Fitting Keratoconus and Other Complicated Corneas

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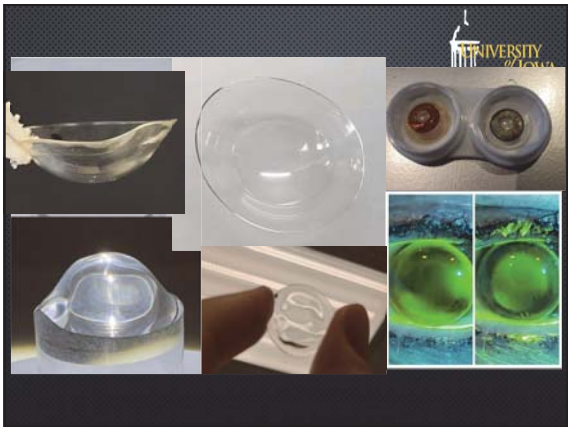
Disclosures

- Owner:
  - EyePrint Prosthetics
- Grant Support:
  - MDM Optical

Contact Lens Indications

Optical Correction	Ocular Protection	Ocular Comfort
Keratoconus	Neurotrophic Keratitis	Pinguecula
Pellucid marginal degeneration	Ocular Surface Disease (Dry Eye)	Pterygium
Post LASIK ectasia	Graft vs Host Disease	Scarring
Post Radial Keratometry	Steven Johnson Syndrome	Scleral Patch Graft
Corneal Transplants	Ocular Cicatricial Pemphigoid	Adverse Environment
High Myopia / Hyperopia	Chemical Burns	Rosacea
Aphakia	Stem Cell Failure	Limbal stem cell disease



Options

- Gas Permeable Lenses
  - Corneal Lenses
  - Scleral Lenses
- Soft Lenses
- Hybrid lenses

General Fitting Principles

- Avoid mechanical pressure on the cornea
- Distribute bearing areas
- Avoid Limbal irritation and inflammation
- Avoid endothelial cell stress by removing oxygen barrier to endothelium

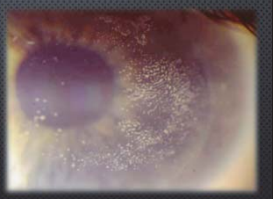
What Determines The "Right" Lens Design?

- **Vision?**
- **Oxygen?**
- **Disease State?**
- **Ocular Geometry?**
- **Physiological Response?**

Vision Issues

Mid-Day Fogging

- Sick eyes make mucus
  - Covers as much of the globe as possible if severe dryness
- Lens removal drives a form of mucous fishing syndrome
  - Exchange the posterior fluid by squirting out the lens
- Remind patient drying on the surface of the lens is better than drying of the corneal surface
  - Squeegee the lens from surface with a solution moistened cotton q-tip or plunger



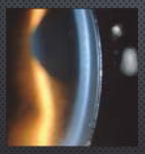
Front Surface Dryness and Haze

- Poor tear film/ MGD
- Hydra-PEG
- Squeegee with solution-moistened cotton q-tip or vented plunger
- Put a Daily disposable on front surface and either
  - Refract through it and adjust the lens power
  - Leave it on the lens for half hour and remove- surface will wet.

Hydra-PEG

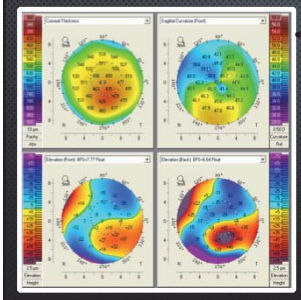
by Tangible Sciences

Posterior Lens Fogging

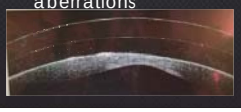


- The drier/ sicker the eye, the more debris
  - Inflammatory cells, cellular debris, mucin
- Use buffered saline
- Apply FL to anterior surface of lens to see if leaking
  - Adjust haptics
  - Decrease Vault
  - Fit a corneal GP
- Piggy back

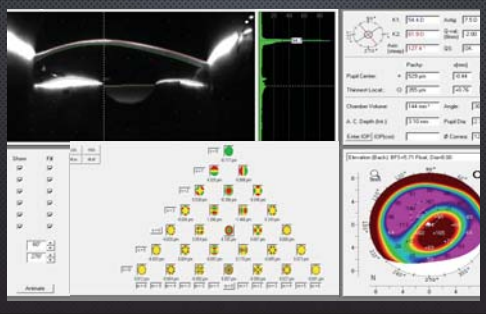
Watch the Posterior Elevation!

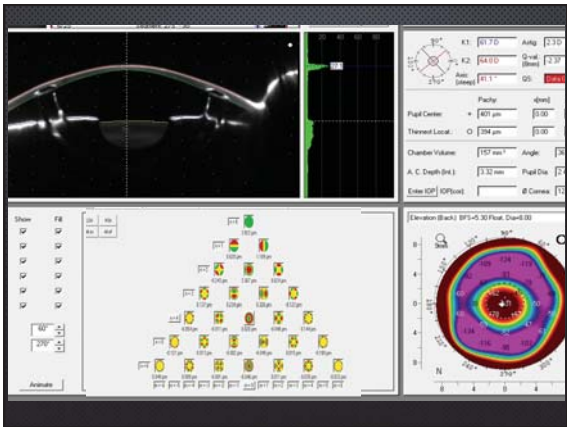


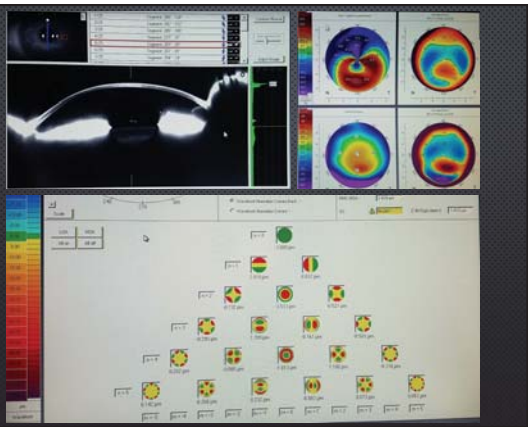
- If > 100 microns posterior backbowing, vision will be compromised
  - Reduced visual acuity
  - Increased aberrations



HOA and Scatter are Different Things!



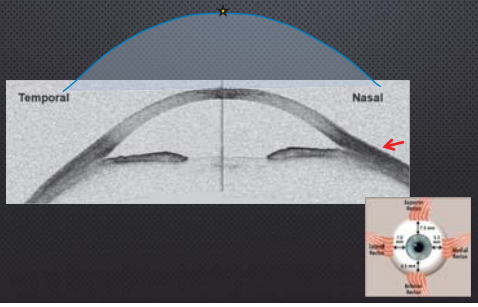




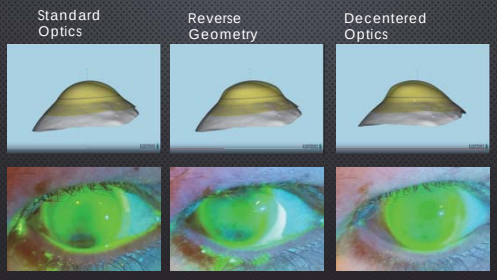
Small Central Cones

- TRADITIONAL GP CONE DESIGNS WORK WELL

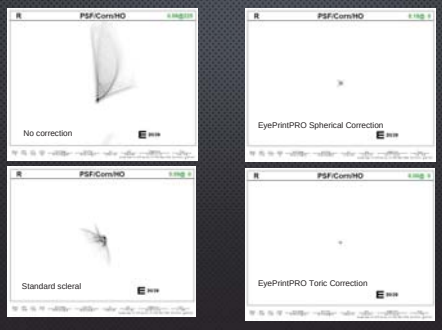
Conventional Scleral Lenses



Manipulating the Optic Zone



Centered Optics



Optics

Multifocal

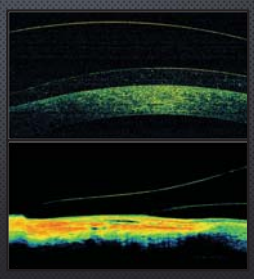
- Applied to the back or surface
  - Multi-zone
  - Aspheric
- Decentered

- When ordering, please provide:
  - ADD power
  - Primary focal distances
    - Distance vision
    - Computer
    - Reading
  - Pupil size

Optics

Prism

- Stabilized by the global toricity and irregularity of the eye
- Prism in ANY direction
- Limited to 4PD per eye
  - O_2 transmission
  - Not good for very high myopes due to thickness
- Order total amount of vertical and horizontal
  - split between the eyes



Optics

Higher Order Aberrations

- Front surface correction
- Will correct total HOA of the ocular system
- Ideal for Keratoconus with clear cornea and back surface cornea bowing
- Caution with:
  - Cataracts
  - Corneal scarring

Oxygen Issues

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Clinical Signs of Corneal Hypoxia

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- CORNEAL EDEMA
- CORNEAL STAINING
- NEOVASCULARIZATION
- CONJUNCTIVAL INJECTION
- REFRACTIVE ERROR SHIFT
  - >-0.50D
- ENDOTHELIAL CHANGES
  - POLYMEGATHISM
  - PLEOMORPHISM
  - DECREASED CELL DENSITY
  - INCREASED PACHYMETRY

Epithelial Stress

- Reduction of epithelial adhesions
  - Decreased hemidesmosome synthesis
- Hypoxia-induced intracellular calcium

Epithelial stress

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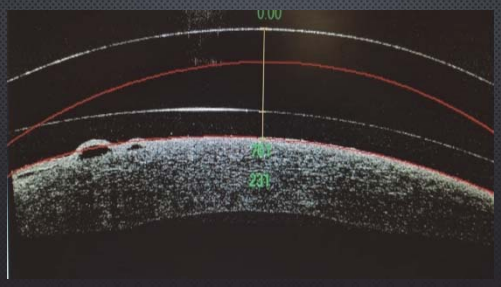
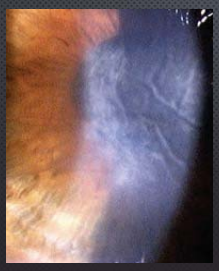


Striae and Folds



- Striae
  - 3.6-6% swelling
- Folds
  - 10-15% swelling
- Haze
  - Gross separation of collagen fibers
  - Full thickness cornea

Oxygen Calculator

Change in lens thickness

Dk/t Calculator			
CT of lens (microns)	250	350	450
Dk of lens	100	100	100
PLTL Thickness (microns)	200	200	200
Dk of Saline	80	80	80
Final Dk/t	20.00	16.67	14.29

Change in tear layer thickness

Dk/t Calculator			
CT of lens (microns)	350	350	350
Dk of lens	100	100	100
PLTL Thickness (microns)	100	200	300
Dk of Saline	80	80	80
Final Dk/t	21.05	16.67	13.79

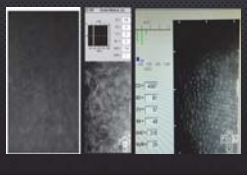
- Both lens thickness and tear layer thickness affect oxygen transmission
- Modifying the lens parameters rarely allows for enough increased oxygen to affect endothelial cell function
- BEWARE: a lens which is too thin causes flexure = many problems
  - Do NOT cause inflammation in your pursuit of increased oxygen

Scleral Lens and Endothelial Cells

"Endothelial cell count of less than 800 cells/mm2 is where the problems may arise (Sindt 2010a), and endothelial cell counts <1,000 cells/mm2 should be handled with extra care and should not be fitted with scleral lenses to avoid edema."

Eef van der Worp, 2015. A Guide to Scleral Lens Fitting (2 ed.)

Exhaust other options first:



Endothelial Function

- Monolayer of hexagonal cells
  - simple squamous
  - 350,000 to 500,000 posterior cornea
- Secretes a collagen matrix Descemet's membrane
- Supplies nutrients to the avascular cornea
  - Diffusion of glucose, amino acids, vitamin C from anterior chamber

Normal Endothelium

- 60% of cells are 6 sided
- Size and shape are important because adjacent cells with similar dimensions are necessary to maintain barrier function.
- Why hexagonal?
  - this is thermodynamically the most efficient shape to cover a surface without gaps and be watertight.

Cell density alone cannot determine corneal stability

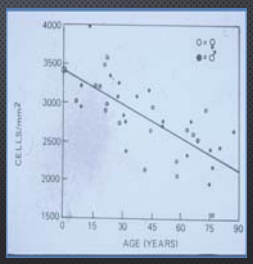
- Normal Cell Count
  - **2,500 cells / mm²**
- CV = 10
  - **Low variation in size**
- HEX = 100%
  - **Highest strength and efficiency of endothelial cellular structure**

- Normal Cell Count
  - **2,500 cells / mm²**
- CV = 79
  - **High variation in size = Polymegethism**
- HEX = 25%
  - **High variability in shape = Pleomorphism**

Morphologic Assessment

Normal Endothelium

- Endothelial cells
  - Non-mitotic
  - 3500-6000 cells/mm^2 at birth
  - 2500 cells/mm^2 adults
    - declines by 0.5%/year
- The minimum number of cells (critical cell density) is between 300 and 500 cells/mm^2
- Density differs by race
  - Japanese > Caucasian



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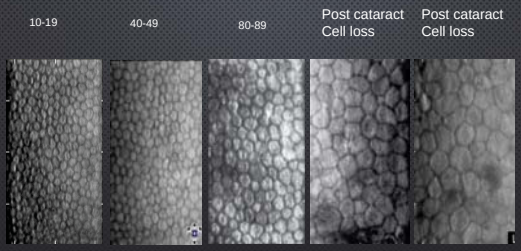
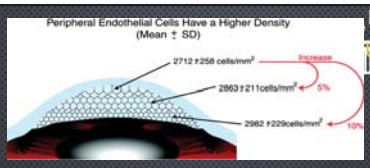
Natural Aging Cell Loss

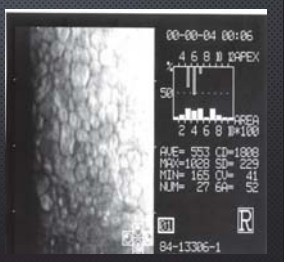




- COMPLETE COVERAGE OF THE POSTERIOR SURFACE IS REQUIRED TO MAINTAIN FUNCTION.
- CENTRAL CORNEA LOSES 100 TO 500 CELLS/ YEAR
- THEY SLOUGH OFF INTO THE ANTERIOR CHAMBER
  - CREATING A GAP
- GAP REPAIR REQUIRES MIGRATION AND CELLULAR FUSION
  - CELLS EITHER STRETCH OR SLIDE INTO A DIFFERENT POSITION
  - MUST FUSE TOGETHER TO RE-ESTABLISH COVERAGE
  - VARIATIONS IN SIZE CAUSED BY THIS MOVEMENT IS CALLED POLYMEGATHISM.

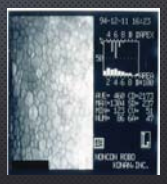
Pleomorphism

- Significant drop in the hexagonal pattern
  - Decreases the endothelial pump stability
- Less than 50% hexagonal cells= clinical significance.
- Indicates physiological stress and overactive wound repair
  - May be more susceptible to additional trauma



Causes of Pleomorphism & Polymegathism

1. Injury
   1. Metabolic
   2. Toxic
   3. Trauma
      1. Keratoplasty
      2. Cataract surgery
      3. LASIK
      4. CXL
   4. Hypoxia
      1. Contact lens wear
5. Disease states
   1. Diabetes
   2. Glaucoma
6. Dystrophies and degenerations
   1. Fuch's
   2. PPMD
7. Inflammation
8. Aging



Corneal Endothelial Injury

ENDOTHELIAL STRESSORS:

- METABOLIC: HYPOXIA, HYPERGLYCEMIA
- TOXIC: DRUGS, PRESERVATIVES
  - EPINEPHRINE (TRANSIENT), TIMOLOL, BETAMETHESONE, GENTAMICIN
- ALTERATIONS IN PH, IONIZATION, OR OSMOLARITY
- TRAUMA FROM SURGERY

CHANGES TO ENDOTHELIUM CAN APPEAR LOCALLY, AND THEREFORE NOT SEEN ON RANDOMLY SELECTED SPECULAR MICROSCOPY PHOTOGRAPHS.

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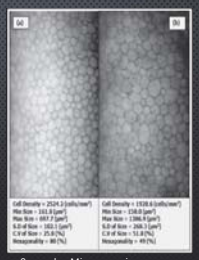
Diabetes

- Endothelial cell density is significantly lower in diabetics than non-diabetics
  - Specifically if diabetic greater than 10 years
  - Diabetic more endo damage during phaco



Specular Microscopic photograph. (a) Normal Cornea (b) Diabetic Cornea

Photo: Pak J Med Sci. 2017 Nov-Dec;

Glaucoma

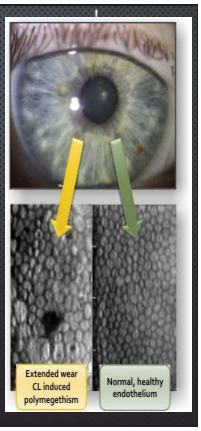
- Endothelial loss in patients with ACG and POAG
- Proposed mechanisms
  - Direct damage from IOP
  - Congenital alteration of the corneal
  - Glaucoma medication toxicity
    - Increased # of meds, increased cell loss
- Tube shunts- increased cell loss
  - Mechanical
  - Inflammatory

Inflammation

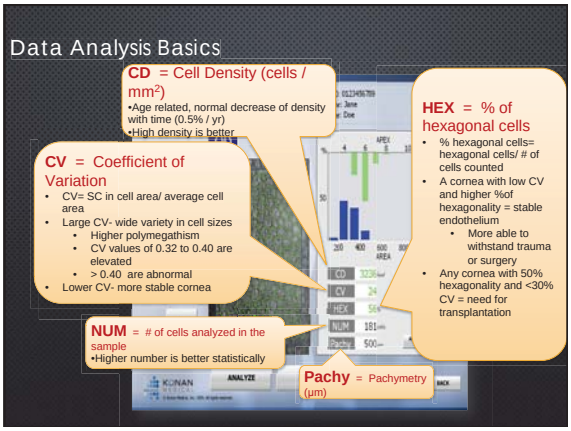
- Uveitis
  - Release of immune response proteins in to the anterior chamber- leads to endo cell death
  - Inflammatory cells penetrate tight junctions
    - Insert themselves between endothelium and Descemet's membrane
    - Dislodge endo cells

What have you been missing?

- Standard bio-microscopy doesn't reveal most abnormalities
- Clear/normal looking corneas may be masking serious problems
- Most guttata aren't seen until they reach significant density

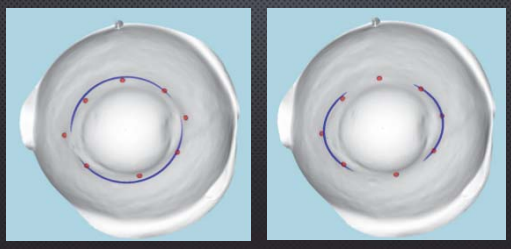


Data Analysis Basics

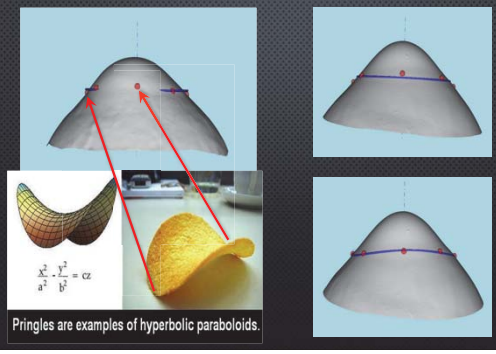


Ocular Geometry

The Limbus is Not Round



Hyperbolic Paraboloid



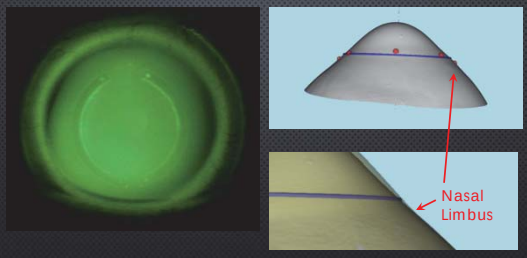
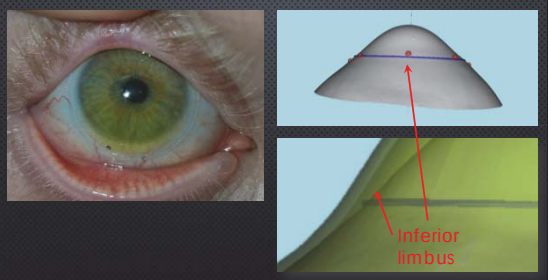
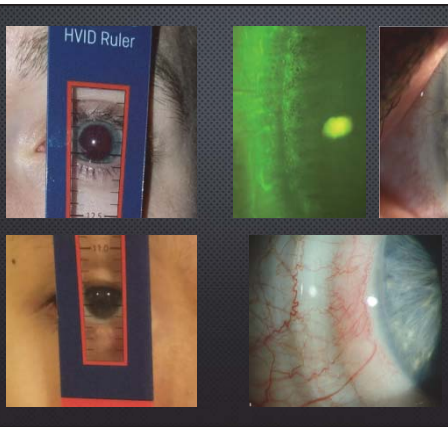
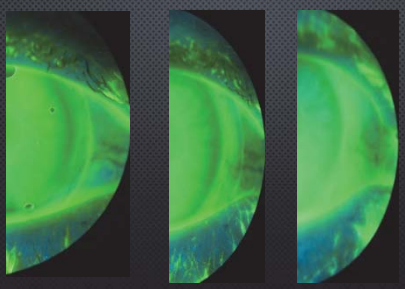


Photo: Dr Tom Arnold





Landing Area

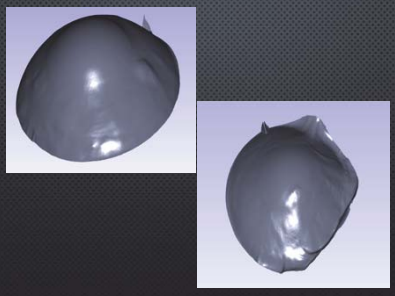


13.6mm 15.0mm 18.2mm

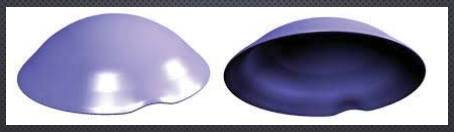
It takes about 3mm of landing not to sink in

But then more concerned about toric peripheral

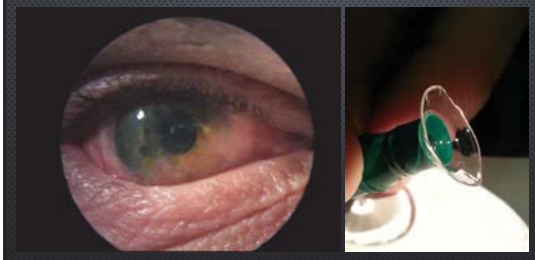
Unexpected Geometry



Micro vault



Wednesday, 25 September 19 56

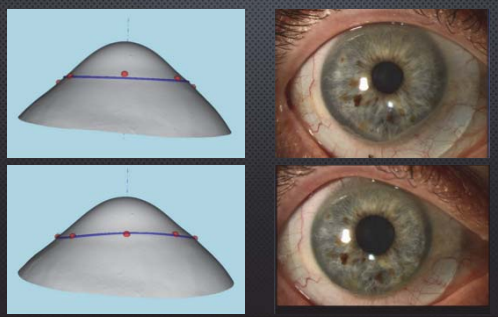


Physiological Responses

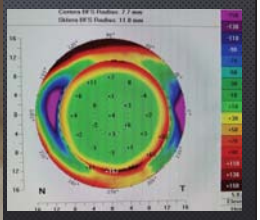
Superficial Pannus
Limbal Stem Cell Deficiency

Corneal Haze

Herpes Simplex Virus

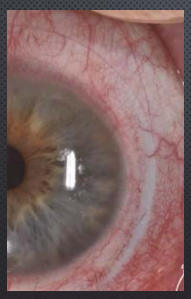


Toric Peripheries



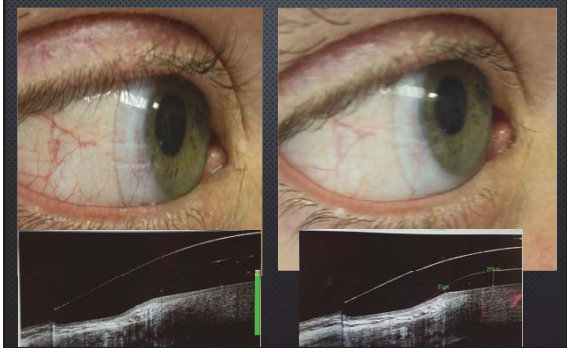
Impression Rings

Limbal Inflammation



- **Go:**
  - **–Larger/ Smaller**
  - **–Flatter**
  - **–Toric**

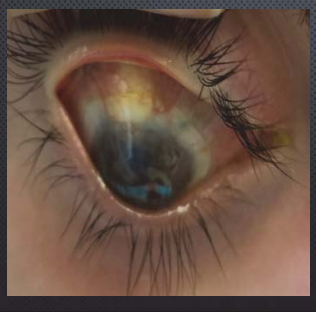
"Heeling"



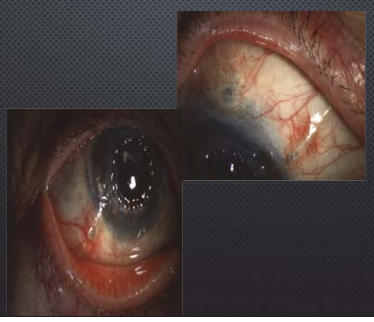
"Toeing"

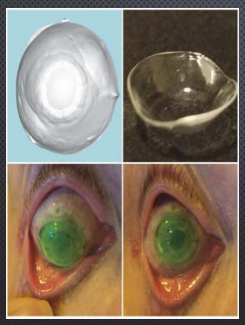
Disease States

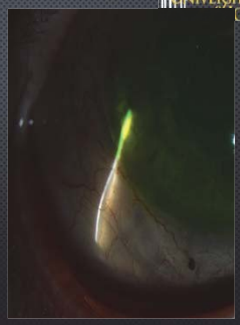
Evaluating a Bleb or Patch Graft



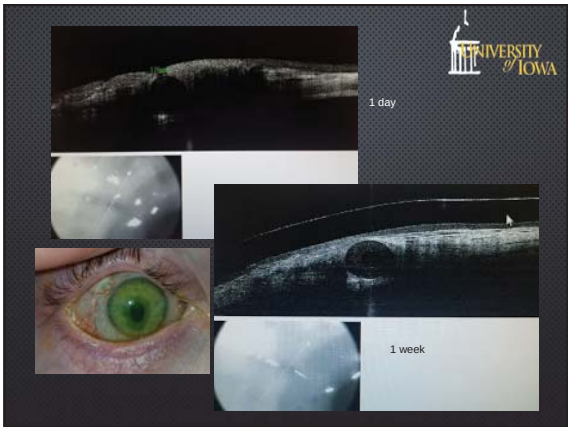
Patch Graft Erosion

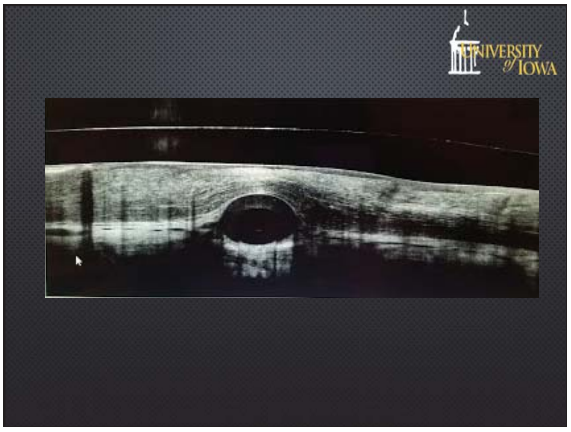


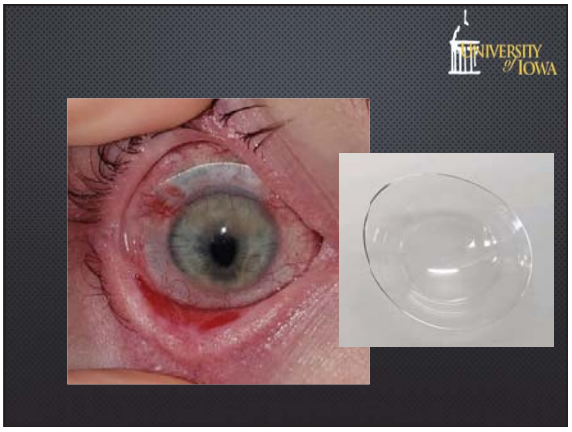




Only elevation specific technology can create extra vault specifically over IOL's and Blebs

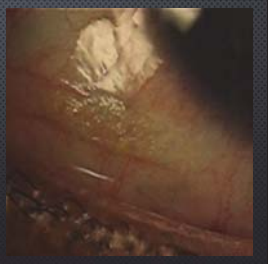


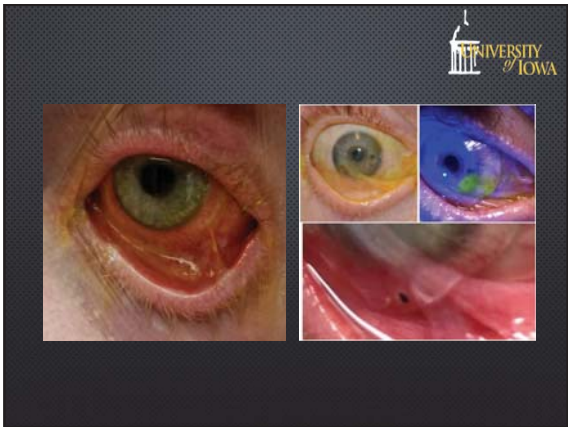


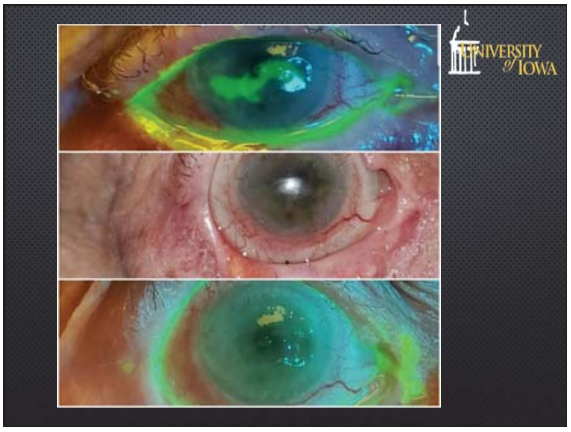


Severe Ocular Surface Disease

- GVHD
- Sjogren Syndrome
- Ocular Cicatricial Pemphigoid
- Severe dry Eye







Pinguecula

Corneal Scar Protection

3 YEARS LATER

PRESENTATION

Episodes of Inflammation Flare

Inflammatory/ Fibrotic lids

Post Surgical Inflammation

- Lid care
  - In house
- Glaucoma drugs

Granulomas

Always Suspect Carcinoma

Post Surgical Corneas

- PKP
- LASIK
- RK
- ARTIFICIAL CORNEA

Artificial Corneas

Epithelial Downgrowth

So How Do You Design a Lens?

The First Question YOU Must ask yourself…

WHAT DIAMETER AM I GOING TO USE?

Nomenclature

Terminology

	Alternative Names	Diameter	Bearing	Tear Reservoir
Corneal		8.0 to 12.5 mm	All lens bearing on the cornea	No tear reservoir
Corneo-scleral	Corneal-Limbal Semi-scleral Limbal	12.5 to 15.0 mm	Lenses share bearing on the cornea and the sclera	Limited tear reservoir capacity
(Full) Scleral	Haptic	15.0 to 25.0 mm	All lens bearing is on the sclera	
		Mini-scleral 15.0 to 18.0 mm		Somewhat limited tear reservoir capacity
		Large-scleral 18.0 to 25.0 mm		Almost unlimited tear reservoir capacity

Initial Lens Selection

- Typically your choice of a lens design is based upon
  - Unique characteristics of a specific design and the disease you are working with
    - Keratoconus
    - Post penetrating keratoplasty
    - Post refractive
    - Ocular Surface disease
    - Endothelial Cell health

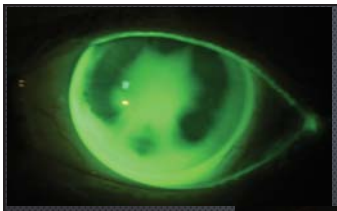
Lens Selection

- Lens Diameter
  - Small
    - +/- easier to handle
    - Less tear reservoir
    - Non-compromised eyes
  - Large
    - More vault/ clearance
      - May be easier to clear the limbus
    - Easier to fit for compromised eyes
    - Larger landing zone

What Should You Consider In Lens Design?

- Ease of fitting
- trial sets/ Emperic Fitting
- Simple fitting guide
- Minimal fitting time
- High first fit success
- Minimal corneal insult
- Increased patient comfort
- Repeatable replacements

K's versus Sag

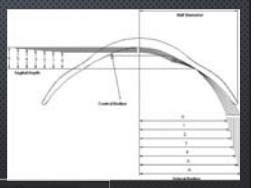


Question to ask yourself:
Do I have enough sagittal depth?
Where do I need to make changes?
central
intermediate
peripheral

Changes in lens design

Sagittal Depth

- Sag depth = {R-sqrt(R^2-(1-SF)xC^2)}/(1-SF)
- R= apical curve radius (Base curve)
- SF= shape factor (Peripheral curves)
- C=visible iris diamter/2 (Lens diameter)



Changing Sagittal Depth

- Increase
  - Steepen base curve
  - Steepen/ lengthen peripheral curves
    - Intermediate
    - Limbal
    - Peripheral
  - Increase diameter of lens or optic zone
- Decrease
  - Flatten base curve
  - Flatten/ shorten peripheral curves
    - Intermediate
    - Limbal
    - Peripheral
  - Decrease diameter of lens or optic zone

Contact Lenses and the PKP

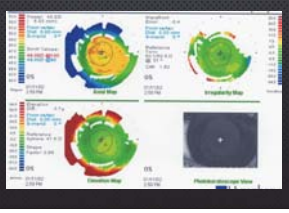
University of Iowa

Indentifying Corneal Grafts Topographically

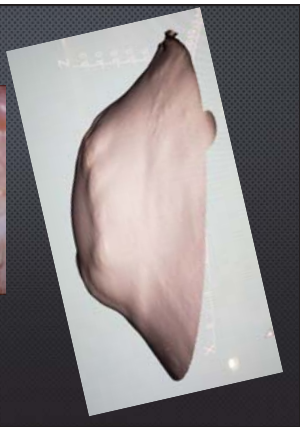
- The perfect graft
- The plateau graft
- The proud graft
- The tilted graft
- The high cylinder graft

The Perfect Graft

- These are not the eyes that will be sent to you to be fit
- Every surgeon has different definition of "perfect"
  - Usually VA 20/40 or better
  - Some consider success to be spherical equivalent within 2 D of emmetropia



The Plateau Graft



The Plateau Graft

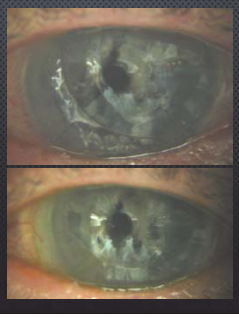
- Contact Lens Correction
  - Fit very small (within the graft)
  - Fit very large (reverse geometry)
  - Do not land on the sutures

The Plateau Graft

- Small/ flat lenses will ride high

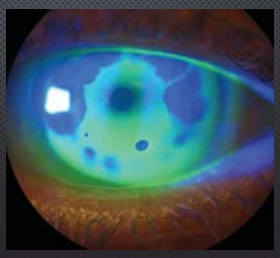
The Plateau Graft

- Central Bubble



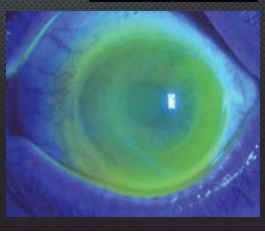
The Plateau Graft

- Good Plateau fit may need extreme curves
- Graft host junction may be site for lens adherence



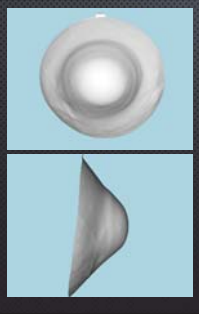
The Plateau Graft

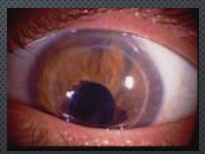
- Large OAD
- Oblate design with large optic zone
  - Vault running suture
- Fit PC's separately

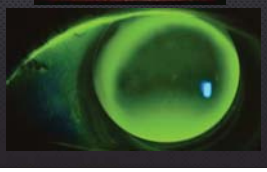


The Proud Graft

- The graft is evenly elevated above the host



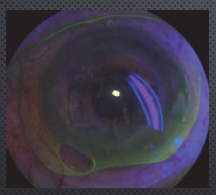




The Proud Graft

- BROAD AREA OF CENTRAL ELEVATION
  - LARGE OPTIC ZONE
- NEED REVERSE CURVE TO BRING ALIGN PERIPHERY WITH HOST
  - STEEPER PC
  - LONGER PC

The Proud Graft



- MINI SCLERAL ARE A POOR CHOICE
  - WITHOUT ENOUGH SAG, USUALLY GET INFERIOR LIFT OFF
  - SMALL LANDING AREA = COMPRESSION

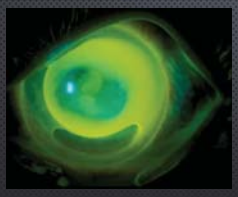
The Tilted Graft

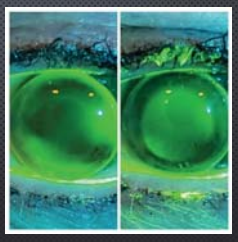
- USUALLY SEEN IN KCN/ PMD
  - TOUGH TO REMOVE ENTIRE CONE
  - OLD GRAFTS
- TREPHINE DEPENDENT
  - USE VACUUM TREPHINE TO AVOID UNDERCUTTING
- WOUND DEHISCENCE
- TISSUE MAL-APPOSITION
- IMPROPER SUTURE PLACEMENT
- UNEQUAL SUTURE TENSION

Graft Tilt

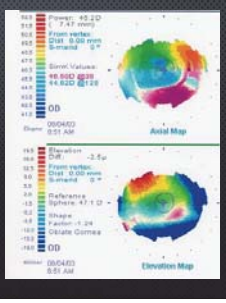
- LARGE LENSES
  - BEWARE OLD GRAFTS WITH POOR ENDO FUNCTION
- GP LENSES
  - FIT SMALL, FLAT AND HIGH
  - FIT LARGE AND ASYMMETRIC
- SCLERAL LENSES
  - FULL SCLERAL
  - DECENTER OPTICS
  - FENESTRATE?

The Tilted Graft





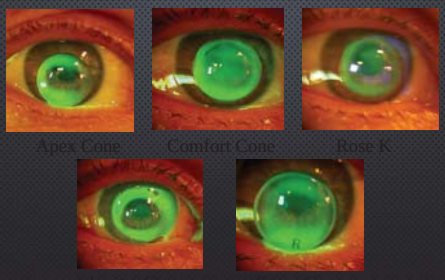
Topography vs Elevation



Keratoconus

UNIVERSITY of IOWA

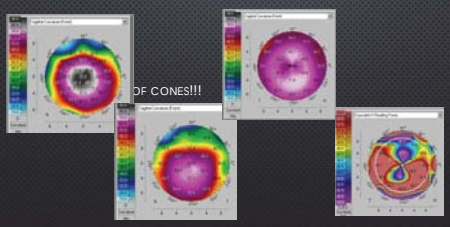
Many Design Options



Apex Cone Comfort Cone Rose K

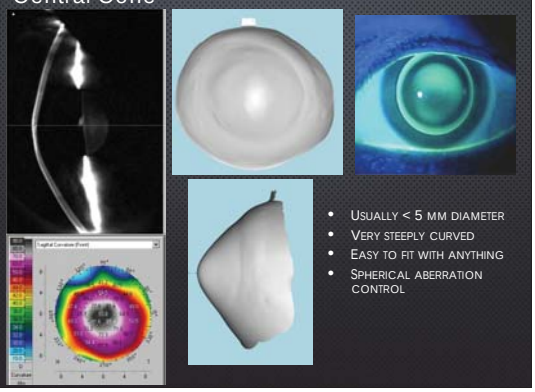
Jupiter Cone Super Cone

Why Do You Need More Than One Lens Design?



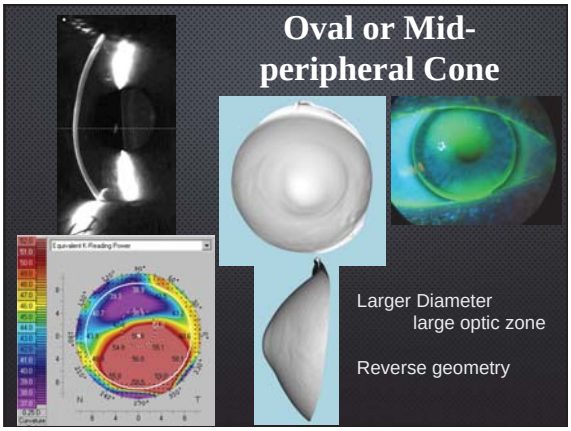
OF CONES!!!

Central Cone



- USUALLY < 5 MM DIAMETER
- VERY STEEPLY CURVED
- EASY TO FIT WITH ANYTHING
- SPHERICAL ABERRATION CONTROL

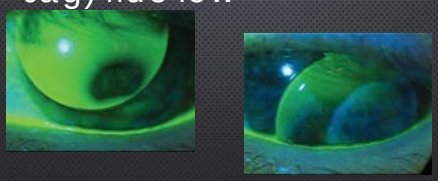
Oval or Mid-peripheral Cone



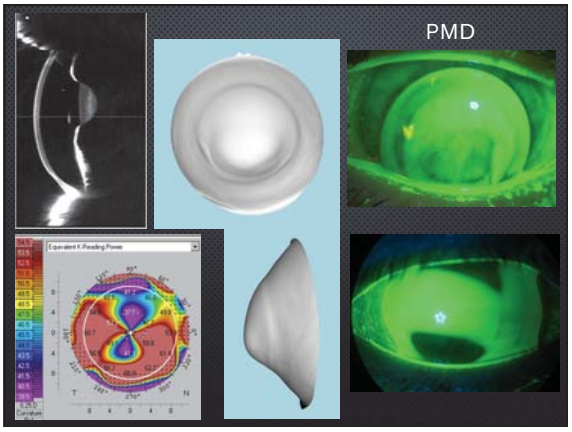
Larger Diameter
large optic zone

Reverse geometry

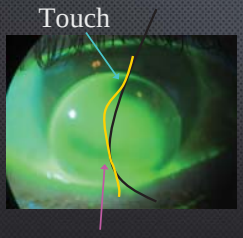
Flat lenses (low sag) ride high, steep lenses (high sag) ride low



0.25mm BC 0.50mm BC



PMD

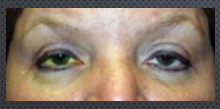


Traditional KC designs don't fit

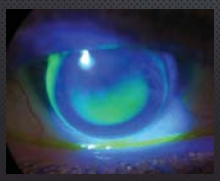
Lens Location

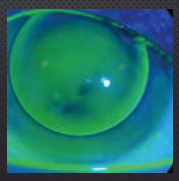
- Riding High
  - Reduce diameter
  - Steepen base curve
  - Reduce edge lift
- Low Riding
  - Increase diameter
  - Flatten base curve
  - Increase edge lift

Lid Location



Post ptosis surgery



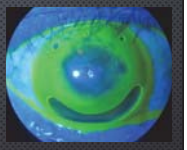


Pearls

- Finish refraction with lights on.
- Reassure patient if VA is not optimum at initial fitting.(tearing)
- VA often improves over first few weeks wear.
- Educate patient about VA expectations. (night driving)

- A lens which slides or is tipped or tilted on the cornea can induce significant amounts of unwanted aberration

SUMMARY



- Respect the squishy tissue
  - You can cause inflammation
    - Adjust the fit
  - The body can cause inflammation
    - Control the inflammation
    - Don't change the fit
  - Know the difference
- You don't know what you don't know
  - Get an endothelial camera
  - Get some type of corneal OCT
- Just because you can, doesn't mean you should

Most Importantly

- Don't make too many changes all at once
  - Large fitting sets are helpful
  - Practice altering once parameter at a time to learn how each change impacts the overall fit
  - Remember, these are general principles and each lens will have its own specific nuances.

Thank You

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Facebook:
Scleral lens Practioners
OD Divas
L'optometria femminile