the bulbar surface.
- Lift the conjunctival flap until insertion of the Tenon capsule at the limbus: carry subconjunctival dissection into 1 mm of the clear cornea. Use a number 15 blade (or crescent blade, but the

sharper number 15 blade allows the surgeon to ensure adequate depth) to dissect and excise the limbal tissue.

- Place the donor tissue in BSS: do **not** let it dry out.

Cadaveric Donor Eye: Preparation of Donor Tissue

The technique below assumes minimal conjunctiva skirt on the corneoscleral rim:

Perform a snip biopsy in which the limbal tissue is pinched using a Lim's forceps and one-clock hour is cut out using a Vannas or Wescott scissors.

Cadaveric corneal tissue is usually thicker and has more stromal component than from a live donor and may require further stromal trimming before transplantation. We recommend that the surgeon **resist** the temptation to take a larger biopsy because the risk of immunological rejection increases with the increase in the amount of transplanted allogeneic tissue.

Recipient Eye

- Release any symblepharon preventing speculum insertion, and allow it to recess.
- Start 2 to 3 mm peripheral to the estimated limbus and perform a 360-degree peritomy. Using scissors, dissect toward the limbus. Remove the scarred pannus over the cornea, but be careful to leave any healthy corneal epithelium undisturbed, and do not attempt to manually debulk the cornea scarring. Use gentle cauterization to control any bleeding.
- Use tenotomy scissors to recess/free the peripheral conjunctiva by blunt dissection.
- Cover recipient cornea with hAM epithelium side up.

- Affix to the hAM surface with fibrin glue. The hAM should be of sufficient size to cover the cornea and sclera up to the extent of the peritomy, and it is critical to ensure that all borders are tucked under the conjunctiva.

Placement of Donor Tissue

- Cut the limbal graft into approximately 6 to 10 pieces, with nontoothed forceps and Vannas. (We do not recommend using a surgical blade on a cutting block, as it has the potential to damage the tissue.)
- The cut fragments of the transplant are then placed on the surface of the amniotic membrane. This is usually carried out just inside the limbus, distributed evenly around the circumference, sparing the visual axis. If future keratoplasty is anticipated, then it is beneficial to distribute the fragments outside the zone of planned keratoplasty.
- Try to orientate the pieces epithelium side up.

> For the SLET specimens, the epithelium side will have pigmentation and a smooth surface versus the stromal side, which will have white fibrous strands. Try to avoid cutting the specimen into too many tiny pieces, as it can make the epithelium side hard to see.

- A very small amount of fibrin glue (preferably Tisseel, Baxter International Inc) is applied on top of each individual graft piece. Wait at least 1 minute to make sure the fibrin glue has polymerized before proceeding to the next step.
- Place a 14-mm bandage contact after 1 minute when the glue has polymerized.
- In very young children, a suture tarsorrhaphy is recommended for the first couple of weeks to prevent early loss of the bandage

contact lens or transplants, because of the risk that children may inadvertently rub their own eyes.

Although there are publications of good outcomes with a second-layer of amniotic membrane (on top of the SLET tissue), the authors have not found that that this affects outcomes. If there is concern that the bandage contact lens will come off, then the authors recommend a suture tarsorrhaphy.

Unique SLET Postoperative Considerations

- Most patients are started on broad-spectrum postoperative antibiotic (like moxifloxacin four times daily) until the contact lens is removed or the donor eye heals.
- The contact lens is removed at 7 to 14 days. If the epithelium has not healed by that time, a bandage contact lens is replaced until the epithelium has grown completely.
- Postoperatively, topical prednisolone acetate 1% eye drops are administered six times a day for 1 week and then tapered every week over the next 6 weeks in both the recipient and the donor eyes. Long-term topical corticosteroids are not needed for autologous transplants.
- If a temporary suture tarsorrhaphy is in place in the recipient eye, oral steroids (to reduce periocular tissue edema) and topical antibiotic-steroid ointments (instead of eye drops) are prescribed until the tarsorrhaphy is released, typically during the 1- to 2-week visit.

CLAU, KLAL, AND LR-CLAL: COMMONALITIES

Preoperative Drops

To reduce intraoperative bleeding, some surgeons prefer to use two to three preoperative applications of brimonidine tartrate 0.15% and phenylephrine 5% eye drops (alternating) for 5 to 10 minutes before bringing the patient to the OR.

Surgical Technique

Preparation of the Recipient Eye

- A 360-degree conjunctival peritomy is performed, including release of any symblepharon that are present at the limbus.
- In the recipient, there is often much more bleeding: wet field cautery or phenylephrine (2.5 % or 10%) pledgetting with Weck-cells is needed to achieve hemostasis.
- The conjunctiva is allowed to recess 2 to 3 mm from the limbus, which usually occurs naturally (secondary to release of conjunctival tension).
- Owing to chronic inflammation, the Tenon capsule is often extremely thickened in these eyes: Tenon may be liberally excised (with care taken to preserve the overlying conjunctiva). In the event that excess conjunctiva is present, a conservative amount may be trimmed.

  The operating microscope may obscure the beginner surgeon's sense of scale, and extensive scarring may mask the rectus muscle insertions. It is important to avoid accidental disinsertion of the rectus muscles in dissecting the Tenon capsule. The surgeon may find it helpful to periodically check with calipers (to verify where the muscle insertion would normally sit) and/or consider using muscle hooks to verify rectus muscle location.

- Topical epinephrine (1:10,000 dilution) and wet-field cautery are used to maintain hemostasis and allow for better visualization of the surgical field.

- Next, abnormal corneal epithelium and fibrovascular pannus are removed by superficial keratectomy using a #64 Beaver blade (or an equivalent crescent blade), taking care to avoid deep passes into corneal stroma.

Placement of Donor Tissue in Recipient Eye

- During suturing, the donor tissue should be protected from trauma with a viscoelastic coating (this is true for all LSCT donor tissue).
- At the conclusion of the operation, subconjunctival corticosteroids and cefazolin are injected into the recipient eye. A large-diameter soft bandage contact lens like a Kontour may be placed, and a protective patch and shield are taped on.

If the surgeon elects to place amniotic membrane at the end of the case, the authors recommend sticky side up and epithelial nonsticky side down; otherwise, if sticky side down, sometimes the stroma incorporates itself into the cornea and causes postoperative haze and reduces the final best corrected visual acuity.

Postoperative Care

Donor Eyes

- Topical corticosteroid (difluprednate 0.05% or prednisolone acetate 1%) four times daily.
- Topical fluoroquinolone (moxifloxacin 0.5% or levofloxacin 0.5%) four times daily.
- Once the conjunctiva has re-epithelialized (typically within 1 week), the bandage contact lens and fluoroquinolone are discontinued while the corticosteroid is tapered over 1 month.

Recipient Eye

- Difluprednate four times daily (continued at three to four times daily unless there is a corticosteroid-induced IOP response.
    - If there is an IOP response, the strength of the corticosteroid is decreased to prednisolone acetate 1% or loteprednol etabonate 0.5%.
- Fourth-generation fluoroquinolone four times daily (while a contact lens is in place). Many patients with severe lid margin disease and keratinized lid margins (such as in Stevens Johnson syndrome) may require long-term bandage contact lens wear to prevent lid trauma to the corneal surface.
- Topical lifitegrast 5% or cyclosporine 0.05% twice daily (for the duration of the patient's follow-up).
    - Topical lifitegrast and cyclosporine are used off-label for their immunosuppressant properties to decrease transplant rejection.
- Frequent nonpreserved artificial tears.

CONJUNCTIVAL LIMBAL AUTOGRAFT

CLAU-Specific Indications and Contraindications

Recipient Eye

- Indications: severe unilateral total ocular surface failure (stage IIb, IIc, and III disease).
- Contraindicated in bilateral disease.

Donor Eye

Same as for SLET.

CLAU Surgical Technique (Video 32.2)

Living Donor Eye (Autologous): Preparation of Donor Tissue

- The selected donor eye is marked in the 12- and 6-o'clock positions with a gentian violet marking pen to outline the conjunctival portions of the grafts (about 2 clock hours in the limbal circumference or ~6 to 6.25 mm). The surgeon should try to avoid marking directly over the limbus with the marking pen owing to potential toxicity.
- Calipers are used to ensure that the extent of total tissue to be harvested is always **less than half the circumference** (ie, ~6 clock hours).
- The conjunctiva is elevated from the Tenon capsule with BSS on a tuberculin syringe.
- Dissection of the graft is performed by incising along the lateral borders and undermining with blunt Westcott scissors to cut the adhesions of the conjunctiva to the cornea.
- Posterior conjunctival dissection is performed, and the peripheral conjunctival border is cut:
    - The superior conjunctival distal border (for the 12-o'clock segment) is 8 mm from limbus.
    - The inferior conjunctival border (for the 6-o'clock segment) is 5 mm from limbus.
- The conjunctiva is reflected anteriorly over the cornea, and blunt dissection is continued to a point 1 mm anteriorly beyond the limbus (into the cornea) and the peripheral corneal vasculature to ensure inclusion of the stem cells. Once the tissue is free, it is transferred into BSS to avoid dissection.
- After retrieval of both donor segments of the tissue, the

conjunctival defect is closed with 1 mm posterior to the limbus. Although tissue glue closure is the most comfortable, either two 10-0 Vicryl sutures or 10-0 nylon sutures have also been reported.

- A bandage contact lens (like a Kontur Contact Lens, Co, Richmond, CA) is placed on the donor eye.

Recipient Eye

See earlier section.

Placement of the Donor Tissue. The harvested CLAU tissue is sutured into the 12-o'clock position at the limbal edge using two 10-0 nylon sutures cut short. This is repeated at the 6-o'clock position. Tissue glue is applied to secure the base of the CLAU tissue segments to the recipient sclera.

Postoperative Considerations. Owing to the exposed 3:00 and 9:00 border, a common limitation of the CLAU technique is that neovascularization and conjunctivalization will recur postoperatively at these locations.

KERATOLIMBAL ALLOGRAFT

KLAL Recipient-Specific Indications and Contraindications

Indications

- Best for conditions that primarily affect the limbus and have minimal to no conjunctival involvement (like aniridia or limited chemical injury).

Contraindications

- KLAL success is inversely correlated with active conjunctival

inflammation or conjunctival keratinization (better outcomes with lr-CLAL).

- Contraindicated in patients who cannot receive SI (see earlier section guidelines).

Requests to Eye Bank: Allogenic (Deceased Donor Eye) for KLAL

- A 4-mm scleral rim
- No cancer of any kind
- Younger the better; no older than 50 years
- Fresher the better; no more than 5 to 6 days from date of death
- Vent time less than 72 hours
- Two corneas needed for KLAL recipients, since 1.5 donor eyes are needed to generate the necessary keratolimbal segments

KLAL Surgical Technique (Video 32.3)

Deceased Donor Eye: Preparation of Donor Tissue

- The central cornea of the corneoscleral rim is excised with a 7.5 mm trephine (smaller if pediatric patient).
- The remaining corneoscleral rim is cut into equal halves, and scissors are used to dissect the excess peripheral scleral tissue.
- Put the viscoelastic on keratolimbal portion to prevent desiccation. The posterior half to two-thirds of each hemisection needs to be removed by lamellar dissection using a crescent blade.

> Lamellar dissection of the corneoscleral rim is necessary because if the graft is too thick, then re-epithelialization will be

impaired secondary to eyelid friction and the step-off between the recipient cornea and the donor graft. If there is concern of staying in the same plane throughout the length of the donor dissection, the surgeon could potentially use a guarded knife with a preset depth to set the plane before using the crescent blade.

- This may be performed via one of two ways:
  - Technique #1 (free hand with assistant):
    - Use Wescott scissors to dissect the excess peripheral scleral tissue, leaving the 1 mm of scleral rim adjacent to the limbus.
    - Now, under the microscope, have your assistant help stabilize the tissue with forceps.
    - Using a fresh crescent blade, remove the posterior half to two-thirds of each hemisection: perform lamellar dissection to remove posterior sclera and posterior cornea (ie, DM and endothelium).
  - Technique #2 (using block and cyanoacrylate glue)
    - Use Wescott scissors to dissect the excess peripheral scleral tissue, leaving the 1 mm of scleral rim adjacent to the limbus.
    - Place cyanoacrylate glue on a sterile smooth surface (plastic surface or surgical cutting block), and then place anteriorly a layer of viscoelastic.
    - Place half of the donor crescent on top with the epithelium side up (so the endothelial layer is against the viscoelastic and away from the surgeon): the sclera part should rest on the cyanoacrylate glue, and the corneal portion on the viscoelastic.
    - Using a fresh crescent blade, remove the posterior half to

two-thirds of each hemisection (perform lamellar dissection to remove posterior sclera and posterior cornea [DM and endothelium])

- The two pieces are then placed in storage medium until placed on the eye later in the operation.

Recipient Eye

Similar to earlier CLAU section, but there needs to be sufficient space ~4 to 5 mm from limbus so sufficient denuded sclera can be exposed to position the KLAL. This may necessitate the surgeon resecting diseased/scarred conjunctiva and/or Tenon capsule.

Placement of Donor Tissue on Recipient Eye

- The KLAL segments are positioned just behind the corneal limbus, ensuring no gaps where the conjunctiva can grow in between (allows for complete placement of three KLAL segments, from 1.5 donor eyes).
- Fix with tissue glue (some surgeons combine with 10-0 nylon).

Unique KLAL Postoperative Considerations

- KLAL alone, compared with lr-CLAL alone, has been shown to have an increased risk of rejection. This has been attributed to the increased antigenic load, as typically matching by blood type and HLA type is not performed. In Ontario, where one of the authors has been using organ donor tissue to select KLAL donors that are blood-type O only, there has been a correlation noted with reduced rejection rates.
- Unless very fresh donor is utilized, usually any KLAL conjunctiva does not stay viable.

LIVING RELATED CONJUNCTIVAL LIMBAL

ALLOGRAFT

Lr-CLAL Recipient-Specific Indications and Contraindications

Indications

- For patients with conjunctival involvement, lr-CLAL has better reported outcomes than KLAL.

Contraindications

- Success inversely correlated with active conjunctival inflammation or conjunctival keratinization.
- Contraindicated in patients who cannot receive SI (see earlier section guidelines).

Lr-CLAL Donor-Specific Selection (Brief Summary)

- Patients also need an available living-related donor, ideally one who is an HLA crossmatch.
    - Siblings have the potential to be an HLA-identical match.
    - Parents and children often are at least HLA-haploidentical (50% identical).
- If the living-related donor and the patient are blood type ABO compatible, then HLA typing, DSA, and virtual crossmatch testing are performed.
- Additional details are beyond the scope of this chapter, but SI is still used even if there is an HLA match.

Requests to Eye Bank

Same as for KLAL, but in addition to the 4 mm scleral rim, there is a

conjunctival skirt (note this is a special recovery procedure for most eye banks since leaving conjunctiva makes tissue preparation harder for endothelial keratoplasty preparation).

Lr-CLAL Surgical Technique

Living Donor Eye: Preparation of Donor Tissue

See CLAU section (same operative technique, but performed on allogenic donor rather than autologous eye).

Deceased Donor Eye: Preparation of Donor Tissue

See KLAL section (same operative technique), with the exception that the conjunctival tissue is preserved. The surgeon may wish to balloon the conjunctiva with fluid to decrease the chance of buttonholing the conjunctiva.

Recipient Eye

Same as for CLAU or KLAL.

Placement of Donor Tissue on Recipient Eye

Same as for CLAU, but additional lr-CLAL-specific notes below.

- Suture the harvested living-related tissue in the 12- and 6-o'clock meridians with 10-0 nylon: first suture the keratolimbal portion down: many surgeons do not bury these knots, as they serve as a future marker of the graft location.
- Then, suture the deceased-donor KLAL segments down, starting at the keratolimbal portion of the 3:00 and 9:00 position.
- Some surgeons also suture the peripheral donor conjunctiva to the border of the recipient eye's conjunctiva with Vicryl or 10-0 nylon sutures.
- Fibrin glue is applied to secure the base of the CLAU tissue

segments to the recipient sclera.

- Some surgeons will also drape and fix an amniotic membrane over the previously scarred area.
- At the conclusion of the operation, subconjunctival corticosteroids and antibiotics are injected into the recipient eye. A large-diameter soft bandage contact lens (like Kontour) is placed, and a protective patch and shield are taped on.

Unique Lr-CLAL Postoperative Considerations

Similar to those of KLAL.

References

1. Chan CC, Biber JM, Holland EJ. The modified Cincinnati procedure: combined conjunctival limbal autografts and keratolimbal allografts for severe unilateral ocular surface failure. *Cornea*. 2012;31(11):1264-1272.
2. Deng SX, Borderie V, Chan CC, et al. Global consensus on definition, classification, diagnosis, and staging of limbal stem cell deficiency. *Cornea*. 2019;38(3):364-375.
3. Cheung AY, Sarnicola E, Kurji KH, et al. Cincinnati protocol for preoperative screening and donor selection for ocular surface stem cell transplantation. *Cornea*. 2018;37(9):1192-1197.
4. Ang AY, Chan CC, Biber JM, Holland EJ. Ocular surface stem cell transplantation rejection: incidence, characteristics, and outcomes. *Cornea*. 2013;32(3):229-236.
5. Holland EJ, Mogilishetty G, Skeens HM, et al. Systemic immunosuppression in ocular surface stem cell transplantation: results of a 10-year experience. *Cornea*. 2012;31(6):655-661.
6. Serna-Ojeda JC, Basu S, Vazirani J, Garfias Y, Sangwan VS. Systemic immunosuppression for limbal allograft and allogenic limbal epithelial cell transplantation. *Med Hypothesis Discov Innov Ophthalmol*. 2020;9(1):23-32.
7. Shanbhag SS, Patel CN, Goyal R, Donthineni PR, Singh V, Basu S. Simple limbal epithelial transplantation (SLET): review of indications, surgical technique, mechanism, outcomes, limitations, and impact. *Indian J Ophthalmol*. 2019;67(8):1265-1277.

CHAPTER 33

Corneal Biopsy

Nandini Venkateswaran, MD

A corneal biopsy is an effective tool to help determine the etiology of a corneal ulcer when other methods have proven to be inconclusive.

INDICATIONS FOR A CORNEAL BIOPSY

- A corneal ulcer for which multiple corneal cultures that have returned with negative results.
- A corneal ulcer that has extended deep in the corneal stroma and cannot be adequately cultured with corneal scraping.
- A corneal ulcer that is failing intensive antimicrobial therapy.
- A corneal ulcer suspected to be caused by organisms that are challenging to grow in culture media, ie, fungi or Acanthomoeba (Fig. 33.1).

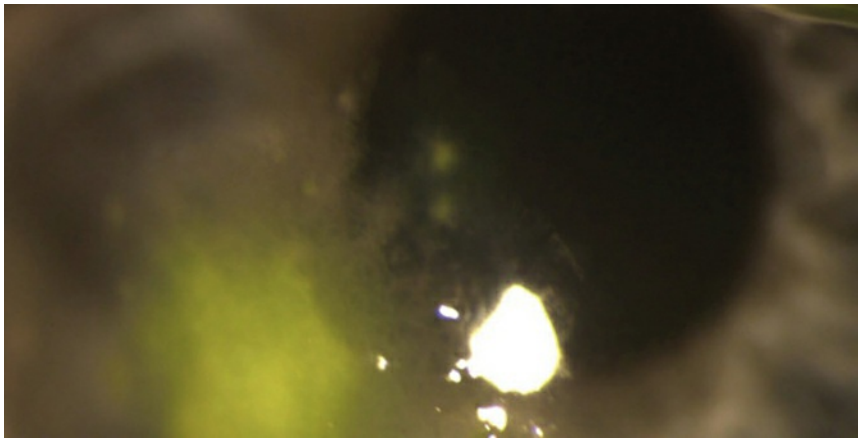

FIGURE 33.1 **A 59-year-old patient presented with nonhealing waxing and waning epithelial defect and developed new patches of stromal spiculated and branching haze adjacent and underneath this defect. Corneal cultures were negative. Topical fluoroquinolone and oral antiviral therapy did not improve the appearance of this infiltrate. The differential diagnosis included herpetic keratitis, crystalline keratopathy, or fungal keratitis. This image shows the appearance of the corneal infiltrate.**

TECHNIQUE

- This procedure can be performed in the minor procedure room or the surgical OR depending upon patient and physician comfort.
- Prep the affected eye with topical betadine solution and place eyelid drapes.
- Place an eyelid speculum in the affected eye.
- Identify the area where a biopsy can be safely performed. Ideally, avoid areas with marked corneal thinning. Biopsies can be taken in the center of the infiltrate or at the border of the infiltrate and healthy corneal tissue.
- Obtain a single-use, sterile, dermatologic punch, typically 2 or 3 mm in diameter.
- Carefully use the dermatologic punch to dissect the cornea. The punch should be used like a manual corneal trephine. Hold the punch perpendicular to the corneal surface and rotate with the tips of your fingers to avoid placing excess pressure on the eye. Forceps can be used to hold the globe in position while performing this.
- Corneal dissection depth should be approximately 30% to 40% of the stroma in order to obtain a sizable sample. Check frequently to assess the biopsy depth to prevent corneal perforation, especially in eyes with marked corneal thinning.

- Utilize 0.12 forceps and a sterile crescent blade to carefully dissect the biopsy lenticule.
- The biopsy can be sectioned with Wescott scissors and plated on culture media and also sent for histopathological analysis.

NEXT STEPS

- Restart the patient on topical antimicrobial therapy and tailor treatment based on biopsy results.
- Ensure the biopsy site epithelializes and does not develop further thinning or a new infiltrate (Fig. 33.2).
- Counsel the patient carefully on corneal perforation precautions following the corneal biopsy procedure.

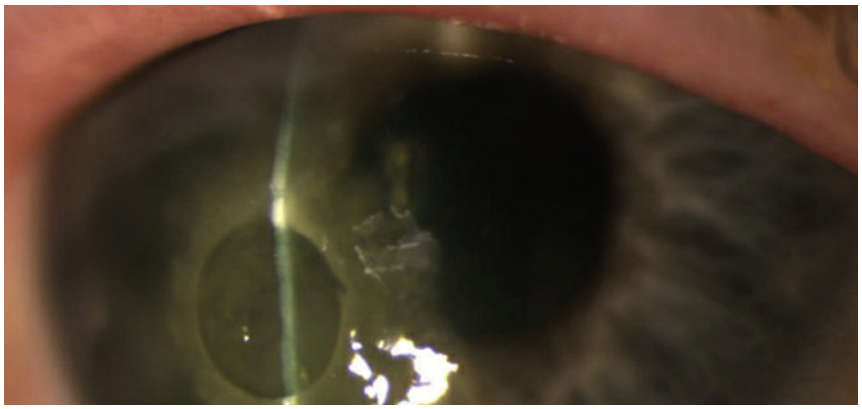

FIGURE 33.2 **A corneal biopsy was performed owing to the recalcitrant nature of this corneal infection. The biopsy showed branching septate hyphae. The patient was subsequently started on topical antifungal therapy and continues to be followed. This image shows the location and appearance of the corneal biopsy site.**

CHAPTER 34

Graft Rejection Management

Michelle J. Kim, MD

PREOPERATIVE CONSIDERATIONS

Medical Management

- Frequent topical corticosteroids (ie, prednisolone acetate 1%, difluprednate 0.05%, dexamethasone 0.1% dosed QID to Q1H) are the mainstay of treatment for mild to moderate rejection episodes.
- For poorly compliant patients, subconjunctival or sub-Tenon injection of steroids (ie, triamcinolone, dexamethasone, or betamethasone) may be helpful.
- In cases of severe rejection, intravenous steroids (ie, methylprednisolone 500 mg) or oral steroids (1 mg/kg) may be necessary.
- If there is no response after 1 month of treatment, repeat transplant should be considered.

SURGICAL PLANNING

- If there is significant corneal neovascularization, anti-VEGF agents (administered subconjunctivally or intrastromally) can be used to reduce the risk of subsequent rejection. Multiple injections may be required to achieve adequate regression of neovascularization.
- Consider herpes virus prophylaxis pre- and postoperatively to

reduce risk of rejection if the patient has history of herpetic keratitis.

- Request tissue from the eye bank. Consider ABO blood type matching if there have been multiple episodes of rejection.
- In cases of multiple failed full-thickness grafts, consider keratoprosthesis instead.

SURGICAL PROCEDURE

Repeat DSAEK/DMEK

- Place two paracenteses and fill the anterior chamber with cohesive viscoelastic.
- Create the main wound.
- Use a Sinskey hook or endothelial stripper to detach the original graft and pull it out through the main wound.
- Proceed with DSAEK/DMEK as per usual technique.

Caution must be taken when removing the old graft in case there are adhesions to the iris or surrounding host DM.

Repeat PKP

- Place Flieringa ring and corneal markings, if this is part of your usual technique.
- Prepare the donor graft per usual technique. Check old operative notes to confirm the size of the previous graft, but the graft should be remeasured intraoperatively with calipers. The repeat graft should generally be 0.25 to 0.5 mm larger than the original graft, especially if there is concern that the edges of the graft host junction will be largely disrupted when removing the old graft.

- If the graft is relatively recent, use toothed forceps (0.12 or 0.3 mm) to grasp the donor edge, and use another toothed forceps to grasp the host edge. Pull the two apart until a small, full-thickness opening is created.
- Inject cohesive viscoelastic into the anterior chamber through the small opening.
- Resume pulling apart the graft-host junction all the way around the cornea, regrasping as needed. Corneal scissors can also be used to help cut the original graft.
- Proceed with PKP as per usual technique.

If the graft and host cannot be easily pulled apart with forceps without causing trauma to the host tissue, trephination should be performed instead.

POSTOPERATIVE CONSIDERATIONS

Aggressive medical management will be necessary to prevent recurrent rejection episodes. More frequent and prolonged topical corticosteroid therapy should be applied. If the patient is unable to tolerate topical corticosteroids, topical cyclosporine or tacrolimus can be considered. Topical corticosteroids can be used along with topical cyclosporine 2% or tacrolimus 0.03% or 0.06% for the prevention of rejection as well as reversal of rejection in high-risk grafts. If topical therapy is insufficient, systemic corticosteroids, cyclosporine, tacrolimus, or mycophenolate mofetil can be used. These systemic agents can be started with assistance of a rheumatologist, taking care to monitor for systemic side effects.

CHAPTER 35

Selection and Evaluation of Donor Cornea Tissue for Transplantation

Working With Your Eye Bank for Optimal Outcomes

Terry Semchyshyn, MD

ESTABLISH A RELATIONSHIP WITH YOUR LOCAL EYE BANK

- Meet with the Executive Director and Clinical Services Director when establishing clinical practice.
- Discuss specific needs and concerns for various transplantation procedures (recipient age, other medical and ocular factors, prior transplant history, etc).

REVIEW DONOR CRITERIA

- Endothelial cell count >2500 cells/mm^2.
- Cornea preservation time <7 days is common. The Cornea Preservation Time Study supports tissue safety and effectiveness up to 11 days.[1]
- Longer death to preservation time (DTP) may be related to epithelial sloughing, which is linked with epithelial defects on postoperative day 1, but the long-term impact is unclear; surgeons may want to consider shorter DTP (ie, 4 to 10 hours) for

patients with ocular surface dryness, inflammatory eye disease, or risk for exposure keratopathy.[2]

- Consider older, nondiabetic donors (>60 years) for initial DMEK cases—tissue is easier to unfold.
- All tissue screening should be negative for HIV1 and 2, hepatitis B surface antigen, hepatitis C, and syphilis.
- Older donor tissue can still be excellent if good cell counts noted as supported by the Collaborative Donor Study.[3]

CONSIDER LAMELLAR TISSUE (DMEK AND DSEK) PREPREPARED BY EYE BANK

- Preprepared endothelial keratoplasty tissue (DMEK and DSAEK) is associated excellent outcomes. Certified processing rooms meet International Organization for Standardization class 5 sterility standards (similar to Operating Room).
- Minimizes the potential for nontransplantable tissue due to damage with surgeon preparation.
- Saves intraoperative preparation time (approximately 10 to 15 minutes for DMEK tissue).
- Have a spare modified Straiko-Jones tube #80000 (Gunther Weiss 503-644-4056) available if performing DMEK in case the provided tube with the preprepared tissue is cracked or chipped.

NONPROFIT EYE BANKS VERSUS FOR-PROFIT TISSUE SERVICES (IE, CORNEAGEN)

Is For-Profit the Right Path?[4]

- There is a perceived public concern with profit resulting from freely donated tissue.
- Impact on cooperation and sharing of current and future tissue preparation techniques—note that lamellar preparation of donor tissue was established without any for-profit/venture capital support.
- Potential impact on public willingness to donate.
- Most local eye banks are able to prepare tissue locally for lamellar keratoplasty.
- Tissue may be procured by a local nonprofit eye bank and then sent to regional nonprofit eye bank with expertise in lamellar tissue preparation such as Miracles in Sight (www.miraclesinsight.org 336-765-0932) and then delivered to surgeon.

References

1. Rosenwasser GO, Szczotka-Flynn LB, Ayala AR, et al. Effect of Cornea preservation time on success of descemet's stripping automated endothelial keratoplasty – a randomized clinical trial. *JAMA Ophthalmol*. 2017;135(12):1401-1409.
2. Van Meter W, Katz DG, White H, Gayheart R. Effect of death to preservation time on donor corneal epithelium. *Trans Am Ophthalmol Soc*. 2005;103:209-224.
3. Mannis MJ, Holland EJ, Gal RL, et al. The effect of donor age on penetrating keratoplasty for endothelial disease – graft survival after 10 years in the cornea donor study. *Ophthalmology*. 2013;120:2419-2427.
4. Mannis MJ, Sugar A. Is this the future of eye banking? *Cornea*. 2018;37(7):811-812.

CHAPTER 36

Biopsy and Excision of Suspected Ocular Surface Squamous Neoplasia

Ashiyana Nariani, MD, MPH, Gargi K. Vora, MD, Melissa B. Daluvoy, MD, Carol L. Karp, MD

DEFINITION OF OSSN

Ocular surface squamous neoplasia (OSSN) refers to a spectrum of pathologic entities of the conjunctiva and cornea, ranging from dysplasia, carcinoma in situ to invasive squamous cell carcinoma of the ocular surface epithelium, conjunctiva, and cornea. [1-2]

PREOPERATIVE CONSIDERATIONS

- Document a detailed history including risk factors (sun exposure, chronic inflammation, cigarette smoking) and personal medical history (xeroderma pigmentosum, human papillomavirus, HIV, history of skin cancer or other cancers). [2]
- Perform a slit-lamp examination, gonioscopy, slit-lamp photography, and ultrasound biomicroscopy. Always check preauricular and submandibular nodes and evert the eyelids to check the palpebral conjunctiva. [2]
- Obtain an "optical biopsy" with anterior segment optical coherence tomography (AS-OCT) imaging to differentiate OSSN from other ocular surface lesions and degenerations, particularly

if there are multiple comorbid ocular surface disorders present (Fig. 36.1).

- High-resolution OCT (HR-OCT) and ultra-HR OCT (UHR-OCT), in particular, provide excellent resolution to visualize subtle features of the lesion(s).[3-5]
- Classic OSSN characteristics on "optical biopsy" include:
  - Thickening of the epithelial layer with hyperreflectivity and an abrupt transition between normal and abnormal tissue.[6]
  - In cases of intraepithelial disease, a clear plane of separation between the thickened epithelium and underlying tissue may be seen.
  - A thick lesion, over about 400 μm, or a keratinized lesion, may cause shadowing and obscure the view to the underlying tissue.[7]

- Not all OSSN-suspected lesions require surgical excision. In noninvasive cases, medical therapy with topical chemotherapy alone has shown great success without surgical excision. Clinical acumen combined with classic HR-OCT findings has high sensitivity and specificity for OSSN (Figs. 36.2 and 36.3).[7] When treating medically, an incisional biopsy can be performed at the slit lamp and is advised in any cases where the diagnosis is in doubt. Medical therapy is especially helpful in cases of recurrent tumors, extensive disease, or annular lesions where surgical excision would lead to stem cell deficiency. The decision to treat medically or surgically, or in combination, is based on multiple factors including tumor, patient compliance, and cost.
- When surgical excision is required, discuss the case with a pathologist in advance of the procedure, and be sure to orient the tissue on a piece of paper with marked margins. If on paper, the surgical ink markings of location (ie, temporal, nasal, superior) should be retraced with pencil prior to placement in formalin as

the surgical ink dissolves.

- Regional lymph nodes should also be checked. Any systemic involvement should be looked for, and the patient should be evaluated by an oncologist.

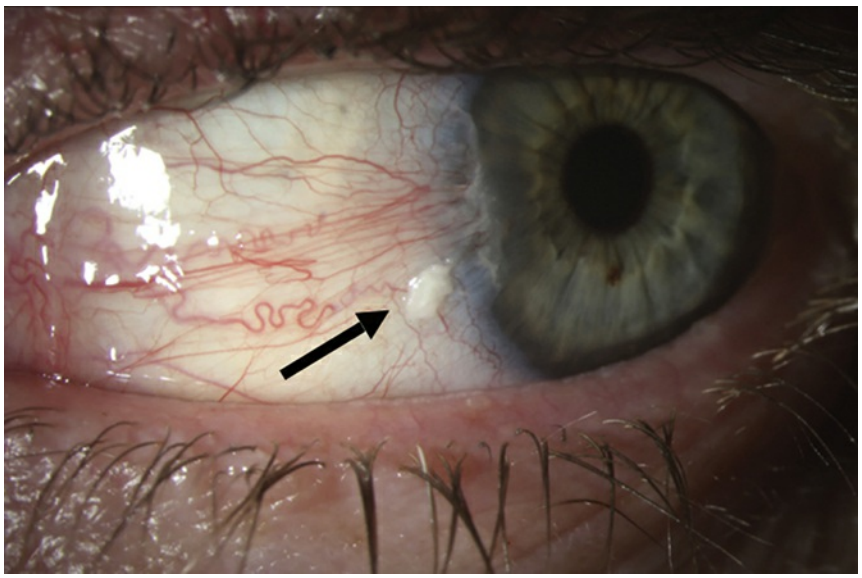

FIGURE 36.1 **Slit-lamp photograph of a 49-year-old white man with a history of kidney transplant for Berger disease and long-term sun exposure who presents with leukoplakic ocular surface squamous neoplasia (black arrow) within a pterygium.**

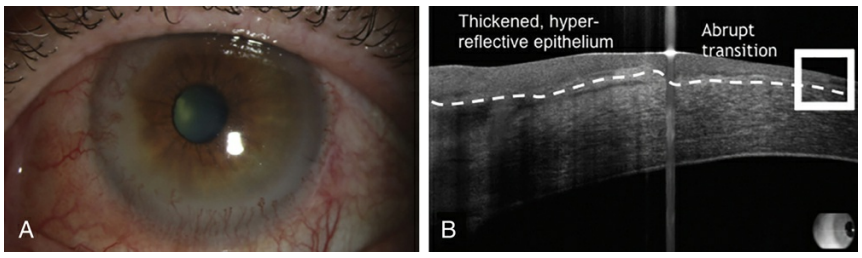

FIGURE 36.2 **Slit-lamp photograph and HR-OCT of OSSN. A. Slit-lamp photograph of a 69-year-old Hispanic man with 360 degrees of limbal neovascularization and corneal opacification. B. HR-OCT reveals thickening and hyperreflectivity of the epithelium with an abrupt transition between normal and abnormal epithelium (rectangle), consistent with**

OSSN. Dashed line is the base of epithelium.

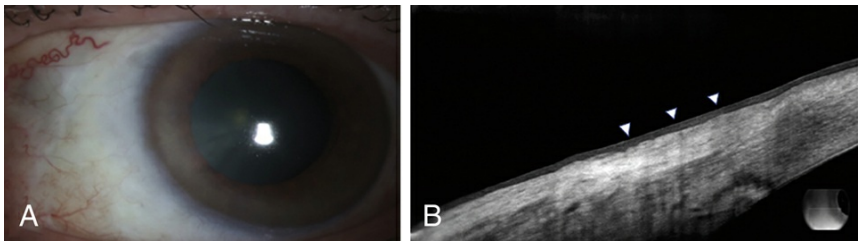

FIGURE 36.3 Slit-lamp photograph and HR-OCT after 5-FU medical treatment. A. Slit-lamp photograph after four cycles of 5-FU 1% used four times a day for 1 week on, 3 weeks off. Note clinical resolution of OSSN. B. HR-OCT confirms resolution with the presence of normal hyporeflective and thin epithelium (arrowheads) after treatment.

SURGICAL PROCEDURE

Surgical Instruments

The following instruments are required: calipers, marking pen, conjunctival scissors, nontoothed forceps, filter/cardboard paper, foam tip applicators, cautery, cryotherapy, amniotic membrane, Vicryl suture or fibrin glue, MMC 0.02%, or 0.04%, absolute alcohol.

Step-By-Step Surgical Technique of an Excisional Biopsy for OSSN-Suspected Lesions (Fig. 36.4 and Video 36.1)

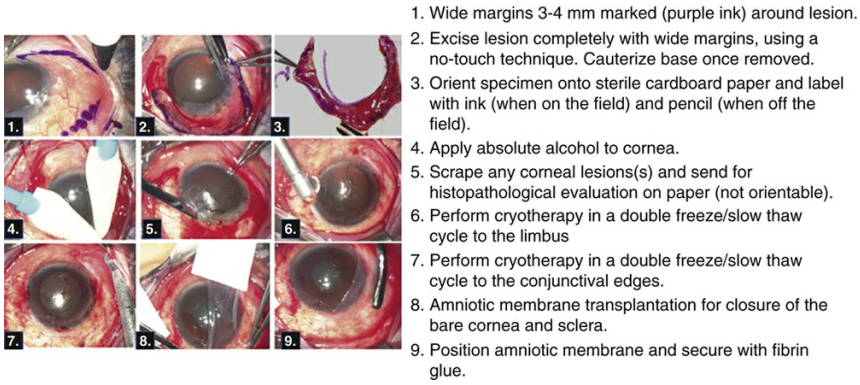

FIGURE 36.4 Step-by-step surgical technique of an excisional biopsy for an OSSN-suspected lesion.

- Mark wide margins (3 to 4 mm) around the lesion with calipers.
- Excise the lesion completely with wide margins, using a dry, no-touch technique. [8] The borders of the lesion should be touched with instruments with no disruption or manipulation of the lesion itself. Cauterize the base once the lesion is removed.
- Orient the specimen onto sterile rigid paper with careful marking of the tumor margins on the paper. Be sure to retrace surgical ink (on the field) with pencil (off the field) prior to placing in formalin. Thin lesions will stick well to the cardboard and should be tested prior to placing in bottle. Some surgeons prefer to mark margins with sutures, and this is especially needed in thicker, bulkier tumors that will not stick to the cardboard.
- Apply absolute alcohol to cornea for 60 seconds. Rinse with Tissue-sol.
- Scrape the corneal lesion and send for histopathological evaluation, also placing the cells on a piece of cardboard. These cells are not oriented. Do not violate Bowman layer as to not allow for intraocular seeding of tumor cells.
- In cases of adherent and invasive tumor, a sclerectomy may need to be performed, along with MMC 0.02% or 0.04% application to the base of the tumor for 30 seconds.

- Change instruments and gloves prior to cryotherapy. This is done to avoid contamination of healthy tissue with possible malignant tumor cells. Perform in a double freeze/slow thaw cycle to the limbus.
- Perform cryotherapy in a double freeze/slow thaw cycle to the conjunctival edges.
- Amniotic membrane transplantation for closure of the bare cornea and sclera with fibrin glue or Vicryl suture (size: 6-0 or 7-0).
- Consider placement of a symblepharon ring in cases of extensive surgery to prevent forniceal scarring.

TABLE 36.1 Dosing and regimen of topical chemotherapy agents for OSSNB

MMC	5-FU	IFN-2b
0.02%–0.04% MMC. Four times daily. 1 wk on, 2–3 wk off until eye white and quiet. Repeat until resolved. Generally takes 3–4 cycles. Use punctal plugs, tears. and topical steroids as needed	1% topical 5-FU. Four times daily. 7 d on, 21 d off. Generally takes 4–6 cycles. No plug needed. Tears and topical steroids as needed	Topical: 1 million IU/mL IFN-2b. Four times daily, until lesion resolved. Generally takes 4–6 mo. No plug needed, tears and topical steroids as needed
		Subconjunctival: 3 million IU/0.5 mL. 0.5 mL weekly

POSTOPERATIVE CONSIDERATIONS

- Evaluate pathological margins from histopathological report. Positive conjunctival margins need addressing with reexcision or topical chemotherapy. Treat positive deep margins with plaque therapy.
- Tailor chemotherapy agent of choice to patient (Table 36.1). Topical chemotherapy agents include MMC, 5-FU, and IFN-2b.
- Close follow-up with serial slit-lamp photography and other imaging modalities to monitor for progression or recurrence.

- In cases of recurrent OSSN following a surgical excision, we favor medical treatment trial.

Clinical “Pearls”

- Use “optical biopsy” with anterior-segment HR-OCT imaging to differentiate OSSN from other ocular surface lesions.
- OSSN can be treated medically or surgically.
- Chemo- or immunotherapy agents may be used as the primary treatment, or as intraoperative adjunctive therapy when the tumor is adherent to sclera.
- Tailor chemotherapy agent of choice to patient.
- In cases of recurrent, large, or annular OSSN lesions, medical therapy is preferred over surgical intervention.
- During medical therapy, use HR-OCT to monitor progress.
- When surgical excision is performed, use intraoperative cryotherapy, label specimen, and communicate with the pathologist.

References

1. Lee GA, Hirst LW. Ocular surface squamous neoplasia. *Surv Ophthalmol*. 1995;39(6):429-450.
2. Jacobs S. Ocular surface squamous neoplasia offers physicians unique challenges. *Ocular Surgery News India Edition*. August 1, 2008.
3. Atallah M, Joag M, Galor A, et al. Role of high resolution optical coherence tomography in diagnosing ocular surface squamous neoplasia with coexisting ocular surface diseases. *Ocul Surf*. 2017;15(4):688-695.
4. Thomas BJ, Galor A, Nanji AA, et al. Ultra high-resolution anterior segment optical coherence tomography in the diagnosis and management of ocular surface squamous neoplasia. *Ocul Surf*. 2014;12(1):46-58.
5. Davila JR, Mrithyunjaya P. Updates in imaging in ocular oncology. *F1000Res*. 2019;8. doi:10.12688/f1000research.19979.1

6. Singh S, Mittal R, Ghosh A, et al. High-resolution anterior segment optical coherence tomography in intraepithelial versus invasive ocular surface squamous neoplasia. *Cornea*. 2018;37(10):1292-1298.
7. Tran AQ, Venkateswaran N, Galor A, Karp CL. Utility of high-resolution anterior segment optical coherence tomography in the diagnosis and management of sub-clinical ocular surface squamous neoplasia. *Eye Vis (Lond)*. 2019;6:27. doi:10.1186/s40662-019-0152-3
8. Shields CL, Chien JL, Surakiatchanukul T, Sioufi K, Lally SE, Shields JA. Conjunctival tumors: review of clinical features, risks, biomarkers, and outcomes – the 2017 J. Donald M. Gass Lecture. *Asia Pac J Ophthalmol (Phila)*. 2017;6(2):109-120.

CHAPTER 37

Pterygium Excision Techniques

Karen E. Grove, MD

PREOPERATIVE CONSIDERATIONS

Possible Surgical Indications

- Threat to visual axis
- Induction of significant irregular or regular astigmatism
- Inflammation refractory to medical management
- Motility restriction

SURGICAL PROCEDURE

Primary Pterygium

- Place a superior stay suture to increase exposure of the pterygium with a 7-0 Vicryl suture.
- Outline the lesion with a surgical marker.
    - Tip: Despite anesthesia with a retrobulbar block, infiltrate lidocaine with epinephrine beneath the lesion to facilitate easier dissection from sclera and hemostasis.
- Use blunt scissors (recommend micro-Westcott) to incise along the marked perimeter and periodically undermine the entire area to sclera using blunt dissection.

    - Tip: Always keep in mind the location of rectus muscle insertions. In primary pterygium removal, if you are working the blunt dissection anterior to posterior, the surgeon is unlikely to require a muscle hook to isolate and avoid the muscle, but this is a useful step in the excision of a recurrent pterygium, which can often involve the muscle.
- The corneal portion of the lesion can be excised by a number of techniques. A blunt knife like a Tooke or a sharp knife like a crescent blade can be used in quick, sweeping motions starting just central to the pterygium head to scroll a bit of normal epithelium and find a plane between normal and abnormal tissue. This can then be undermined with either of these instruments. Alternatively, the previously excised conjunctival portion can be grasped and pulled toward the corneal portion while creating some torque to strip the corneal head.
- The corneal lesion bed and limbus should be left as smooth as possible.
    - Orient one of the aforementioned blades perpendicularly to the corneal surface and scrape and remove limbal residue taking care to not cut into tissue.
    - Consider conservative lamellar dissection and/or a series of burrs to address an irregular corneal surface.
- Place the lesion in formalin and send for pathological evaluation.
- Undermine along the conjunctival edges to bluntly dissect both the conjunctiva off of underlying Tenon capsule and Tenon off of sclera. Circumferentially remove a significant amount of Tenon avoiding muscle and orbital fat.
- Maintain hemostasis throughout the case with the minimum of wet field cautery. Do not create an avascular scleral bed.
- Measure the defect with calipers.
- Create a conjunctival free graft.

    - Use the stay suture to expose superior conjunctiva and mark an area with the dimensions of the defect.
    - Infiltrate with lidocaine with epinephrine.
    - Use blunt scissors and fine, nontoothed forceps like conjunctival tissue forceps to incise the edges and dissect conjunctiva off of Tenon without buttonholes or variable thickness.
- Reorient the globe with the stay suture.
- Use two nontoothed forceps to rotate the graft to the pterygium bed.
- Use a fibrin sealant to adhere the conjunctival edges to sclera without significant tension.
- Use the fibrin sealant to allow the free graft to adhere within the defect with care to approximate the edges to limbus and conjunctiva.
    - Tip: Closed angles forceps or muscle hooks can be used to squeegee excess glue and to flatten the graft. Also, excess graft can be trimmed with scissors or a blade.
- If preferred, the surgeon may place interrupted 8-0 Vicryl sutures to further secure the graft instead of fibrin glue.

While AMG is superior to bare sclera, the recurrence rate is higher than with conjunctival or limbal autografts.

RECURRENT PTERYGIUM

- Start with dissection of the pterygium head off of the cornea and carefully continue to dissect the scarred tissue off of the limbus and then posteriorly to expose bare sclera.

    - Tip: Although some cicatrix must be excised, tissue removal should be very conservative.
- Isolate the rectus muscle on a muscle hook and dissect all scar off of the muscle.
- Use of mitomycin C 0.02% or 0.04% 3 to 5 minutes:
    - Consider in recurrent pterygia.
    - Associated with serious complications such as scleral necrosis and delayed healing.
    - Tip: Create a pocket for the soaked pledget between conjunctiva and the remaining Tenon to decrease direct exposure to the underlying sclera and irrigate copiously once removed.
- Conjunctival autograft should be used to cover the defect. If the defect is larger than the maximized, harvested graft, use AMG to cover the remaining scleral surface. A combination of fibrin and sealant and interrupted sutures should be used to secure the combination of grafts.
- Motility should be full with release of all symblepharon and re-formation of the conjunctival fornix and caruncle.

POSTOPERATIVE CONSIDERATIONS

- Aggressively control postoperative inflammation to decrease scarring and recurrence. Consider a slow steroid taper over 1 to 2 months to reduce the risk of recurrence and scarring.

Reference

1. Kaufman SC, Jacobs DS, Lee WB, Deng SX, Rosenblatt MI, Shtein RM. Options and adjuvants in surgery for pterygium: a report by the American Academy of Ophthalmology. *Ophthalmology*. 2013;120(1):201-208.

CHAPTER 38

Conjunctival Melanoma Treatment Techniques

Mona L. Camacci, MD, Gargi K. Vora, MD

PREOPERATIVE CONSIDERATIONS

In an eye with a pigmented conjunctival lesion concerning for a conjunctival melanoma, the following considerations are needed:

- Pertinent patient history should include past sun exposure, systemic medications, and any personal and/or family history of malignancy (especially skin cancer).
- If possible, review old photographs to determine how long the lesion has been present.
- External examination should include lymph node palpation.
- Particular attention on slit-lamp examination should be placed on the eyelids, conjunctiva (including double eversion and assessment of the palpebral conjunctiva), gonioscopy, and dilated fundus examination.

Clinical Workup

- Obtain slit lamp photographs and have a detailed clinical drawing to document the location and size of the lesion.
- Use gonioscopy and UBM to further ascertain the extent of the conjunctival lesion if located near the limbus.
- When melanoma is confirmed with histopathology, refer patient

to the oncology service to initiate a systemic workup. Further laboratory testing and imaging of the brain, lungs, liver, and abdomen may be warranted with CT, MRI, ultrasound, and/or PET-CT.

Surgical Planning

- If there is concern for micrometastasis to lymph nodes, a multidisciplinary approach with otolaryngology and nuclear medicine specialists should be utilized for consideration of a sentinel lymph node biopsy.
- Prior to the day of surgery, collaborate with the surgical pathologist to determine the appropriate protocols regarding specimen and tissue handling.
- It is critical to communicate with the OR staff regarding the importance of tissue orientation and careful tissue handling.
- The OR staff should be prepared with two sets of instruments to enable a "no touch" protocol.

SURGICAL PROCEDURE: CONJUNCTIVAL MELANOMA EXCISION

- Carefully outline the area of tissue to be excised (ensuring 4 to 7 mm margins) with a marking pen.
- If there is corneal involvement of the lesion, a localized superficial corneal epitheliectomy should be performed. Absolute alcohol can be applied to the corneal epithelium and epitheliectomy can be performed. Take careful caution to not disrupt the Bowman membrane as this can promote intraocular invasion. Try to remove the corneal part in one piece (along with the conjunctival part).
- Excise the conjunctival portion of the tumor. Use the "no touch"

technique, where only the margins of the conjunctiva are grasped and the tumor is left untouched.

- For superficial lesions, the underlying Tenon capsule should be excised with the conjunctiva for histopathological evaluation of the deep margins.
- If the tumor is deeper such that there is scleral adhesion or pigmentation, then a lamellar dissection of the sclera should be performed.
- Carefully mark and orient the specimen, paying particular attention to the margins so that the pathologist understands the orientation and nearby structures. It is helpful to mark a superior or inferior limbal edge with a suture when first starting to excise. Oftentimes a drawing is sent with the specimen to aid the pathologist.
- The tissue should be carefully flattened out over a piece of filter paper with a drawing of its orientation and location on the globe. Unroll specimen edges as much as possible, since assessing the presence of tumor cells in the margin is paramount.
- Once the sclera is exposed, the exposed base can be treated with absolute alcohol and further scraping of the sclera can be performed with a blade. Some surgeons may also apply mitomycin C at this step to the bare sclera.

> A dry surgical field should be maintained to avoid tumor cell seeding during the procedure (there is no BSS irrigation throughout the case). Bipolar cautery can be utilized as needed to achieve hemostasis.

- At this point in the procedure, the OR staff should be made aware that all new instrumentation is required.
- Double freeze-thaw cryotherapy is critical and should be used at the conjunctival margins (and corneal limbus if applicable) of the

tumor for all cases.

- For small defects, a conjunctival reconstruction can be performed by undermining the conjunctiva and Tenon capsule bluntly with a clean set of instruments. This conjunctival flap can be used for adequate closure of the defect.
- If a large resection was completed, an amniotic membrane graft is placed on bare sclera for adequate coverage. The amniotic membrane is cut to the proper size. The tissue and possible amniotic graft are sutured at the four corners, anchoring the first two absorbable sutures to the episclera. In place of sutures, fibrin glue may also be used.

POSTOPERATIVE CONSIDERATIONS

- If the margins are read as positive for tumor cells at the border of the excision, re-excision of 2 to 3 mm of conjunctival margin with repeat double-freeze thaw cryotherapy is recommended.
- If the margins are read as positive for primary acquired melanosis with atypia, then topical chemotherapy (typically mitomycin C, and rarely interferon-alpha-2B or 5-fluorouracil) can be considered.
- If there is concern for scleral involvement, additional considerations could be given to the use of plaque radiotherapy.
- For the postoperative course, steroids and antibiotics should be given to reduce inflammation and prevent infection.
- Long-term follow-up is necessary to ensure monitoring for recurrence or metastasis. After the acute postoperative period, patients must undergo thorough repeat ophthalmic examination at increasing intervals and systemic monitoring as directed by oncology service.

Section 8

Corneal Refractive Surgery

CHAPTER 39

Photorefractive Keratectomy

Garett Frank, MD

PREOPERATIVE CONSIDERATIONS

PRK is a procedure that reshapes the anterior surface of the cornea to correct myopia, hyperopia, and astigmatism. As an alternative to LASIK, PRK disturbs less corneal tissue by avoiding the creation of a corneal flap.

Advantages of PRK

- Allows for a thicker residual stromal bed, which can be important in patients with thin corneas. This also provides an extra margin of safety in corneas with slightly atypical topography or tomography.
- Less disruption of corneal nerves decreases postoperative dry eye syndrome.
- Can be performed in corneas with mild amounts of ABMD. ABMD that induces significant irregular astigmatism should be treated prior to PRK.
- In patients with high risk of ocular trauma, PRK avoids flap creation, which, rarely, can be dislodged with direct trauma.

Disadvantages of PRK

- Recovery is longer compared with LASIK, both in comfort and visual function. Mild to moderate discomfort usually lasts 2 to 3 days. Vision typically improves in 7 to 10 days but can rarely

change 3 to 6 months postoperatively.

- Postoperative complications related to contact lenses can be observed. This includes infectious and/or sterile keratitis.
- Corneal haze can develop. Mild amounts of haze are common, but visually significant haze is rare with use of antimetabolite compounds during surgery and the use of postoperative steroids. Haze risk is increased with higher ablation profiles.
- If postoperative outcomes are unfavorable, LASIK is usually retreated by lifting the flap. In PRK, the whole procedure needs to be repeated, but it is generally advisable to wait 6 months to assure stability.

Indications/Surgical Planning

- This procedure is FDA-approved for age ≥18 years, and stability has been demonstrated by change in MRSE not greater than 0.5 D in the last year.
- Indications include myopia less than −12.0 D with or without astigmatism up to −6.0 D and hyperopia up to +5.0 D with or without astigmatism up to +3.0 D. Mixed astigmatism up to +6.0 D can also be treated. FDA approval varies based on machine and type of ablation.
- Topographic and tomographic evaluation needs to be done to assess for any potential irregular astigmatism or forme fruste keratoconus. Special attention should be taken if there is significant posterior corneal elevation or a Belin-Ambrosio D-score >2 on the Pentacam.
- An ERSS score of 3 indicates moderate risk of ectasia induction and 4 represents a high risk. PTA should be less than 45% to prevent complications. All indices have to be taken in consideration of patients age, tomographic analysis, and preoperative refractive error.

- The FDA considers a RSB of less than 250 μm a contraindication. Most experts argue against going below 300 μm. RSB can be calculated with the Munnerlyn formula and pachymetry. This is more problematic in patients undergoing LASIK or patients with very thin corneas and/or high refractive error.

SURGICAL PROCEDURE: PHOTOREFRACTIVE KERATECTOMY

- The first step of PRK is to anesthetize the eye. This is usually done topically with proparacaine or tetracaine.
- Most surgeons then apply ethanol to the ocular surface. Placement of 20% ethanol for 30 seconds using an 8.0- to 9.0-mm well is used to delaminate the epithelial basement membrane. This aids in removing the epithelium prior to ablation.
- Removal of corneal epithelium is the next step. Various techniques have been successfully used including blunt debridement, mechanical debridement with a rotating brush, and excimer laser transepithelial ablation. Most surgeons favor blunt debridement after alcohol delamination.
- Excimer laser ablation is then applied to the anterior cornea to change the refractive state of the eye. This can be based on the eye's refraction (wavefront optimized), wavefront (wavefront guided), or topography.
- Antimetabolite compounds, like MMC, is subsequently applied to the ocular surface when applicable. Some surgeons use it only for higher ablations such as myopia >5 D or astigmatism >1.5 D, or for repeat treatments. Others use it for all ablations. The usual dosage is 0.02% on an 8.0-mm corneal sponge for 12 to 120 seconds based on risk factors for haze development. I typically apply it for 20 seconds on all ablations.

- After copious irrigation of MMC, a bandage contact lens is placed for comfort. This is usually a contact that has high oxygen permeability since it will be continuously worn while the epithelium heals.

POSTOPERATIVE CONSIDERATIONS

- Typical postoperative drop regimens include an antibiotic drop for 1 week until full epithelial healing is observed, and the contact lens is removed. A tapering dose of topical steroids may be used between 1 and 4 months. Some surgeons provide PRN NSAID drops for the first several days for discomfort.
- As stated previously, mild to moderate discomfort usually lasts 2 to 3 days. Visual decline can occur 4 to 5 days after surgery as the healing "epithelial ridge" enters the visual axis. Vision typically improves in 7 to 10 days but can change for 3 to 6 months postoperatively.
- The contact lens is usually removed 4 to 7 days postoperatively once the epithelium has healed.
- Haze, although rare, can still develop. This can be treated with prolonged use of topical steroids, superficial keratectomy with MMC, PTK with MMC, or rarely lamellar keratoplasty.

CHAPTER 40

Laser In Situ Keratomileusis

Paramjit K. Bhullar, MD, Nandini Venkateswaran, MD, Terry Kim, MD

PREOPERATIVE CONSIDERATIONS

Understand the FDA-Approved Treatment Parameters for LASIK

- Most physicians will perform LASIK in patients with refractive errors of:
  - Spherical range: −10.00 to +4.00 D.
  - Cylinder range: Up to 6.00 D.

Select Appropriate Patients

Patients should meet the following inclusion criteria:

- Have reasonable expectations. They should understand that the goal of the procedure is to reduce, not eliminate, spectacle dependence and understand that LASIK will not prevent cataract formation or presbyopia in the future.
- Be willing to undergo extensive preoperative testing including manifest refraction, cycloplegic refraction, corneal pachymetry, corneal topography and tomography, wavefront analysis, dry eye evaluation, orbital anatomy assessment, and full dilated slit-lamp examination.
- If patients are at the cusp of presbyopia, monovision should be

discussed. Any patients interested in monovision should undergo a contact lens trial first.

- Recognize preoperative measurements may need to be repeated several times to ensure refractive stability and accurate treatment plans.
- Have a stable refractive error for 1 to 2 years.
- Be free of any major ocular comorbidities.
- Have corneas free of contact lens warpage.
    - Soft contact lenses should be discontinued 3 days to 2 weeks prior to measurements.
    - Rigid gas permeable and hard contact lenses should be discontinued for longer. A good rule of thumb is to discontinue these lenses 1 month for every decade of wear prior to measurements (eg if a patient has worn rigid contact lenses for 4 decades, he/she should be out of lenses for 4 months prior to measurements; however, this may be impractical for certain patients).
- Have a residual stromal bed of greater than 250 to 300 μm.
- Understand the risk of postoperative dry eye, especially for the first 6 months after LASIK.
- Be willing to accept the risks of vision loss, postoperative glare and halos, diffuse lamellar keratitis, and possible need for future enhancements.

Key formulas to know:

- **Residual stromal bed (μm)** = central corneal thickness (μm) − lasik flap thickness (μm) + ablation depth (μm)
- Munnerlyn formula: **Ablation depth (μm)** = [intended refractive correction in diopters (spherical equivalent) (D) × (optical zone

diameter)^2 (mm)]/3

- **PTA** = [flap thickness (µm) + ablation depth (µm)]/preoperative central corneal thickness (this is ideally <40% to reduce risk of ectasia)

Good rules of thumb:

- When calculating rough estimates, for each diopter of correction, about 15 to 17 µm of corneal stroma is ablated.
- It is estimated that keratometry flattens by 0.8 to 1.0 D for each diopter of myopic correction and steepens by 1 D for each diopter of hyperopic correction.
- Ensure that corneal K values after treatment are not less than 35 to 36 D or greater than 49 D to avoid diminution in postoperative visual quality due to induction of higher-order aberrations.

Patients should be free of the following relative ocular and systemic contraindications:

- Corneal ectatic diseases, eg, keratoconus, forme fruste keratoconus, or pellucid marginal degeneration
- Corneal stromal dystrophies
- Severe inflammatory ocular disorders
- Systemic conditions that could alter wound healing (eg, pregnancy, uncontrolled diabetes, collagen vascular or connective tissue disorders, immunosuppression, severe dry eye, neurotrophic corneas)
- History of chronic amiodarone or isotretinoin use
- Monocular status
- History of herpes simplex or zoster keratitis

Gather and Prepare the Appropriate Supplies

- Anesthetic eyedrops, eg, proparacaine 0.5%
- Oral anxiolytic, eg, diazepam 5 mg
- Sterile marking pen
- Occluder for nonoperative eye (if applicable)
- Wire eyelid speculum
- Timer
- Five-milliliter syringe
- Balanced salt solution
- LASIK flap elevator
- Irrigating cannula
- Disposable cannula
- Cellulose sponges
- Maloney spatula
- Ultrasound pachymeter
- Topical antibiotic, eg, moxifloxacin 0.5%
- Topical NSAID, eg, ketorolac 0.5%
- Topical steroid, eg, prednisolone acetate 1%

Surgeons should complete training and certification prior to using any lasers. Surgeons should ensure that the lasers have been properly calibrated prior to use and should double check that the desired treatment has been accurately programmed into the system even after the technician has entered this data. Surgeons typically create nomograms after retrospectively reviewing their refractive surgery outcome data and program their nomograms into their

excimer lasers.

SURGICAL PROCEDURE

- Repeat the manifest refraction and preoperative imaging on the day of the procedure. Plan the excimer laser treatment and ensure the correct information has been entered into the laser machines by your technicians.
- Mark the 0 and 180 degrees with a marking pen at the slit lamp, with the patient sitting upright, if the patient has greater than 1 D of astigmatism. This allows for accurate astigmatism axis alignment during the ablation treatment in the setting of cyclotorsion once the patient is supine.
- The nonoperative eye should be occluded.
- Instill topical anesthetic onto the cornea of the eye to be treated (note: topical anesthetic is used sparingly, as excess can lead to epithelial sloughing). Weckcel sponges can be used to distribute the topical anesthetic over the entire corneal and conjunctival surfaces.
- Prep and drape the patient in a sterile fashion. The lids should be cleaned with a 5% povidone-iodine solution; 10% povidone-iodine should not be instilled on the corneal surface.
- Place an eyelid speculum and take care to ensure there are no eyelashes exposed.
- Position the head so that the cornea is centered under the laser scope.
- Place an ink mark on the central cornea to help with flap centration. Marks can also be made on the peripheral cornea to help with flap realignment later in the procedure.
- Create the LASIK flap using the laser platform available at your

facility. Warn the patient that he/she may feel pressure, his/her vision may temporarily dim during the procedure, and that this is normal. At our institution, we utilize the iFS Intralase advanced femtosecond laser (Johnson & Johnson Vision) for flap creation. Femtosecond laser as opposed to microkeratomes (which will not be covered in this chapter) allow for more uniform and precise LASIK flap creation.

- When using the Intralase, first ensure the suction device clip works by clipping and unclipping it. Then center the interface suction device on the pupil. It is important to note that, in many patients, the pupil is often decentered superonasally. As such, the suction device needs to be accordingly positioned to account for this pupil decentration. Distribute equal force around the ring and instruct the technician to engage suction. After suction is achieved, the physician may let go of the interface device. Position the patient under the Intralase laser and dock the cone using the joystick. Once docked, unclip the device and allow for spread of the peripheral tear meniscus. Ensure flap centration. Re-dock if there is any concern for pseudosuction or poor centration of the flap. Start the laser, via the foot pedal, to create the flap. Once completed, turn off suction. Use the joystick to then move the cone and interface away from the patient.

  The Intralase suction device can also be docked with the device unclipped (often referred to as the soft-dock). If the surgeon chooses to do this, the handles of the device must be squeezed together while the cone is docked into the suction device, after which they can be let go.

- Position the patient under the excimer laser. At our institution, we have two platforms for the excimer laser (VISX Star S4 IR Excimer laser by Johnson & Johnson and the Alcon Wavelight EX500). Instruct the patient to look at the amber light. Complete the laser’s pupil/iris tracker registration

and do not allow any repositioning of the patient's head or illumination setting changes after this point.

> If the opaque bubble layer created by the femtosecond laser prevents pupil or iris registration and tracking, this modality can be turned off on certain laser platforms; however, doing so is not ideal. Similarly, if an air bubble enters the anterior chamber during flap creation and prevents pupil or iris registration, the patient can be asked to sit up and wait for several minutes to allow the air bubble to dissolve. Alternatively, the iris/pupil tracking feature can be turned off or the procedure can be completed the following day once the air bubble disappears.

- Dry the fornices with a sponge and then carefully lift the LASIK flap. Position the angulated edge of the flap elevator perpendicular to the flap border to pierce the flap edge and lift the flap. Most surgeons will create a superior hinge for their flaps. Take caution to not disrupt the epithelium during this step. Then use the spatulated end of the flap elevator to dissect the flap from the hinge outward. Flap adhesions can be broken in one smooth motion along the whole diameter of the flap or in multiple motions. Ensure all adhesions at the flap hinge are broken before reflecting the flap. It is helpful to fold the flap into a taco above the hinge to avoid flap trauma or movement during the subsequent ablation steps.
- Achieve hemostasis of any peripheral bleeding corneal vessels with a sponge soaked in apraclonidine 0.5%, if needed.
- Dry the stromal bed with a cellulose sponge.
- Center the patient's eye under the excimer laser, focusing on the surface of the stroma. Instruct the patient not to make any eye movements. Ensure the iris/pupil tracking system is active. If the patient's pupil is too constricted, the pupil

registration will not work. Have the patient wiggle his/her toe or squeeze a stress ball to relax and allow for pupil dilation.

- Complete the ablation portion of the procedure by depressing the foot pedal, taking care throughout the procedure to keep the ablation centered and the axis of astigmatism correction aligned.
- Drape the LASIK flap back over the stromal bed using an irrigating cannula. Irrigate the flap from the hinge outward, removing any debris in the flap-stroma interface. It is important to irrigate well to reduce meibum accumulation in the flap interface.
- Use a slightly moistened cellulose sponge to dry the flap surface in a motion away from the hinge in order to remove any striae. Check the alignment of the flap via the asymmetric markings made at the beginning of the case. You can also confirm that the flap gutters are symmetric with a placement of steroid solution on the surface of the eye, which will settle into the gutter.
- Refloat the flap if you detect any striae or misalignment.
- Wait 2 minutes for the flap to dry. Check flap alignment and adhesion.
- If any epithelium is disrupted along the flap edge, place a bandage contact lens to reduce the risk of epithelial ingrowth.
- Place one drop of each of the following, 2 minutes apart: corticosteroid, NSAID, and antibiotic eyedrops.
- Remove the eyelid speculum carefully, as to not disrupt the flap.
- Repeat the prior steps for the fellow eye.
- Check the LASIK flaps at the slit lamp.
- Place shields on both eyes, and provide the patient with a

postoperative kit and instructions.

POSTOPERATIVE CONSIDERATIONS

- The patient should be advised that blurred vision, tearing, and irritation are commonplace after topical anesthesia wears off.
- Patients are advised not to get any shower water in their eyes for 3 days and not to rub their eyes after the procedure.
- Patients should be available for examination on postoperative day 1. Any bandage contact lenses in place may be removed at this time. Ensure the flap is adherent and centered with no evidence of macrostriae or dislocation.
- Postoperative topical steroid eye drops (eg, prednisolone acetate 1%) and antibiotic drops (eg, moxifloxacin 0.5%) are administered 4 times daily for 1 week and then stopped.
- Patients are checked at postoperative week 1 to ensure there are no signs of diffuse lamellar keratitis, infectious keratitis, or late flap striae or dislocation.
- Patients can then be checked at postoperative month 1 and every 3 months thereafter to ensure refractive stability and satisfaction, as well as monitor for late-onset complications such as epithelial ingrowth.
- Refractive enhancements can be considered 3 to 6 months after the LASIK procedure.

References

1. American Academy of Ophthalmology. *Laser In Situ Keratomileusis in Basic Techniques of Ophthalmic Surgery*. 2nd ed. Academy of Ophthalmology; 2015:175-182.
2. American Academy of Ophthalmology. *Photoablation*: techniques and outcomes. In: *Basic and Clinical Science Course*: Refractive Surgery. Academy of Ophthalmology; 2018-2019:73-100.

CHAPTER 41

Small Incision Lenticule Extraction

Gary Legault, MD

PREOPERATIVE CONSIDERATIONS

Prior to performing SMILE, the surgeon must be competent at creating LASIK flaps with the femtosecond platform. For the Visumax platform utilized for SMILE, the company recommends 50 LASIK flaps prior to starting SMILE.

Surgical planning is similar to other keratorefractive procedures. If a patient is not a good candidate for LASIK, then SMILE is not a viable alternative.

Preoperative Screening

- Evaluate risk for ectasia with emphasis on excluding abnormal corneal topography/tomography or low corneal pachymetry.
- Identify orbital, lid, or ocular anatomy that will interfere with the PI of the laser and consider another procedure.
- Exclude patients with significant dry eye.
- Verify refractive stability.

Surgical Planning

- Measure an accurate refraction. The refraction is used to create the lenticule and program the femtosecond platform.
- Review corneal topography and tomography.
- Mark the cornea at the slit lamp at 0 and 180 degrees if treating

astigmatism. Some surgeons only mark for astigmatism greater than 2.50 diopters because if not carefully marked, the ink or epithelial defect can interfere with the lenticule creation.

SURGICAL PROCEDURE: SMILE (VIDEO 41.1)

- Start with proper patient positioning. Ensure the correct patient position can be attained without the patient using any muscular effort.

> Properly positioning the patient in a comfortable position and talking the patient through the surgery can prevent suction loss.

- Perform a timeout and verify the correct patient and treatment has been entered into the laser and displayed on the laser screen.
- Carefully place a lid speculum. Ideally use a solid blade to avoid expressing meibomian contents onto the cornea and/or tape the lashes with an adhesive.
- Wipe the ocular surface with a wet spear-tip sponge to remove any debris.
- Dock the PI onto the cornea. When docking, the patient should be reminded to focus on the green light. Increase the meniscus to about 80% to 90% and then apply suction. Ensure the docking is centered on the visual axis and align the PI marks to the toric marks if applicable.
- Step on the foot pedal and remind patient to not move or talk while the lenticule is being created. It takes approximately 20 to 25 seconds to create the lenticule and side cut.

> During the femtosecond cutting of the lenticule, it is paramount to observe the bubble pattern on the display screen or through the oculars. Black spots are suggestive of areas where the laser

did not cut through the tissue owing to debris. If a suction loss occurs, follow the femtosecond platform recommendations to determine if it is safe to proceed or abort to another procedure. If for any reason the lenticule was not created successfully, abort the surgery and consider LASIK or a surface ablation.

- Using the joystick, lower the patient from the PI and then move the bed so the patient's surgical eye is focused under the oculars attached to the laser.
- Stabilize the eye with the nondominant hand using 0.12 forceps and open the small incision side cut 100%.

There are various lenticule separator instruments available. Most are based on a modified Sinsky instrument and have a blunt narrow tip and a bulb end on the opposite side. If you use a Sinksy, the sharp tip end can potentially create a false plane.

- Enter the right side of the pocket and use the blunt narrow tip on the right side and dissect 50% of the anterior interface of the pocket lenticule.
- On the left side, dissect 50% of the posterior interface of the pocket lenticule.
- Use the bulb end of the instrument to enter into the cap interface on the right side to bluntly dissect the anterior interface. Sweep in a circular motion to dissect the anterior interface. Do not dissect 100% of the anterior interface in order to allow an adhesion while dissecting the posterior surface.
- Enter the posterior interface on the left side with the bulb end and dissect the posterior interface.

If the posterior interface is dissected first, it is more challenging to remove the lenticule.

- Remove the lenticule using the bulb end instrument or forceps.
- Evaluate the lenticule by spreading it out on the ocular surface to ensure it is 100% complete. If fragments remain, remove these using the bulb instrument and forceps.
- Irrigate the pocket with BSS. Some surgeons do not recommend irrigation, whereas others prefer it.
- Place a bandage contact lens on the cornea if an epithelial defect is present.
- Evaluate the patient at the slit lamp to ensure there are no residual fragments.

POSTOPERATIVE CONSIDERATIONS

- After a successful procedure, manage the patient similar to LASIK.
- Issues to identify and then manage are remnant lenticular fragments, diffuse lamellar keratitis or debris in the interface, epithelial defects, microbial keratitis, epithelial ingrowth, under/over treatment, and ectasia.

Additional Resources

1. For further details, a great resource is "The Surgeon's Guide to SMILE: Small Incision Lenticule Extraction" by Dan Reinstein.

CHAPTER 42

Special Considerations for Post Intraocular Lens Enhancements

Nandini Venkateswaran, MD

In today's society, the desire for complete spectacle independence drives the need for near perfection when performing cataract surgery. The surgeon is expected to achieve the refractive target discussed with the patient, especially with premium IOL technology.

As a cataract surgeon, it is important to have several tools in your toolbox to help the small percentage of patients with residual refractive error after cataract surgery attain the quality of vision they desire.

Below we outline key preoperative considerations as well as treatment options for patients requiring treatment of residual postoperative refractive error after previous cataract surgery.

PREOPERATIVE CONSIDERATIONS

- It is best to consider a postoperative enhancement 3 to 6 months after the initial cataract surgery to ensure that the patient's refractive error is unchanged.
- Determine if your patient is okay with wearing spectacles and/or contact lenses after surgery. Not all patients need to be 20/20 but need to more importantly be 20/happy. Have a candid discussion with your patient to determine what their goals are.
- Perform testing to understand why a patient has residual

refractive error. This will help guide the management approach.

- Perform a manifest refraction to determine the degree of residual refractive error. Perform multiple measurements to ensure stability.
- Obtain corneal topography and tomography to assess for any corneal ectasia or sources of irregular corneal astigmatism.
- Measure tear osmolarity and perform matrix MMP-9 as well as Schirmer tear testing to assess for ocular surface dryness and inflammation.
- Perform macular OCT to ensure there is no postoperative CME that could explain a refractive shift.
- Repeat IOL biometry to confirm if the accurate IOL power was used at the time of the initial cataract surgery.
- Perform a thorough anterior and posterior segment slit-lamp examination to assess the corneal surface (ie, anterior basement membrane dystrophy, Salzmann nodules, corneal scars, keratoconjunctivitis sicca), the position of the IOL (IOL tilt, decentration, posterior capsular rupture with vitreous in the AC, toric IOL malrotation, posterior capsular opacification), and the posterior pole and periphery for any abnormalities.

Ensure the corneal surface is stable prior to obtaining your initial biometry and keratometry measurements—this can include treating dry eye disease or performing a superficial keratectomy to address anterior basement membrane dystrophy or Salzmann nodules. Severe dry eye disease or ocular surface scars or lesions can impact measurements and can lead to calculation of the wrong IOL, causing postoperative refractive errors.

ENHANCEMENT OPTIONS

- Keratorefractive surgery.
- Piggyback IOL.
- IOL exchange.

KERATOREFRACTIVE SURGERY

- Keratorefractive surgical options include LASIK or PRK.
- Prior to considering a keratorefractive enhancement, perform preoperative testing including manifest refraction, corneal topography and tomography, wavefront analysis, corneal pachymetry, and a thorough slit-lamp and dilated examination.
- Typically, PRK is performed for patients with low degrees of residual refractive error; however, LASIK can be preferred if the patient is a suitable candidate and can allow for faster visual recovery.
- It is important to counsel patients that LASIK more than PRK can exacerbate dry eye syndrome and both procedures can induce higher-order aberrations postoperatively, which can influence visual outcomes (particularly relevant for patients with multifocal, trifocal, or extended depth of focus IOLs).
- Keratorefractive surgery can address both spherical refractive error as well as residual astigmatism.
- Please see chapter on LASIK and PRK on details of how to perform this procedure.

If LASIK is performed sooner than 3 months after cataract surgery, there is a risk for wound dehiscence and AC instability during suction for the LASIK flap creation. PRK may be preferable in these

scenarios.

PIGGYBACK IOL

- A piggyback IOL can be placed in the ciliary sulcus over the existing IOL implant in cases with residual refractive error.
- Piggyback IOLs are often best in patients with a hyperopic postoperative refractive error (ie, patients with a history of RK with residual hyperopic refractive error after cataract surgery).
- Important anatomical considerations for piggyback IOL implantation include a normal corneal endothelium, a deep AC, and an intact capsular bag. Anatomical contraindications include a history of corneal decompensation, preoperative pigment dispersion syndrome, zonulopathy, or pseudoexfoliation syndrome.
- Piggyback IOLs can only correct spherical refractive error. Postoperative astigmatism cannot be corrected, and manual or femtosecond limbal relaxing incisions or keratorefractive surgery may need to be coupled with piggyback IOL implantation.

  To calculate the power of a piggyback IOL, the pseudophakic refractive spherical equivalent needs to be calculated. The spherical equivalent is then multiplied by 1.5 to calculate the piggyback IOL power for a hyperopic refractive error. In contrast, the spherical equivalent is multiplied by 1.2 or 1.3 to calculate the piggyback IOL power for a myopic refractive error. The Holladay R formula or the Refractive Vergence formulas can also be used.

- Interlenticular opacification, or formation of a membrane between the primary IOL implant and the piggyback IOL, occurs when the piggyback IOL is the same material as the primary IOL

implant (ie, two acrylic IOLs).

> Previously used piggyback IOLs (ie, Clariflex and STAAR QQ5010V) are no longer manufactured. As such, three-piece IOLs that come in low dioptric powers suitable for use as a piggyback IOL in the ciliary sulcus include LI61AO or LI61SE (Bausch & Lomb), or AR40M, AR40E, or AR40e (Johnson & Johnson).

- Monitor these patients carefully for postoperative uveitis-glaucoma-hyphema syndrome. UBM can be used preoperatively to assess the depth of the ciliary sulcus prior to IOL placement and postoperatively to confirm IOL positioning and stability.

IOL EXCHANGE

- In cases with postoperative residual refractive error where the patient is not a good candidate for keratorefractive surgery or a piggyback IOL, an IOL exchange can be performed.
- IOL exchange is preferably performed earlier in the postoperative course when there is no significant fibrosis or adhesions of the IOL in the capsular bag.
- The procedure is significantly more challenging when the posterior capsule has been opened from a previous YAG capsulotomy. There is a higher risk for posterior dislocation of the IOL, vitreous loss, and retinal tears or detachments.

> When posterior capsular opacification is noted on slit-lamp examination in cases with decreased postoperative visual acuity, it is important to wait to perform a YAG capsulotomy if you are considering an IOL exchange in the future. Aim to optimize the ocular surface, obtain a manifest refraction, and trial glasses or contact lenses to improve vision before performing a YAG

capsulotomy. An open posterior capsule can render IOL exchange to be difficult and may not adequately address the patient's visual complaints.

Steps for an IOL Exchange (Video 42.1)

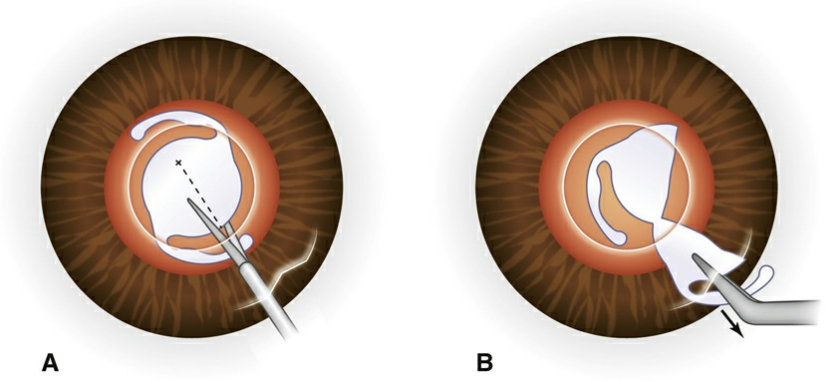

FIGURE 42.1 **A. One-piece IOL is dialed into the anterior chapter and microsurgical scissors are used to partially bisect the IOL optic. B. The IOL is then removed through the main wound.**

- Step 1: Either a superior or temporal approach can be used. Multiple paracenteses are created with a side port blade to allow for easy access into the AC.
- Step 2: Viscoelastic is instilled in the AC; a keratome is used to create the main wound.
- Step 3: A 27G cannula is used to carefully inject viscoelastic underneath the anterior capsular rim to separate the anterior capsule from the IOL optic. In cases with a fibrotic anterior capsule, a Sinsky hook or retrobulbar Atkinson needle can be used on viscoelastic to lift the anterior capsular rim from the IOL optic. Once the anterior capsular rim is separated from the IOL optic, viscoelastic should also be injected underneath the IOL to generously inflate the capsular bag. The equator of the capsular bag should also be inflated with viscoelastic to loosen adhesions

of the bag to the IOL haptics.

- Step 4: A Sinsky hook is used to dial the IOL into the AC. The Sinsky hook should be placed in the optic-haptic junction when dialing the lens out of the bag.
- Step 5: Microsurgical forceps are often required to carefully separate fibrosed IOL haptics from the equator of the capsular bag. In cases of marked adhesions of the haptics to the capsular bag, microsurgical scissors can be used amputate the haptics.
- Step 6: Once the IOL optic and/or haptics are brought into the AC, it can be cut into halves or thirds with microsurgical scissors and removed through the main incision. The IOL can also be partially bisected and pacmann-ed through the main wound in cases where the posterior capsule is open to prevent loss of the IOL into the posterior pole (Fig. 42.1).
- Step 7: Care must be taken to exert minimal stress on the capsular bag and zonules throughout the IOL exchange. If the posterior capsule is intact, an IOL can be inserted into the capsular bag after instillation of viscoelastic. If the posterior capsule is compromised, a sulcus IOL can be placed with optic capture in the intact anterior capsulotomy.
- Step 8: Ensure all wounds are securely sealed, and consider placing a 10-0 nylon suture in the main wound.

In cases where the posterior capsule is compromised, perform an anterior vitrectomy if there is any vitreous in the AC. Dilute triesence can be used to stain the vitreous. The vitrector can be placed through a port in the pars plana to decompress the vitreous when starting an IOL exchange in cases where a YAG capsulotomy had previously been performed. Care must be taken to not hydrate the vitreous (the infusion should be kept in the AC) or to have marked intraoperative shallowing of the AC to prevent vitreous migration anteriorly and vitreous traction.

References

1. Goldman D. *Piggyback IOL as an Enhancement Technique*. Cataract & Refractive Surgery Today; 2018. https://crstoday.com/articles/2018-may/piggyback-iol-as-an-enhancement-technique/
2. Rubenstein JB. *Piggyback IOLs for residual refractive error after cataract surgery*. Cataract & Refractive Surgery Today; 2012. https://crstoday.com/articles/2012-aug/piggyback-iols-for-residual-refractive-error-after-cataract-surgery/

CHAPTER 43

Management of Postoperative Photorefractive Keratectomy Complications

Terry M. Semchyshyn, MD

INFECTIOUS KERATITIS

- This condition is uncommon, but clinicians should have a high index of suspicion if an infiltrate is noted, especially in the setting of bandage contact lens use.
- When an infiltrate is noted, remove the bandage contact lens and perform corneal cultures and Gram and/or Giemsa stain.
- Antibiotic prophylaxis should be broad spectrum and should include gram-positive coverage.
- Note that gram-positive infections are more common (which is the opposite of typical infectious keratitis). Consider starting vancomycin (as well as amikacin) every 1 hour, especially in health care workers with heightened potential MRSA exposure likelihood.
- Tailor antimicrobial therapy based on culture results and follow patient closely. Advise patient that final visual acuity may be limited by formation of corneal scar and/or haze from the infectious keratitis.

CORNEAL HAZE DEVELOPMENT

- Consider using MMC at the time of the procedure, especially for higher refractive errors.
- Use a slow postoperative steroid taper with an extended course for higher refractive corrections.
- Consider other refractive procedures (LASIK or phakic intraocular lens) if the patient requires higher corrections with associated greater ablation depths.
- Consider longer-term ultraviolet light protection for high-exposure patients.
- Implement aggressive strategies to help with re-epithelialization if the corneal epithelium closure is delayed >1 week (see below).
- Perform epithelial debridement/laser scrape/PTK with MMC application for more advanced haze.

SLOW EPITHELIALIZATION

- Verify patient is not using topical anesthetic drops.
- Avoid topical NSAID drops.
- Pretreat blepharitis and ocular rosacea (warm compresses with lid hygiene, oral minocycline or doxycycline, manual expression, Lipiflow, intense pulsed light therapy, etc).
- Consider replacement of epithelium at time of procedure (LASEK).
- Use amniotic membrane graft placement for delayed healing (cryopreserved or dehydrated versions).
- Maximize surface moisture.
    - Aggressive preservative-free tears every 1 hour.
    - Serum tears.

- Punctal plugs.
- Nighttime moisture goggle and lid taping if bandage contact lens removed.
- Avoid potential drying sources such as ceiling fans.
- Avoid oral antihistamines and decongestants.

POSTOPERATIVE PAIN

- Set realistic expectations before the procedure; highlight the need for rest 4 to 5 days.
    - Most patients report 8 to 9 out of 10 pain in the first 24 hours that improves with time.
    - Symptoms include foreign body sensation, light sensitivity, tearing, irritation, itching, and burning.
- Use chilled saline rinse along with frozen popsicles at the time of the procedure.
- Advise patients to use chilled preservative-free artificial tears every 15 minutes along with cool compresses.
- Place a bandage contact lens (silicone hydrogel with high dKa) at the time of the procedure.
- Encourage sunglasses use and minimal screen time.
- Administer oral NSAIDs prior to pain every 4 to 6 hours. Can consider a short course of topical NSAIDs (2 to 3 days), but there is concern for delayed re-epithelialization with these medications.
- Consider oral gabapentin, but data are conflicting; can also consider oral sumatriptan.
- Hypertonic saline drops and ointment can be given after bandage contact lens removal.

- Advise biofeedback and relaxation techniques with adjusted workload.

STEROID-INDUCED OCULAR HYPERTENSION

- Monitor IOP after steroid use.
- Consider switching to lower-strength steroid drops (ie, loteprednol) if an extended steroid taper (>8 weeks) is required.
- Add topical antihypertensive drops (ie, brimonidine) if needed.

CORNEAL ECTASIA

- Ectasia is less common with PRK compared with LASIK; risk of ectasia is related to the degree of ablation and PTA and baseline corneal characteristics (ie, thin central corneal pachymetry, posterior corneal abnormalities).
- If ectasia is noted, avoid additional ablative correction; if in doubt, continue to monitor.
- Consider Intacs/Collagen cross-linking if progression is noted.
- Use contact lenses (ie, scleral or RGP lenses) as nonsurgical modalities to improve vision.

DRY EYE

- Dry eye is thought to be less common with PRK than with LASIK.
- Thorough preoperative screening for underlying dry eye syndrome is critical.
- Evaluate for dry eye by measuring contact lens wear time, tear osmolarity, tear break up time, and by testing rose bengal and

lissamine green staining as well as Schirmer scores.

- Utilize topical drops for lubrication.
    - Preservative-free tears.
    - Serum tears.
    - Topical cyclosporine 0.05% or 0.09% BID or lifitegrast BID.
    - Punctal plug placement.
- Ensure adequate blepharitis/ocular rosacea management.

CHAPTER 44

Management of Post Laser In Situ Keratomileusis Complications

Matthew Caldwell, MD

LASIK is an extremely well-tolerated refractive procedure; however, it can rarely be associated with postoperative complications. Detailed below are the common post-LASIK complications that should be recognized and managed by the surgeon.

EPITHELIAL INGROWTH (<3% OF EYES, LESS COMMON WITH FEMTOSECOND LASER FLAP/INVERTED SIDECUT)

- Mild stable cases and isolated islands do not require treatment (this comprises most cases).
- Consider treatment if there is decreased vision, significant astigmatism, advancement of epithelial cells toward visual axis, or flap melt.

Treatment

- Lift the flap, and scrape the underside of the flap and stromal bed with a crescent blade to remove all epithelial cells. A small piece of rigid foam, such as what comes with collagen punctal plugs, is a convenient surface on which to evert the flap and scrape.
- Consider removing the epithelium at the edge of the flap.

- Reposition the flap and place a bandage contact lens until the epithelial defect closes.
- Traction sutures (using 10-0 nylon) or fibrin glue in the gutter can improve flap apposition to the host cornea to prevent recurrence.

INFECTIOUS KERATOPATHY

- It is important to differentiate infectious keratopathy from sterile inflammation (DLK):
- With infections, patients will experience pain, redness, and decreased vision more commonly.
- Symptoms typically start 2 to 3 days after surgery.
- Inflammation is focal but not confined to the flap interface (as seen in DLK).

Treatment

- Scrape the infiltrate for culture, sensitivity, and Gram/Giemsa staining.
- If needed, consider lifting the flap for the culture. Irrigate with broad-spectrum antibiotics.
- Initiate empiric treatment with broad-spectrum topical antibiotics Q1-2H.

Onset	Likely Organism	Appropriate Treatment Options
First 10 d	Bacteria	Vancomycin (10–50 mg/mL)/tobramycin (14 mg/mL) Fourth-generation fluoroquinolone/cefazolin (50 mg/mL)
>10 d	Atypical mycobacteria	Clarithromycin (topical 10 mg/mL, plus oral 500 mg bid) Amikacin (8 mg/mL)
>10 d	Filamentous fungi	Natamycin (50 mg/mL) Voriconazole (topical 10 mg/mL, plus oral 400 mg bid)
>10 d	Yeast	Amphotericin (1.5 mg/mL) Voriconazole (topical 10 mg/mL, plus oral 400 mg bid)

- Empiric treatment with topical antibiotics should be started early. Antifungal treatment is best started after confirmation of the

inciting organism (using smear, culture, confocal microscopy, and/or biopsy) as empiric antifungal treatment use can be a confounder when assessing for clinical response.

- Consider flap amputation if there is melting or an inadequate response to antimicrobial therapy.
- In refractory cases intrastromal, antibiotics can be considered.

DIFFUSE LAMELLAR KERATITIS

- DLK is a nonspecific sterile flap interface inflammation due to toxic or mechanical insults.
- Signs and symptoms typically start in the first 24 hours postoperatively.

Treatment Depends on the Stage of DLK

Stage	Appearance	Treatment
1	Faint peripheral WBCs	Topical prednisolone or difluprednate QID-Q2H
2	Central scattered WBCs	Topical prednisolone or difluprednate Q1-2H
3	Central dense WBCs	Lift flap, irrigate, start topical prednisolone or difluprednate Q1-2H
4	Stromal melt/scarring	Lift flap, irrigate, start topical prednisolone or difluprednate Q1-2H, consider oral prednisone 1 mg/kg

- In advanced stages, removal of WBCs from the interface by irrigation is critical. Topical steroid can be placed directly under the flap.
- If there is any concern for infection, cultures should be taken at the time of flap lift.
- DLK can occur in outbreaks. Evaluate for changes in sterile processing, medications, equipment, supplies, and procedures.

PRESSURE-INDUCED STROMAL

KERATOPATHY

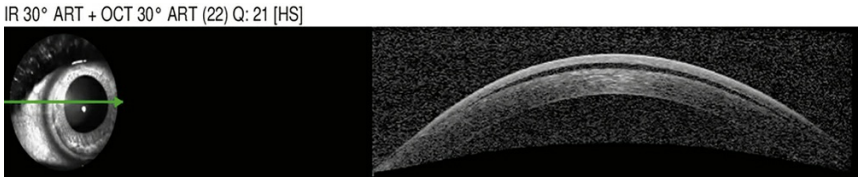

FIGURE 44.1 **Anterior segment OCT image illustrating PISK in a patient with a history of LASIK and an IOP of 45 on presentation. Normalization of IOP resulted in normalization of the corneal architecture with resolution of the fluid cleft. *Green arrow* indicates the location of the image cut. (Courtesy of Nandini Venkateswaran, MD.)**

- PISK (Fig. 44.1) is due to steroid-induced IOP elevation.
- Presentation may mimic DLK but has a later onset (10 to 14 days).
- The classic presentation is a visible fluid cleft in interface. Anterior segment OCT can be used to better visualize the fluid cleft.
- Interface fluid may cause artificially low IOP measurement, so IOP must be measured peripherally and centrally.

Treatment

Lower the IOP using IOP-lowering medications and institute a rapid steroid taper.

STRIAE (FLAP FOLDS OR WRINKLES)

- Striae are most easily visualized with iris retroillumination. Fluorescein staining can also be helpful.
- Macrostriae: parallel lines often with an adjacent asymmetric gutter due to flap slippage.

- Microstriae: fine hair-like lines in random directions like cracked mud, less often visually significant.
- Treatment is much more effective if early rather than delayed.
- All patients should have an immediate postoperative day 0 slit-lamp evaluation with a low threshold to refloat the flap.
- After the first 24 hours, only treat striae believed to be visually significant.

Treatment

Early: In the first 24 hours, simply refloating the flap may be effective

- Under a laser or operating microscope, float the flap with an irrigating cannula.
- Using a cannula and/or moist and dry sponge spears, stroke the flap away from the hinge first and then perpendicularly from the center to the edges.

Late: After 24 hours, reactive epithelial hyperplasia may fix folds into position

- Float the flap as above, but also consider using:
- Hypotonic saline or sterile water to temporarily swell the flap stroma.
- Removal of the central epithelium to release fixed folds.
- 10-0 nylon interrupted or running antitorque traction suture to secure the flap, but this may cause additional astigmatism.

CENTRAL ISLANDS

- Central islands are areas of relative topographic elevation that can impact visual acuity and quality.

- They are less common with newer lasers.

Treatment

- If symptomatic, consider glasses, medical contact lenses, or topography-guided laser ablation.
- Investigate the laser for aberrations in calibration cards, defective optics, and evaluate fellow patients for similar problems.

DECENTERED ABLATION

- Decentered ablations can result in decreased visual acuity and poor quality of vision.

Treatment

- If symptomatic, consider glasses, medical contact lenses, or topography-guided laser ablation.

RESIDUAL REFRACTIVE ERROR (UNDERCORRECTION/OVERCORRECTION/AS

- Most patients reach refractive stability within 1 to 2 weeks, but hyperopes, mixed astigmats, and some myopes may take longer.
- Optimize the ocular surface.
- Verify refractive stability with at least two refractions spaced by at least 2 weeks.
- Compare pre- and postoperative tomographic changes (K values, pachymetry) for consistency with refractive change. There should be approximately 0.8 D of flattening per 1 D treatment of myopia and 16 μm of thinning per 1 D myopia. This rule of thumb only applies to myopic treatments.

- After 1 to 2 months, consider an enhancement (retreatment).

Treatment

- If less than 12 months postoperatively, a flap lift with repeat ablation offers the fastest recovery.
    - Visualization and initial flap entry with a Sinsky hook is often easier at the slit lamp.
    - After replacing the flap, ensure no irregular epithelial remnants are caught in the interface.
- If greater than 12 months postoperatively, lifting the flap can be more difficult, but PRK offers equivalent visual results.
    - Loosen the epithelium with 20% ethanol in a well for 30 to 45 seconds. Mechanical brushes risk flap slippage.
    - Rinse thoroughly and remove the epithelium scraping from the center toward the periphery.
    - Perform surface laser ablation.
    - Be careful not to disrupt the inner flap edges if the treatment depth is greater than the flap stromal thickness.

POOR QUALITY OF VISION/OPTICAL ABERRATIONS (GLARE, HALOS, STARBURSTS)

- These visual phenomena are more common with smaller ablation zones.
- Wavefront aberrometry may demonstrate increased higher-order aberrations, especially spherical aberration.

Treatment

- Optimize the ocular surface.
- Consider miotics (brimonidine, dilute pilocarpine) as needed to reduce the pupil size.
- Manage lower-order aberrations with glasses or consider an enhancement.
- Severe cases may benefit from contact lenses.

REMOTE FLAP TRAUMA (DISLOCATION, TEAR, AVULSION)

- Flap slippage is uncommon after the first 24 hours of surgery but has been reported up to many years later.

Treatment

- Urgent restoration of flap anatomy under a laser or operating microscope is indicated.
- Refloat the flap with an irrigating cannula and reapproximate the edges.
- Place a bandage contact lens until the surface is re-epithelialized.
- If repair is not possible, flap amputation generally provides fairly good vision, although risks of haze and residual refractive error are increased. Advise the patient that he/she may require glasses or contact lenses for optimal vision.

ECTASIA

- This condition is typically discovered years after LASIK surgery and can be unilateral or bilateral.
- Ophthalmologists should have a low threshold to perform

corneal tomography in symptomatic postrefractive surgery patients (ie, decreasing or fluctuating vision).

- Monitor closely with corneal tomography and serial refractions for progression.
- If progression is detected, early CXL is recommended.
- Medical contact lenses may provide best vision.

DRY EYE

- Transient dry eye should be considered universal in the early postoperative period following LASIK and PRK. A thorough preoperative ocular surface examination can better help counsel patients about the future dry eye postoperatively.
- All patients should be encouraged to treat dry eye aggressively for the first several months following surgery with frequent preservative-free artificial tears regardless of whether or not they have symptoms.
- Additional therapies such as punctal plugs, topical cyclosporine or lifitegrast, oral MMP inhibitors, thermal pulsation therapy for the meibomian glands, and a short course of topical steroids can also stabilize the ocular surface. In more severe cases, serum tears can be considered.

CHAPTER 45

Phakic Intraocular Lenses Techniques

Lloyd B. Williams, MD, PhD

Phakic IOLs are IOL implants designed to reduce or eliminate myopia and in some cases astigmatism as well. Although phakic IOLs can be used to treat hyperopia and mixed astigmatism outside of the United States, none of these are currently available in the United States. Phakic IOLs can be used to treat much higher degrees of astigmatism than LASIK and PRK.

There are currently two FDA-approved phakic IOLs in the United States:

- Visian ICL—Staar Surgical Company—approved December 22, 2005.
- Artisan/"Verisyse" Phakic IOL—OPHTEC BV—approved September 10, 2004.

VERISYSE LENS

Approved for:

- Myopia from −5.00 to −20.00 D.
- No more than 2.5 D of cylinder.
- AC depth greater than or equal to 3.2 mm.
- Stable refraction (change less than or equal to 0.5 D for 6 months).

VISIAN ICL

Approved for:

- Age 21 to 45 years.
- Myopia from −3.00 to −20.00 D.
- Nontoric model, no more than 2.5 D of cylinder.
    - Note that the toric model (approved in 2018) now allows greater treatment of cylinder.
- True AC depth greater than or equal to 3.0 mm (measured from posterior cornea to anterior surface of crystalline lens).
- No more than a 0.5-D change in refraction for 1 year.

VISIAN TORIC ICL

- Age 21 to 45 years.
- No cataract or prior cataract surgery.
- Myopia from −3.00 to −20.00 D.
- Cylinder of 1.00 to 4.00 D.
- True AC depth greater than or equal to 3.0 mm (measured from posterior cornea to anterior surface of crystalline lens).
- No more than a 0.5 D change in refraction for 1 year.

CONTRAINDICATIONS TO VISIAN ICL

- Shallow AC—depth less than 3.0 mm.
- Narrow angle—less than grade III on gonioscopic examination.

- Pregnant or nursing.
- Younger than 21 years.
- Endothelial cell count minimum based on age and AC depth. See the FDA packaging requirements. For *ACD > 3.0, †ACD > 3.2, and ‡ACD > 3.5
    - Age 21 to 25 years: 3875* 3800† 3250.‡
    - Age 26 to 30 years: 3425* 3375† 2900.‡
    - Age 31 to 35 years: 3025* 2975† 2625.‡
    - Age 36 to 40 years: 2675* 2675† 2350.‡
    - Age 41 to 45 years: 2350* 2325† 2100.‡
    - Age > 45 years: 2075* 2050† 1900.‡

Although there are variations in surgical procedure across surgeons and locations, my preferred technique for inserting the ICL is as follows:

- I generally sit temporally for ICL placement, but one could perform the procedure sitting superiorly as well. In patients with small amounts of astigmatism that I want to correct, sometimes I sit so that the main wound acts to reduce astigmatism and place that wound on the steep axis of astigmatism, often 90 degrees in young patients.
- Side port incision: I angle the side port incision toward the location of the distal tabs of the ICL so that they can be reached and positioned without causing any distortion of the cornea. Many make a second side port for placing the distal haptic most distal to the first sideport.
- Inject a small amount of OcuCoat OVD into the AC through the sideport. Unlike phacoemulsification where the goal is to completely fill the AC with viscoelastic and flatten the lens, in the ICL procedure, the goal is to place just enough to prevent the

chamber from shallowing and prevent damage to the crystalline lens when making the main incision. Other OVDs may be used, but OcuCoat is suggested by the manufacturer for ease of removal from the AC. If choosing another viscoelastic, make sure to choose a cohesive viscoelastic that can be easily removed from the AC with irrigation alone.

- I fixate the eye with the OcuCoat cannula and make a 3.0-mm main incision. Other fixation techniques would be possible, but use caution to not create pressure on the eye that will shallow the AC or that would cause subconjuntival hemorrhage.
- After loading the ICL into the injector, inject it into the AC.
- Using the ICL manipulator through the main wound, tuck the proximal haptics into the sulcus. It is absolutely essential to not touch the crystalline lens during this maneuver.
- Then using the ICL manipulator through the sideport, tuck the distal haptics into the sulcus. Again, do not touch the crystalline lens. If using a toric, dial the lens to the appropriate position.
- Using BSS on a 27G cannula, wash viscoelastic from the AC.
- Add miochol to achieve pupillary miosis.
- At this stage, if a laser PI has been performed, then seal the wounds with BSS and the case is complete.
- I usually make a PI with a vitrector and so I would add viscoelastic and then using a cut rate of 1 cut while pinching the infusion tubing, make a single superior PI with a vitrector. Then remove viscoelastic again using BSS irrigation and then seal the wounds.
- I usually perform same-day bilateral surgery with a complete turnover of the operation room and new lot numbers and supplies for all parts of the operation. This depends on the practice patterns where you operate.

- After surgery is complete, I have the patient wait at the surgery center for at least an hour to allow for IOP check and slit lamp examination before discharge. I see all patients personally at postoperative day 1.
- On postoperative day 1, in addition to normal postoperative examination, you will need to examine carefully for the ICL vault (ideal is about 500 μm or about one central corneal thickness) and presence of wound leakage, confirm patency of peripheral iridectomy, and rule out narrow angles or increased IOP. Most patients should be at or near 20/20 by postoperative day 1. Corneal edema should not be present and if present indicates a need to evaluate the operative technique to reduce corneal endothelial stress.

Table 45.1 is the nomogram I use for sizing, specifically the alternate optimized. Sizing has also been done with anterior segment ultrasound to provide direct measurement of the sulcus and swept source measurements. I have used anterior segment ultrasound and think that it works very well; however, it is very dependent on the quality and skill of the ultrasonographer.

TABLE 45.1 Table of FDA recommended visian ICL overall disaster by WTW and ACD measurements

WTW (mm)	ACD (mm)	Recommended ICL length
<10.5	All	Not recommended
10.5–10.6	≤3.5	Not recommended
10.5–10.6	>3.5	12.1
10.7–11.0	All	12.1
11.1	≤3.5	12.1
11.1	>3.5	12.6
11.2–11.4	All	12.6
11.5–11.6	≤3.5	12.6
11.5–11.6	>3.5	13.2
11.7–12.1	All	13.2
12.2	≤3.5	13.2
12.2	>3.5	13.7
12.3–12.9	All	13.7
≥13	All	Not recommended
Alternate optimize		
10.7–11.4 WTW		12.1 MICL
11.5–12.1 WTW		12.6 MICL

12.2–12.7 WTW		13.2 MICL
12.8–13.1 WTW		13.7 MICL

Results of the ICL can be quite good. In my experience most patients are at or near 20/20 or better and are happy with outcome despite starting with very high myopia. In 6 years of implanting lenses, with a total of about 300 ICLs, I have had four eyes develop cataract; however, one of those patients had peripheral cataract even before ICL implantation. A study of 10-year follow-up of ICL showed that, of 110 eyes, no eyes in a patient under 30 years old developed cataract. In addition, the postoperative mean refractive spherical equivalent was −0.35 D and the uncorrected distance visual acuity was logMAR 0.04 or very nearly 20/20. The preoperative average spherical equivalent was 12.01 D.[1] These data match well with my experience using the ICL.

ARTISAN VERISYSE IRIS CLAW LENS

In the literature, the artisan iris claw lens seems to be more commonly used to treat aphakia than as a refractive surgery tool in phakic patients. It has been implanted in a retropupillary and AC position. One major complication of the lens is postoperative astigmatism due to the large wound (5.5-mm incision) required for implantation. This can be mitigated by using a scleral tunnel for insertion rather than a corneal wound. With the many possible options for treating aphakia, there has been little evidence for clear superiority of one method over another. For surgeons experienced with the method, iris claw lens is a good method comparable with other techniques in treating aphakia.[2] Surgeons should choose methods based on surgical expertise, available materials, and patient individual characteristics. In patients with low endothelial cell counts, AC lenses and anterior placement of the iris claw lens may lead to increased risk of endothelial cell loss.[2] In Europe a foldable version of the Artisan lens is available, called the Artiflex lens. It is not available in the United States.

In the FDA trials of the Verisyse lens, 84% achieved vision 20/40 or

better, similar to the trials of the ICL. Possible reasons for the somewhat low visual acuity results would be that most of these patients started with very severe myopia (up to −20 D) and neither the ICL nor the Verisyse was available in astigmatism correcting models. The ICL is now available in a toric lens. It is also possible to use LASIK to correct residual astigmatism after phakic IOL implantation.

It is approved for −5.0 to −20.0 D with less than 2.5 D of astigmatism. Patients must have an AC depth of 3.0 mm or more. Caution in, or contraindication of, implantation should be used in the following:

- Congenital cataract.
- Uveitis.
- Ocular disease.
- Prior retinal detachment.
- Amblyopia or poor vision in one eye.
- Uncontrolled or severe glaucoma.
- Endothelial dystrophy or low endothelial cell counts.
- Diabetic retinopathy.

The size and configuration of the lens is shown below and it comes in a 5-mm and a 6-mm optic size (Fig. 45.1). An implantation video can be found on vimeo.com, although a YouTube search would also likely provide many videos of implantation of ICL and Verisyse.

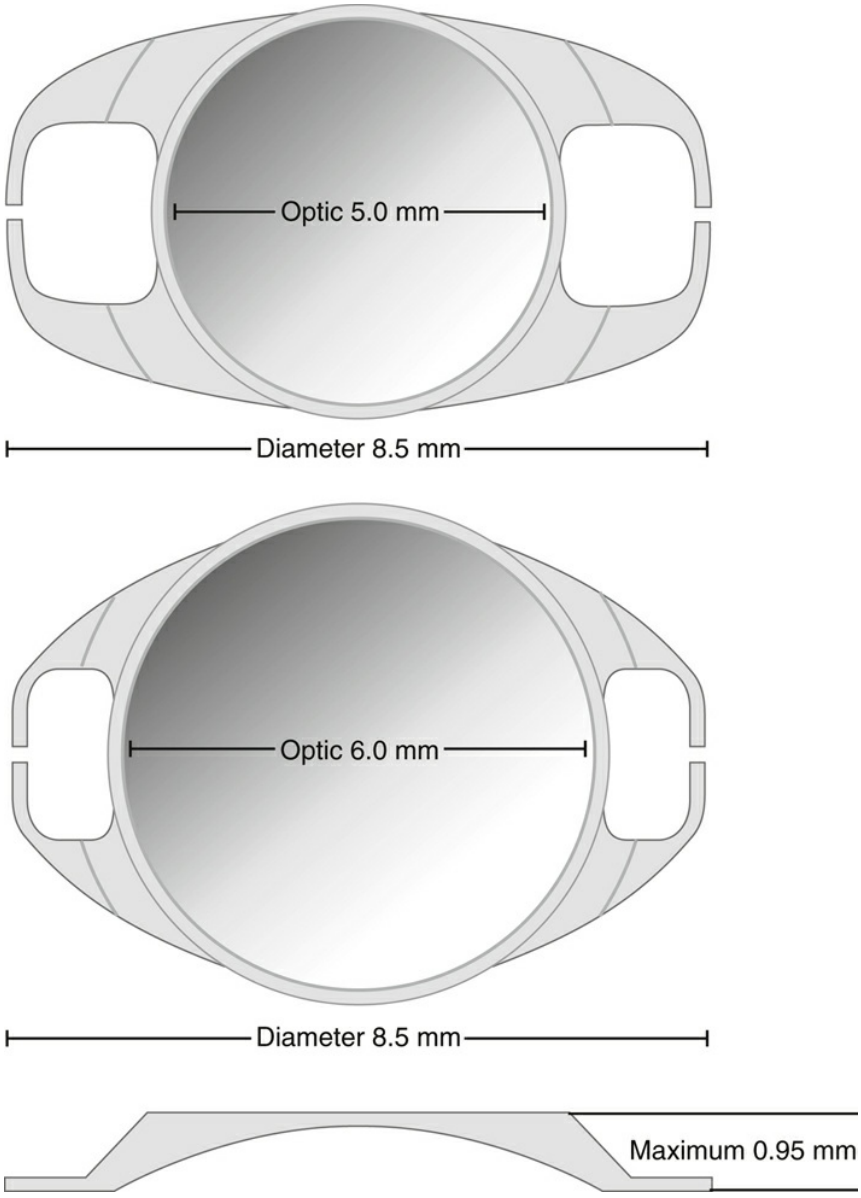

FIGURE 45.1 Schematic diagram showing the different sizes and configurations of the Verisyse phakic intraocular lenses. The Verisyse phakic intraocular lens comes in both a 5-mm and a 6-mm optic size.

References

1. Choi JH, Lim DH, Nam SW, Yang CM, Chung ES, Chung TY. Ten-year clinical outcomes after implantation of a posterior chamber phakic intraocular lens for myopia. *J Cataract Refract Surg*. 2019;45(11):1555-1561.
2. Toro DT, Longo A, Avitabile T, et al. Five-year follow-up of secondary iris-claw

intraocular lens implantation for the treatment of aphakia: anterior chamber versus retropupillary implantation. *PLoS One*. 2019;14(4):e0214140.

3. https://vimeo.com/142181115

Section 9

Management of Iris Abnormalities

CHAPTER 46

Iris Defects, Iridodialysis, and Artificial Iris Implantation Techniques

Gordon T. Brown, MBChB, MPH, Lloyd B. Williams, MD, PhD, Balamurali Ambati, MD, PhD, MBA

IRIS DEFECTS

Preoperative Considerations

Obtain a thorough history from the patient to understand the impact of the iris defect on both their vision and overall quality of life (eg, glare, photophobia, cosmetic appearance).

Examination

- What is the nature of the iris defect?
    - Etiology: coloboma, traumatic, iatrogenic, atrophic, iridodialysis, aniridia?
    - How many clock hours does the iris defect span?
    - What is the degree of iris stromal loss? Is there sufficient residual tissue for repair?
    - Is surgical repair likely to offer the best outcome versus less invasive approaches?
    - If so, is the defect suitable for closure with a suture-only technique, or is a prosthesis required?

- Is a cataract present?
    - If pseudophakic, is the intraocular lens (IOL) in a satisfactory position?
    - Does the cataract need to be removed?
- How is the health of the rest of the eye?
    - Are there coexisting conditions that may complicate surgery or recovery?
- Perform gonioscopy to visualize angle and aid exposure of any peripheral iris defects.

Iris Repair Surgical Procedure

Typically, defects less than one quadrant (three clock hours) can be sutured, whereas a defect spanning more than one quadrant is more likely to require a prosthesis. In defects extending to the pupil, aim for a pupil size that allows good visualization of the fundus but is small enough to reduce symptoms while achieving a satisfactory cosmetic outcome. A surgical video of how to repair the following iris defect is included. Our preferred method of repairing iris defects is through using a modified Siepser knot technique with 9-0 Prolene on a CTC needle (Fig. 46.1).

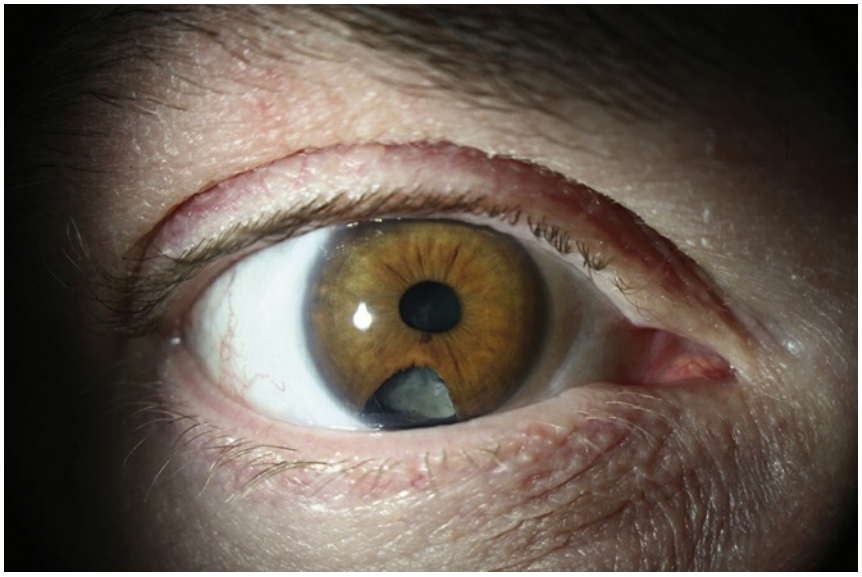

FIGURE 46.1 **Slit lamp photograph showing an inferior sectoral iris defect.**

Suture Choice for Iris Sutures

We recommend 9-0 Prolene. The 9-0 or 10-0 Prolene sutures have been used on various needles. Both can be used, but Dr Edward Buckley of Duke showed in a retrospective analysis that 10-0 Prolene sutures can degrade leading to suture failure and subluxation of IOLs attached via transscleral suture techniques.[1] Dr Mamalis also showed degradation and breakage of 10-0 Prolene and suggested that 9-0 Prolene is likely less prone to breakage owing to having a 2.25 times greater cross-sectional area than 10-0 Prolene.[2]

Needle Choice for Iris Sutures

We prefer CTC-6L needles when available. You will need a long needle, preferably curved. Two common Ethicon needles in this configuration are the CIF-4 needle and the CTC-6L needle. The CIF-4 needle is a tapercut needle and comes on both 10-0 and 9-0 Prolene. The CTC-6L needle is a spatula cutting needle. We find it much easier to pass the CTC-6L needle through cornea if needed, but depending on technique and whether using a cannula for docking, either needle can be used. In a pinch, a straight needle such as an STC-6 can be

bent slightly by hand or with a needle driver.

Suture Pass Technique

Preference varies based on individual case. Sutures are generally placed by passing through cornea, through iris, and then back through cornea, but there are multiple ways of accomplishing this. One way is directly passing the needle through the cornea on one or both passes of the needle. This has the advantage of having a very small corneal incision but can make the suture pass difficult because of decreased visualization if the needle is causing striae in the cornea while advancing. A second technique is to use paracentesis (1 mm) corneal incisions to pass the distal, proximal, or both passes of the needle. In addition, a larger wound such as the main wound of a cataract incision can be used. This technique requires care to not capture the cornea with the needle but allows greater latitude in manipulating the needle without causing corneal striae. A 25G or 27G cannula can be passed into the distal incision allowing the needle tip to be docked into the cannula and then withdrawn with minimal risk to adjacent structures. This technique of docking can also assist in circumstances where the needle pass involves difficult angles.

Suture Tying Technique

Our preference is the modified Siepser knot as described by Ike Ahmed, except in cases of poor visibility. There are two main techniques for tying an iris suture, the McCannel and the Siepser knots. Osher and Cionni described a very good technique for the Siepser knot,[3] and we use a modification of that technique shown by Ike Ahmed.[4] The advantage of the Siepser knot over the McCannel knot is that it generally allows for a tighter knot, which can be important especially when suturing an IOL to the iris. The McCannel knot on the other hand can be faster and easier to tie and is probably simpler in cases where visibility is poor as the Siepser knot requires multiple passes into the eye to retrieve suture strands for tying. McCannel sutures also requires less specialized instruments as there are no intraocular scissors required (Fig. 46.2; Video 46.1).

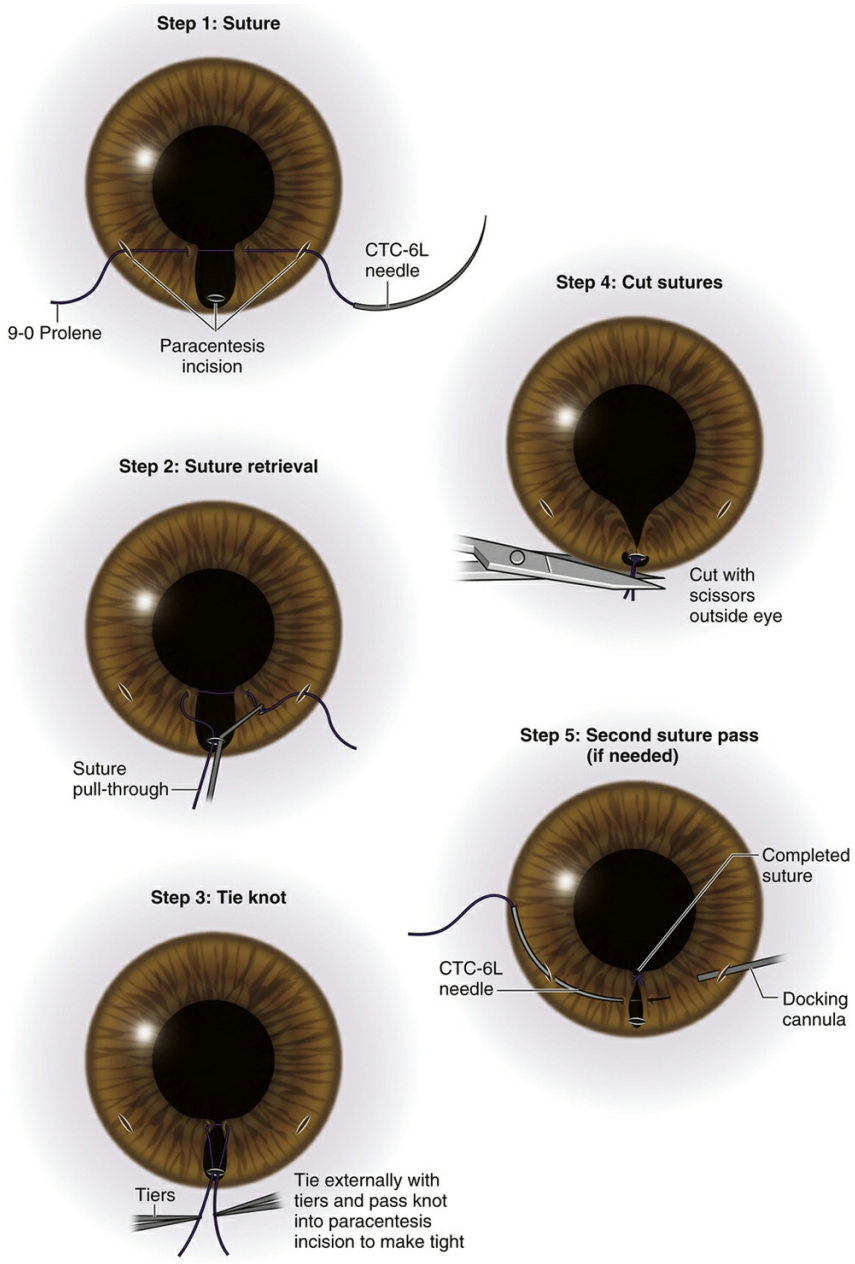

FIGURE 46.2 Schematic drawing outlines the steps of the McCannel suture technique.

It is also worth noting that Morcher GMBH out of Germany makes several different aniridia and partial aniridia segments. None of these are FDA approved or available in the United States without a humanitarian device exemption but could be useful in international settings.

Postoperative Considerations

There are a few important postoperative complications to be aware of following surgery for iris repair:

- Suture cheese wiring
- Iris hemorrhage
- Iris incarceration
- Glaucoma

Sutures should be tied firmly enough to ensure lasting closure of the defect, but sutures tied excessively tight or at unequal levels of tension may lead to suture cheese-wiring and erosion of iris tissue, with subsequent wound instability, ectopic pupil, or recurrence of the iris defect. Hemorrhage is a risk for any intraocular surgery and may result in a postoperative hyphema as a consequence of injury to iris vasculature. Iris tissue may become incarcerated in the corneal wound or under the sclera, which requires delicate surgical management to reposition. Obstruction of aqueous outflow may lead to postoperative glaucoma secondary to uveitis, corneal edema, hyphema, or scar tissue from the original traumatic defect.

IRIDODIALYSIS REPAIR

Iridodialysis is a defect characterized by localized iris separation at the iris root from the ciliary body, which most frequently occurs as a result of blunt trauma.

Preoperative Considerations

Some additional preoperative considerations for traumatic iridodialysis[5] :

- Is vitreous prolapse present? If so, plan for anterior vitrectomy.
- Is there associated zonular dialysis or insufficiency?

An alternative surgical approach to the suture repair methods described above is the Hoffman pocket technique, which can be used for management of iridodialysis in addition to other iris defects. It involves utilizing one or more scleral pockets initiated from a limbal groove, which removes the requirement for a conjunctival peritomy, scleral cauterization, and burying scleral suture knots, which could potentially reduce the risk of erosion and endophthalmitis. An iridodialysis of less than one quadrant can be repaired with a single pocket and one double-armed suture.[6]

Surgical Procedure: Hoffman Scleral Pocket Technique

The video demonstrates utilization of the Hoffman pocket technique in the following patient who experienced traumatic globe rupture accompanied by partial iris loss (Fig. 46.3; Video 46.2).

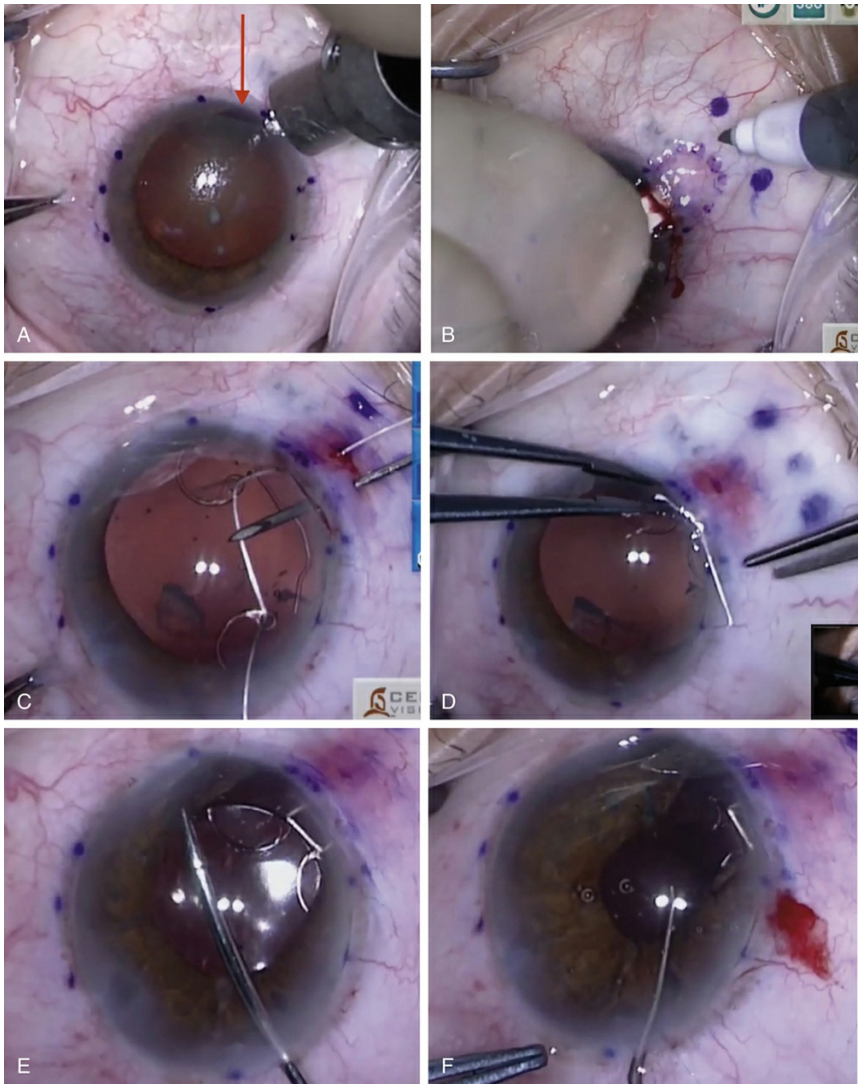

FIGURE 46.3 **Surgical steps of the Hoffman scleral pocket technique for a patient who experienced traumatic globe rupture accompanied by partial iris loss (red arrow, A). A Hoffmann pocket is fashioned 2.5 mm posterior to the limbus as outlined by the violet dots (B). A double-armed 8-0 Goretex suture is threaded onto the eyelets of a capsular tension segment. After the capsular tension segment is inserted into the capsular bag with the Goretex suture in place, each end of the Goretex suture is externalized through the Hoffman pocket (C). The needles are cut off, and the sutures are pulled through the Hoffman pocket, tied down, and buried into the Hoffman pocket (D). This is achieved by docking each needle of the Goretex suture through a 25G needle that is pierced through the sclera 2.5 mm posterior to the limbus (E). The iris defect is then sutured closed using 10-0 Prolene sutures using a sliding Siepser knot (F).**

Technique

For an iridodialysis, make a 300- to 400-μm deep grooved incision at the clear corneal limbus overlying the middle third of the dialysis. This is then dissected posteriorly in the plane of the sclera for approximately 2 mm to create a scleral pocket. It is generally best to create the scleral pocket on the axis of positive astigmatism. A paracentesis is then made 3 to 4 clock hours from the site of fixation, and viscoelastic is injected to stabilize the anterior chamber.

Hoffman originally described this technique for iridodialysis repair using a 10-0 Prolene suture, but in light of the concerns highlighted above regarding suture breakage, we prefer a more robust 8-0 Goretex suture. Pass the selected suture through both the paracentesis and the edge of the dialyzed iris root, approximately one-third the lateral distance from the attached edge of the iris root. Then, pass it through the full thickness of the globe, exiting posterior to the limbus into the dissected scleral pocket. The second arm of the double-armed suture is then passed through the same paracentesis, through the iris root edge, 3 mm adjacent to the first pass, and out through the sclera 2 to 3 mm adjacent to the first pass, and 2 mm posterior to the limbus.

Use a Sinskey hook to retrieve the suture ends through the external opening of the scleral pocket. Once both ends have been externalized, the suture is tightened and tied, allowing the knot to slide under the protective roof of the scleral pocket. The suture ends are then trimmed and no additional wound closure of the pockets is required.[6, 7]

ARTIFICIAL IRIS IMPLANTATION

Surgical Procedure: Complete Iris Replacement With Iris Prosthesis (**Fig. 46.4**)

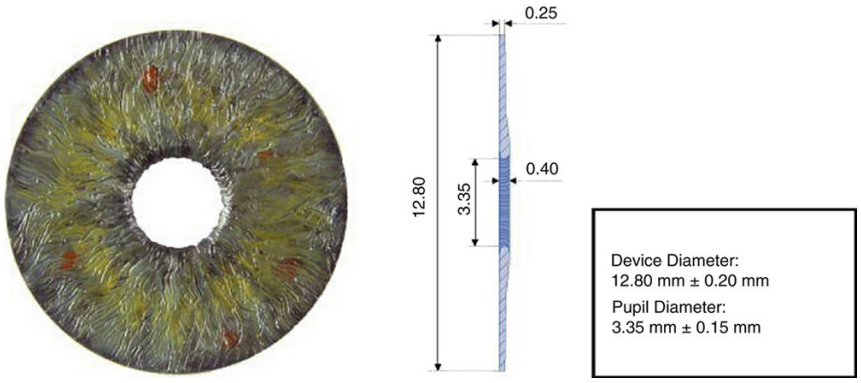

FIGURE 46.4 **Image of the Customflex Artificial Iris recently approved for repair of partial to complete iris defects by the FDA.**

The CustomFlex artificial iris is the only FDA-approved artificial iris in the United States. It was approved by the FDA on May 30, 2018. It is made of medical-grade silicone and is foldable. The implant comes in two models: fiber free and with fiber backing. The fiber model contains a polyester meshwork designed to give adequate strength to allow the surgeon to suture the CustomFlex iris to parts of the eye such as sclera and to suture objects such as an IOL to the artificial iris. Each implant is custom hand painted per each individual patient. It is designed to treat congenital aniridia, surgical aniridia, traumatic aniridia, and other forms of profound and generalized iris transparency such as albinism. The implant is intended to treat severe photophobia from increased light transmission and provide an improved cosmetic appearance of the eye.

It can be implanted through a small incision using an Abbott Medical Optics Silver Series IOL injector and the PSCST cartridge.

It can be placed in the capsular bag or sulcus or can be sutured to the scleral wall. It is not designed to be used in phakic patients.

Alternatives to a custom iris prosthesis include

- Colored contact lens
- Iris repair if enough iris remains
- Corneal tattooing

- Tinted glasses

The original FDA study implanted the artificial iris in patients with the following disorders[8]:

- Congenital aniridia
- Post-epithelial ingrowth
- Post-melanoma excision
- Postsurgical iris defects/aniridia
- Posttraumatic iris defects/aniridia
- Iridocorneal endothelial syndrome

Some highlights of the outcomes of the FDA study include:

- 93.8% satisfaction with the cosmetic appearance.
- 67.2% of eyes had improved uncorrected visual acuity.
- 7.9% had a decrease in visual acuity of greater than two lines of best corrected visual acuity, but in none of these cases was the decrease thought to be directly related to the device.
- The percentage of patients experiencing severe glare, photophobia, difficulty night driving was reduced after patients received the device as compared with their preoperative state.

Postoperative Considerations

From a safety standpoint, increases in IOP postsurgically (8% of eyes had IOP > 30 mm Hg after surgery), corneal edema (4% at 1 month), and vitreous hemorrhage and hyphema (0.9% combined) were the most common complications. Device decentration occurred at a rate of 1.8% and device dislocation at a rate of 2.5%.

Video 46.2: Hoffman pocket technique.

References

1. Buckley E. Hanging by a thread: the long-term efficacy and safety of transscleral sutured intraocular lenses in children (an American Ophthalmological Society thesis). *Trans Am Ophthalmol Soc*. 2007;105:294-311.
2. Price MO, Price FW, Werner L, Berlie C, Mamalis N. Late dislocation of scleral-sutured posterior chamber intraocular lenses. *J Cataract Refract Surg*. 2005;31(7):1320-1326.
3. Osher RH, Snyder ME, Cionni RJ. Modification of the Siepser slip-knot technique. *J Cataract Refract Surg*. 2005;31(6):1098-1100.
4. Ahmed I. *Modified Siepser Sliding Knot for Iris Suturing*. 2013. Accessed July 21, 2020. www.youtube.com/watch?v=4QipgGl1HTk
5. Perez M. *Don't Fear the Defect*. The Ophthalmologist; 2016. Accessed July 20, 2020. https://theophthalmologist.com/subspecialties/dont-fear-the-defect
6. Hoffman RS, Fine IH, Packer M. Scleral fixation without conjunctival dissection. *J Cataract Refract Surg*. 2006;32:1907-1912.
7. Hoffman RS. *Iridodialysis Repair Through a Scleral Pocket*. Eyeworld - News and Opinion; 2011. Accessed July 20, 2020. https://www.eyeworld.org/article-iridodialysis-repair-through-a-scleral-pocket
8. U.S. Food and Drug Administration. *PMA P170039: FDA Summary of Safety and Effectiveness Data*. 2018. Accessed July 22, 2020. https://www.accessdata.fda.gov/cdrh_docs/pdf17/P170039b.pdf

CHAPTER 47

Iris Cyst Excision Techniques

Amber Hoang, MD

PREOPERATIVE CONSIDERATIONS

The evaluation of an iris cyst includes a thorough history and complete examination including gonioscopy and ancillary imaging, which allows for proper identification of the location and etiology of the cyst.

History

- Pertinent history of present illness and previous ocular history.
- Obtain travel history. Parasites acquired in endemic areas may travel to the eye and cause cysts. Excision of the cyst may release the parasite (*echinococcosis or cysticercosis*) resulting in severe inflammation.
- Review medication list. Prostaglandin analogues can alter cyst size. Miotics such as echothiophate can cause pigment epithelial cysts.
- Elicit any recent surgery or trauma history. Epithelial downgrowth cysts can develop near surgical or traumatic wounds. Review previous operative notes.

Slit-Lamp Examination

Gonioscopy is crucial to the diagnosis as most iris cysts are located peripherally. Rarely, they may detach from the iris into the vitreous.

Types of cysts:

- *Iris pigment epithelium cysts*: Usually brown/black and velvety in appearance and do not transilluminate. These cysts are typically located underneath the iris and can push the iris forward. They can be single, multifocal, or bilateral. They rarely cause complications and can be observed.
- *Stromal cysts*: Usually translucent or white and transilluminate. They appear like a nodule with varying degrees of pigmentation.
- *Epithelial downgrowth cysts*: Usually contain proteinaceous fluid. They may occur years after the initial trauma or surgery. Examine all wounds.

Transillumination will create a shadow with a solid tumor but never with a cyst.

Imaging

- AS-OCT—can visualize more superficial cysts and has the advantage of allowing for noncontact imaging but may not be able to penetrate darkly pigmented or large, deeper cysts.
- High-resolution UBM—can visualize deeper cysts, especially those near the ciliary body.

An iris neoplasm should be considered in a lesion with the following characteristics: solid component, intraocular hypertension, prominent "feeder" episcleral blood vessels, darkening of sclera, or iris heterochromia. **Consider obtaining an MRI, or perform a biopsy to rule out malignancy.**

SURGICAL PROCEDURE

Most asymptomatic iris cysts can be observed closely. Considerations for surgical intervention include:

- Secondary glaucoma if the cyst is invading angle structures or causing pupillary block.
- Amblyopia if covering the pupillary axis in children.
- Uveitis or inflammation due to leakage of cyst.
- Increase in size at a rapid rate.
- Corneal decompensation.

Iris cysts secondary to echothiophate usually resolve after stopping the medication or by using phenylephrine 2.5%.

Techniques

A combination of these techniques is often utilized depending on surgeon preference and experience.

Drainage and Injection

Inject viscoelastic into the AC to dissect the cyst from other structures of the eye such as the cornea or crystalline lens. Use a 27G needle to aspirate the cyst contents and send for microbiologic and histopathologic analysis. Then, alcohol or MMC can be injected into the cyst before deflating it to eliminate any residual epithelial cells. Injections of 5-FU can also be used to treat epithelial downgrowth cysts.

Cryotherapy

For small and peripheral cysts, cryotherapy can be used to treat the entire cyst. In cases of epithelial downgrowth cysts, cryotherapy can be used to destroy any remaining epithelial cells near the limbus.

Photocoagulation

- Nd:YAG (laser cystostomy) can be used to puncture the cyst;

however, the release of cystic contents can result in significant AC inflammation.

- Argon laser can be used to photocoagulate the iris to shrink the cyst or prevent recurrence. A 20G diode endolaser photocoagulation can also be applied directly to the cyst with the following laser parameters: power 200 mW, duration 100 milliseconds.

Excision

For iris pigment epithelial and stromal cysts, excision using Vannus scissors can be adequate. For epithelial downgrowth cysts, all abnormal epithelial tissue must be resected carefully from the AC to prevent recurrence. Resection with a 1-mm margin of iris tissue can be considered to ensure total removal of epithelium.

En Bloc Resection

In this surgical approach, all areas the cyst is adherent to are removed in one piece to avoid rupturing the cyst. Iris defects can be sutured closed. If the iris defect cannot be closed, a cosmetic contact lens or artificial iris may be necessary to control symptoms of photophobia postoperatively. A partial lamellar iridocorneal trabeculectomy should only be performed in refractory, severe cases as it may cause permanent damage to the AC structures and often a corneoscleral transplant may be necessary.

Steps of Iridocyclectomy

- Perform a peritomy 3 clock hours on each side of the iris cyst.
- Create a 180-degree wide scleral tunnel to allow access to the cyst.
- Use viscoelastic to dissect the cyst from the cornea (if adherent).
- Retract the cornea to fully identify the cyst.

- Achieve hemostasis using intraocular diathermy directed at borders of the cyst or iris.
- Remove the cyst and perform a sector iridocyclectomy.
- Close the scleral tunnel using 9-0 nylon sutures.
- If there is zonular loss associated with the cyst removal, consider lensectomy and anterior vitrectomy via anterior approach if possible.
- Consider leaving patient aphakic until stabilization of the eye.

POSTOPERATIVE CONSIDERATIONS

- Patients should be placed on a combination of topical steroids and antibiotics postoperatively. Duration of treatment will vary with the procedure done and postoperative course.
- Patients should be monitored closely for inflammation and recurrence of cysts or any remaining epithelial tissue.
- Complications can include corneal edema, inflammation, and formation of cataract or secondary glaucoma.
- Recurrence after excision of primary iris cysts is more common in stromal cysts than iris pigment epithelium cysts. Prognosis for secondary iris cysts due to epithelial downgrowth is guarded owing to the large amount of anterior tissue removed and high rate of recurrence.

Bibliography

1. Shields JA, Shields CL. Cysts of the Iris pigment epithelium. What is new and interesting? The 2016 Jose Rizal International Medal Lecture. *Asia Pac J Ophthalmol (Phila)*. 2017;6(1):64-69. doi:10.22608/APO.201613
2. Primary Iris Cysts. *AAO Basic and Clinical Science Course Section 6*: Pediatric Ophthalmology and Strabismus. Elsevier; 2013.

3. Sihota R, Tiwari HK, Azad RV, Khosla PK. Photocoagulation of large iris cysts. *Ann Ophthalmol*. 1988;20:470-472.
4. Lockington D, Altaie R, Moore S, McGhee CN. Successful management of secondary iris cysts with viscoelastic-assisted endophotocoagulation. *JAMA Ophthalmol*. 2014;132(3):354-356. doi:10.1001/jamaophthalmol.2014.12
5. Dorecka M, Miniewicz-Kurkowska J, Michalska-Małecka K, Świątek B, Romaniuk W. Needle aspiration with surgical excision of an epithelial posttraumatic iris cyst—a case report. *Med Sci Monit*. 2011;17(5):CS60-CS62. doi:10.12659/msm.881754
6. Venkateswaran N, Ching SS, Fischer W, Lee F, Yeaney G, Hindman HB. The diagnostic and therapeutic challenges of posttraumatic Iris implantation cysts: illustrative case presentations and a review of the literature. *Case Rep Ophthalmol Med*. 2015;2015:375947. doi:10.1155/2015/375947

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