Refractive Surgery Overview

The goal of refractive surgery is deceptively straightforward and simple: To render the pt less reliant upon refractive accoutrements (ie, contacts and glasses). Ideally, a pt s/p refractive surgery would have 20/20 vision at all distances, under any lighting conditions, with no dysphotopsias (visual experiences that degrade vision quality), and with no risk of future negative repercussions vis a vis the long-term health and/or optical performance of the eye. Also ideally, the above could be achieved irrespective of pre-op refractive status and/or pre-existing ocular conditions.
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Current technology is unable to meet this lofty ideal, and thus refractive surgery necessitates compromises and trade-offs; eg, If you had to pick one, would you rather be spectacle-free at distance, or near? Would it be acceptable if you only needed glasses in dimly-lit restaurants? How bothersome would haloes around lights at night be? Because some aspect of the pt’s post-op visual life will be less than ideal, key to successful refractive surgery is 1) developing a solid understanding of the pt’s visual preferences and requirements, and 2) communicating effectively with the pt regarding what her post-op visual life will be; ie, establishing expectations that are realistic and achievable.
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Let’s start with a brief review of refractive error

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Refractive Surgery Overview

- The refractive state of an eye—that is, whether it is \underline{emmetropic}, \underline{myopic} or \underline{hyperlopic}—is determined by the location of its far point.
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The far point is: *The location in space to the retina when the eye is not*...
Refractive Surgery Overview

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- The far point is: The location in space conjugate to the retina when the eye is not accommodating.

(Accommodation refers to conformational changes in the ciliary body/lens to facilitate vision at near.)
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Refractive Surgery Overview

(The Far Point of) **The Emmetropic Eye**
In the **emmetropic** eye, the parallel rays from a location at infinity are focused to a point located precisely on the retina.
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**Far Point of the emmetropic eye: Infinity**
In the **emmetropic** eye, the parallel rays from a location at infinity are focused to a point located precisely on the retina. **In other words, the far point of the emmetropic eye is at infinity.** Thus, emmetropes see 20/20 (or better) at distance without correction.

**Far Point of the emmetropic eye: Infinity**
In contrast to the sharp uncorrected distance vision of the emmetrope, consider the plight of the myope.
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In the myopic eye, rays from infinity meet in the vitreous. By the time they reach the retina, the rays have diverged to form a blur circle, not a focal point.
In contrast to the sharp uncorrected distance vision of the emmetrope, consider the plight of the myope.

In the myopic eye, rays from infinity meet in the vitreous. By the time they reach the retina, the rays have diverged to form a blur circle, not a focal point.
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To be focused on the retina, the Far Point of a myopic eye will have to offset its excess convergence with an equivalent amount of divergence. To accomplish this…
The myopic eye has too much converging power for its length.

...the Far Point of a myopic eye is just anterior to the corneal plane.
The Myopic Eye

Distance $\ll$ Infinity (<20 feet)

…the Far Point of a myopic eye is just anterior to the corneal plane. Rays from this location are still quite divergent when they reach the eye, and this divergence offsets the excess convergence that is built into the myopic eye. Thus, rays originating from the far point end up sharply focused at the retina.
Refractive Surgery Overview

(The Far Point of) The Myopic Eye

The myopic eye has too much converging power for its length

...the Far Point of a myopic eye is just anterior to the corneal plane. Rays from this location are still quite divergent when they reach the eye, and this divergence offsets the excess convergence that is built into the myopic eye. Thus, rays originating from the far point end up sharply focused at the retina. This is why nearsighted individuals can read without glasses—they’re able to put the material at or near their far point.
Refractive Surgery Overview

(The Far Point of) **The Hyperopic Eye**

Parallel rays from infinity (vergence = 0)

Parallel rays from infinity

Now consider the **hyperope**. Where do parallel rays meet in *these* eyes?
The Hyperopic Eye

Parallel rays from infinity (vergence = 0)

Now consider the **hyperope**. Where do parallel rays meet in these eyes? In the hyperopic eye, rays from infinity never meet—they run out of eyeball first. Thus, like the myopic eye, the rays form a **blur circle**, not a focal point, at the retina.
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The Hyperopic Eye

Parallel rays from infinity (vergence = 0)

Parallel rays from infinity

(The Far Point of) **The Hyperopic Eye**

The hyperopic eye has too little converging power for its length

Note that if the retina was here, the rays from infinity would be focused to a point.

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Now consider the hyperope. Where do parallel rays meet in these eyes? In the hyperopic eye, rays from infinity never meet—they run out of eyeball first. Thus, like the myopic eye, the rays form a blur circle, not a focal point, at the retina. You could say the hyperopic eye has too little converging power for its length. In order to be conjugate to the retina, the Far Point of a hyperopic eye must contribute convergence to compensate for this lack of converging power. **To accomplish this...**
The hyperopic eye has too little converging power for its length. A and B are conjugate points.

...the far point of a hyperopic eye is behind the corneal plane.
Refractive Surgery Overview

(The Far Point of) **The Hyperopic Eye**

*The hyperopic eye has too little converging power for its length*

...the far point of a hyperopic eye is *behind* the corneal plane. It contributes *convergence* to make up for the inadequate native convergence of the hyperopic eye.
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...the far point of a hyperopic eye is *behind* the corneal plane. It contributes *convergence* to make up for the inadequate native convergence of the hyperopic eye. Thus, rays associated with the far point end up sharply focused at the retina.

Don’t get it twisted—hyperopes can’t actually see behind their heads. (Do I really have to say that?) Unlike myopes—who can see at their far point just out in front of their faces—a hyperope is out of focus at all distances (absent correction or accommodation.)
Refractive Surgery Overview

- The myopic eye has too much power for its length, as we said.

Myopic Eye
Refractive Surgery Overview

- The myopic eye has too much converging power for its length, as we said.
Refractive Surgery Overview

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Think of it this way: The myopic eye refracts light as if an extra ‘plus’ lens was built into it. This so-called error lens contributes the excess convergence that produces a myopic refractive error.
The myopic eye has too much converging power for its length, as we said. This explains why myopes wear minus lenses to correct their refractive error—minus lenses are needed to offset the excess convergence induced by the plus error lenses in their eyes.

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Refractive Surgery Overview

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Thus, the hyperopic eye acts as if it has a minus error lens within it, contributing the excess divergence resulting in a hyperopic refractive error.
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This explains why hyperopes wear plus lenses to correct their refractive error—plus lenses are needed to offset the excess divergence induced by the minus error lenses in their eyes.

Thus, the hyperopic eye acts as if it has a minus error lens within it, contributing the excess divergence resulting in a hyperopic refractive error.
The goal of refractive surgery is to produce an error-lens offset that is incorporated into the eye itself, rather than worn on (CLs) or near (glasses) its anterior surface.
As mentioned previously, refractive surgical procedures come in two basic forms—

and
Refractive Surgery Overview

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Likewise, *intraocular procedures* come in two forms—*pseudophakic*, and *phakic IOL (PIOL)*.
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Refractive Surgery Overview

Refractive Surgery

Intraocular

Pseudophakic

Phakic IOL

Corneal

A pseudophakic procedure involves removing the native lens and replacing it with an IOL powered to put parallel rays on the retina. The surgery itself is identical to that performed for cataracts. (Such procedures are referred to as clear lens extraction.)
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Refractive Surgery Overview

In a *phakic IOL procedure* the native lens is left in place, and a corrective lens is placed in front of it—an ‘intraocular contact lens’ if you will.
Refractive Surgery Overview

Phakic IOL
Phakic IOL
Refractive Surgery Overview

Phakic IOL vaulting over the native lens
Before we get into cornea-based refractive surgeries, let’s take a look at corneal optics.
The shape of the human cornea is *prolate*, meaning the central portion is steeper (ie, has a shorter radius of curvature) than the peripheral portion. On average, the central cornea is about 3-4D steeper than the peripheral portion.
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Refractive Surgery Overview

Power differential of central vs peripheral cornea (don’t memorize the numbers)
The anterior corneal surface adds about 49D of convergence to incoming light (note how the air-cornea interface looks like a ‘plus’ lens).
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However, the posterior corneal surface adds about 6D of divergence as light passes through it into the AC (note how the cornea-aqueous interface looks like a minus lens).
Refractive Surgery Overview

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Refractive Surgery Overview

The net result across the cornea is an overall power of about +43D
The human eye averages about 60D of total convergence, implying (correctly) that the cornea accounts for roughly 2/3 of its focusing power.

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Refractive Surgery Overview

The human eye averages about **60D** of total convergence, implying (correctly) that the cornea accounts for roughly **2/3** of its focusing power.

Of course, these are only averages. In order to perform keratorefractive surgery, one must have accurate measurements of central corneal power—ideally, at both its anterior and posterior surfaces.

The net result across the cornea is an overall power of about **+43D**
Two technologies are widely employed to determine central corneal power: Corneal topography, and corneal tomography.
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Refractive Surgery Overview

Corneal topography works by reflecting a set of concentric rings (collectively called a [two words]) from the anterior corneal surface, and a computer analyzes the distances between, and shapes of, the reflected rings.
Refractive Surgery Overview

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Refractive Surgery Overview

**Corneal topography** works by reflecting a set of concentric rings (collectively called a *Placido disk*) from the anterior corneal surface, and a computer analyzes the distances between, and shapes of, the reflected rings. Based on this analysis, the topographer creates a color-coded ‘map’ depicting the curvature across the corneal surface.
Refractive Surgery Overview

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*Corneal Placido-disk topography: Color map demonstrating with-the-rule astigmatism (ie, the cornea is steeper in its vertical meridian)*
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Corneal Placido-disk topography: Color map demonstrating *with-the-rule* astigmatism (ie, the cornea is steeper in its vertical meridian)
Refractive Surgery Overview

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- **Scanning-slit**: A series of overlapping scans are directed at the cornea. The light reflects off both the anterior and posterior surfaces. These reflections are acquired and analyzed to produce a model of the central cornea.
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-- **Scheimpflug imaging**: A series of images are taken and analyzed with respect to anterior and posterior corneal curvature and corneal thickness. The data from each image are knitted together to produce a model of the cornea.

![Scheimpflug image of the cornea](image)
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Refractive Surgery Overview

Pentacam corneal tomographer readout
Refractive Surgery Overview

A) Anterior corneal values
- $K_1$, $K_2$, $K_m$: The two major meridians ($K_1$, $K_2$). $K_m$ is the average of $K_1$ and $K_2$
- $R_f$, $R_s$, $R_m$: Radii corresponding with $K_1$, $K_2$, and $K_m$, respectively
- QS: Quality score (i.e. “OK,” “Data gaps,” “Fix,” “Model”)
- Axis: The meridian that requires no cylinder power to correct astigmatism
- Astig: The central corneal astigmatism

B) Posterior corneal values
The same variables described for the back of the cornea.

C), D) Fuggedaboudit (too much for this overview)
Refractive Surgery Overview

In addition to determining corneal power, pre-op corneal mapping is employed to determine whether a prospective keratorefractive pt has a corneal ectasia. Ectasia is a noninflammatory condition characterized by progressive corneal thinning, the end result of which is corneal warpage. Pre-existing ectasia is a strong contraindication to many elective keratorefractive procedures, eg, LASIK. The two most common ectasias are keratoconus (KCN) and pellucid marginal degeneration (PMD).
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**Refractive Surgery Overview**
Refractive Surgery Overview

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Refractive Surgery Overview

KCN
Topography in KCN: Classic
Ref refractive surgery overview.

Topography in KCN: Classic *inferior corneal steepening*
Refractive Surgery Overview

Topography in PMD: Classic or different words.
Refractive Surgery Overview

Topography in PMD: Classic *kissing doves* or *crab claw*
Refractive Surgery Overview

Corneal Placido-disk topography: Mires typical of KCN? PMD?
Refractive Surgery Overview

Corneal Placido-disk topography: Mires typical of KCN
Most corneal refractive surgeries involve altering the shape of the cornea in a way that impacts the vergence it imparts to incoming light.
Refractive Surgery Overview

Refractive Surgery

- Intraocular
  - Pseudophakic
  - Phakic IOL

- Corneal
  - ?
  - ?
  - Other

Most corneal refractive surgeries involve altering the shape of the cornea in a way that impacts the vergence it imparts to incoming light. These alterations can involve incising the cornea, lasering it, or some other means.
Most corneal refractive surgeries involve altering the shape of the cornea in a way that impacts the vergence it imparts to incoming light. These alterations can involve incising the cornea, lasering it, or some other means.
Refractive Surgery Overview

In a *keratoablative laser procedures* (eg, LASIK), the cornea is reshaped so as to offset the effect of the error lens.
Refractive Surgery Overview

Intraocular
- Pseudophakic
- Phakic IOL

Corneal
- Incisional
- Laser
- Other

In a *keratoablative laser procedures* (eg, LASIK), the cornea is reshaped so as to offset the effect of the error lens. In *myopic keratoablative surgery*, the central cornea is *flattened v steepened* its converging power.

![Myopic Eye](image)
Refractive Surgery Overview

In a *keratoablative laser procedures* (eg, LASIK), the cornea is reshaped so as to offset the effect of the error lens. In *myopic keratoablative surgery*, the central cornea is flattened to reduce its converging power.
Refractive Surgery Overview

Intraocular
- Pseudophakic
- Phakic IOL

Corneal
- Incisional
- Laser
- Other

Think of it as shaving down the peak of a mountain in order to make the structure more mesa-like

Myopic Eye

Plus error lens

the cornea is reshaped so as to offset the surgery, the central cornea is flattened
In a keratoablative laser procedure (e.g., LASIK), the cornea is reshaped so as to offset the effect of the error lens. In myopic keratoablative surgery, the central cornea is flattened to reduce its converging power. Hyperopic keratoablative surgery is the opposite—the central cornea is steepened to increase its converging power.
Refractive Surgery Overview

In a *keratoablative laser procedures* (e.g., LASIK), the cornea is reshaped so as to offset the effect of the error lens. In *myopic keratoablative surgery*, the central cornea is flattened to reduce its converging power. *Hyperopic keratoablative surgery* is the opposite—the central cornea is *steepened* to *increase* its converging power.

**Myopic Eye**
- **Plus error lens**

**Hyperopic Eye**
- **Minus error lens**
Refractive Surgery Overview

In a keratoablative laser procedure (e.g., LASIK), the cornea is reshaped to offset the effect of the error lens. In myopic keratoablative surgery, the central cornea is flattened to reduce its converging power. Hyperopic keratoablative surgery is akin to shaving down the rim of a mesa in order to make its structure more mountain-like.

In contrast, hyperopic keratoablative surgery is akin to shaving down the rim of a mesa in order to make its structure more mountain-like.
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Refractive Surgery Overview

Note that, by definition, keratoablative refractive surgery involves reshaping the central cornea (and thereby altering its refractive power) via the removal (by annihilation) of corneal tissue.
In a keratoablative laser procedure (e.g., LASIK), the cornea is reshaped to offset the effect of the error lens. In myopic keratoablative surgery, the central cornea is flattened to reduce its converging power. Hyperopic keratoablative surgery is the opposite— the central cornea is steepened to increase its converging power.

Note that, by definition, keratoablative refractive surgery involves reshaping the central cornea (and thereby altering its refractive power) via the removal (by annihilation) of corneal tissue.

*One laser-based keratorefractive procedure does not involve tissue annihilation, rather, in it a section of corneal stroma is carved, then removed en bloc.*
What are the five laser-based keratorefractive procedures covered in the BCSC book?
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Refractive Surgery Overview

What are the five laser-based keratorefractive procedures covered in the BCSC book?

Which is the nonablative procedure referred to on a couple of slides ago?
Refractive Surgery Overview

Intraocular
- Pseudophakic
- Phakic IOL

Corneal
- Incisional
- Laser
  - PhotoRefractive Keratectomy (PRK)
  - LASer SubEpithelial Keratomileusis (LASEK)
  - Epipolis LASer In-situ Keratomileusis (Epi-LASIK)
  - LASer In-situ Keratomileusis (LASIK)
  - Small-Incision Lenticule Extraction (SMILE)

What are the five laser-based keratorefractive procedures covered in the BCSC book?

Which is the nonablative procedure referred to on a couple of slides ago? SMILE
In the SMILE procedure, the femtosecond laser, with its ability to be focused at very precise depths within the cornea, is used to carve a segment (called a *lenticule*) of very specific shape within the stroma without disturbing the overlying or underlying tissue.

**SMall-Incision Lenticule Extraction**

What are the five laser-based keratorefractive procedures covered in the BCSC book?

Which is the nonablative procedure referred to on a couple of slides ago?
Refractive Surgery Overview

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In the SMILE procedure, the femtosecond laser, with its ability to be focused at very precise depths within the cornea, is used to carve a segment (called a *lenticule*) of very specific shape within the stroma without disturbing the overlying or underlying tissue. The lenticule is then removed *en bloc* by being extracted through a very small incision (also created by the femto) that connects the femto-created intrastromal space and the corneal surface.

What are the five laser-based keratorefractive procedures covered in the BCSC book?

Which is the nonablative procedure referred to on a couple of slides ago?
Refractive Surgery Overview

- Creation of lenticule and small access (< 4 mm)
- Removal of the lenticule
- Refractive error is corrected

SMILE
Refractive Surgery Overview

Refractive Surgery

Intraocular
- Pseudophakic
- Phakic IOL

Corneal
- Incisional Laser
- Other

Incisional Laser

Other

In the SMILE procedure, the femtosecond laser, with its ability to be focused at very precise depths within the cornea, is used to carve a segment (called a lenticule) of very specific shape within the stroma without disturbing the overlying or underlying tissue. The lenticule is then removed en bloc by being extracted through a very small incision (also created by the femto) that connects the femto-created intrastromal space and the corneal surface. The resulting loss of tissue reshapes the central corneal surface in a way that produces a desired change in its refractive power.

What are the five laser-based keratorefractive procedures covered in the BCSC book?

Which is the nonablative procedure referred to on a couple of slides ago?
Refractive Surgery Overview

In keratoablative procedures, remodeling of the central cornea occurs via annihilation of the corneal stroma with an excimer laser. But before the excimer can get to the stroma, the corneal epithelium has to get out of the way.
In **keratoablative procedures**, remodeling of the central cornea occurs via annihilation of the corneal stroma with an excimer laser. But before the excimer can get to the stroma, the corneal epithelium has to get out of the way.
In **keratoablatiive procedures**, remodeling of the central cornea occurs via annihilation of the corneal stroma with an excimer laser. But before the excimer can get to the stroma, the corneal epithelium has to get out of the way. **The four keratoablative procedures differ solely in how the epithelium is handled.**
In keratoablative procedures, remodeling of the central cornea occurs via annihilation of the corneal stroma with an excimer laser. But before the excimer can get to the stroma, the corneal epithelium has to get out of the way. The four keratoablative procedures differ solely in how the epithelium is handled.

In PRK, the handling of the epithelium couldn’t be more straightforward. It is simply cast aside—via scraping, chemical destruction, brushing, lasing, etc. This makes PRK the simplest of the laser kerotorablative procedures: get the epithelium out of the way, then forget about it.
In *keratoablative procedures*, remodeling of the central cornea occurs via annihilation of the corneal stroma with an *excimer* laser. But before the *excimer* can get to the stroma, the corneal epithelium has to get out of the way. The four keratoablative procedures differ solely in how the epithelium is handled.

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Refractive Surgery Overview

Post-PRK haze
Refractive Surgery Overview

In keratoablative procedures, remodeling of the central cornea occurs via annihilation of the corneal stroma with an excimer laser. But before the excimer can get to the stroma, the corneal epithelium has to get out of the way.

The four keratoablative procedures differ solely in how the epithelium is handled. The well-known LASIK procedure deals with the epithelium by doing an end-run around it.
In contrast, the well-known LASIK procedure deals with the epithelium by doing an end-run around it. A hinged flap is cut in the stroma and reflected, thereby moving the overlying epithelium out of the treatment area.

The four keratoablative procedures differ solely in how the epithelium is handled.
Refractive Surgery Overview

In keratoablative procedures, remodeling of the central cornea occurs via annihilation of the corneal stroma with an excimer laser. But before the excimer can get to the stroma, the corneal epithelium has to get out of the way. The four keratoablative procedures differ solely in how the epithelium is handled. The well-known LASIK procedure deals with the epithelium by doing an end-run around it. A hinged flap is cut in the stroma and reflected, thereby moving the overlying epithelium out of the treatment area. Far less pain; vastly reduced risk of haze formation.
Refractive Surgery Overview

In keratoablative procedures, remodeling of the central cornea occurs via annihilation of the corneal stroma with an excimer laser. But before the excimer can get to the stroma, the corneal epithelium has to get out of the way.

The four keratoablative procedures differ solely in how the epithelium is handled.

In contrast, the well-known LASIK procedure deals with the epithelium by doing an end-run around it. A hinged flap is cut in the stroma and reflected, thereby moving the overlying epithelium out of the treatment area. The underlying stromal bed is then lasered, and the flap (with its intact epithelium) is laid back in place. Far less pain; vastly reduced risk of haze formation.
Refractive Surgery Overview

Step 1: Corneal flap is created with a microkeratome.

Step 2: The corneal flap is folded back.

Step 3: Excimer laser beam reshapes the cornea.

Step 4: The corneal flap is folded back in place.

LASIK
Like PRK, LASEK is a ‘surface ablation’ procedure. However, it deals very differently with the corneal epithelium.

The four keratoablative procedures differ solely in how the epithelium is handled.
Like PRK, LASEK is a ‘surface ablation’ procedure. However, it deals very differently with the corneal epithelium. **In LASEK, the epithelium is chemically devitalized and loosened by bathing it in alcohol.**

The four keratoablative procedures differ solely in how the epithelium is handled.
Like PRK, LASEK is a ‘surface ablation’ procedure. However, it deals very differently with the corneal epithelium. In LASEK, the epithelium is chemically devitalized and loosened by bathing it in alcohol.

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Like PRK, LASEK is a ‘surface ablation’ procedure. However, it deals very differently with the corneal epithelium. In LASEK, the epithelium is chemically devitalized and loosened by bathing it in alcohol. The loosened epithelium is then folded back, and the ablation is performed. Following the ablation, this ‘epithelial flap’ is smoothed back into place and covered with a bandage CL.

The four keratoablative procedures differ solely in how the epithelium is handled.
Refractive Surgery Overview

1. 
2. 
3. 
4. 

LASEK
Refractive Surgery Overview

In keratoablative procedures, remodeling of the central cornea occurs via annihilation of the corneal stroma with an excimer laser. But before the excimer can get to the stroma, the corneal epithelium has to get out of the way.

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Like PRK, LASEK is a ‘surface ablation’ procedure. However, it deals very differently with the corneal epithelium. In LASEK, the epithelium is chemically devitalized and loosened by bathing it in alcohol. The loosened epithelium is then folded back, and the ablation is performed. Following the ablation, this ‘epithelial flap’ is smoothed back into place and covered with a bandage CL. By re-positing the epithelium, LASEK avoids the large epi defect (and resulting severe pain) of PRK.
Refractive Surgery Overview

In keratoablative procedures, remodeling of the central cornea occurs via annihilation of the corneal stroma with an excimer laser. But before the excimer can get to the stroma, the corneal epithelium has to get out of the way.

The four keratoablative procedures differ solely in how the epithelium is handled.

Like LASEK, **epi-LASIK** is a surface-ablation variant designed to avoid the drawbacks of PRK. In it, a blunt keratome (an ‘epikeratome’) slides under the epithelium, separating it. The epithelial flap thus created is folded back, then re-placed after the stroma has been ablated. (BTW, *epipolis* is a Greek word meaning ‘superficial’.)
Like LASEK, epi-LASIK is a surface-ablation variant designed to avoid the drawbacks of PRK. In it, a blunt keratome (an ‘epikeratome’) slides under the epithelium, separating it.

In keratoablative procedures, remodeling of the central cornea occurs via annihilation of the corneal stroma with an excimer laser. But before the excimer can get to the stroma, the corneal epithelium has to get out of the way. The four keratoablative procedures differ solely in how the epithelium is handled.
Refractive Surgery Overview

Epi-LASIK

(For comparison)
Refractive Surgery Overview

In keratoablative procedures, remodeling of the central cornea occurs via annihilation of the corneal stroma with an excimer laser. But before the excimer can get to the stroma, the corneal epithelium has to get out of the way.

The four keratoablative procedures differ solely in how the epithelium is handled.

Like LASEK, **epi-LASIK** is a surface-ablation variant designed to avoid the drawbacks of PRK. In it, a blunt keratome (an ‘epikeratome’) slides under the epithelium, separating it. The epithelial flap thus created is folded back, then re-placed after the stroma has been ablated. (BTW, *epipolis* is a Greek word meaning ‘superficial.’)
Refractive Surgery Overview

Refractive Surgery

Intraocular
- Pseudophakic
- Phakic IOL

Corneal
- Incisional
  - PRK
  - LASEK
  - Epi-LASIK
  - LASIK
  - SMILE
- Laser
- Other

What are the three incisional keratorefractive procedures covered in the BCSC book?
What are the three incisional keratorefractive procedures covered in the BCSC book?
A set of incisions oriented radially (radial keratotomy, RK) will flatten the central cornea, and thereby reduce its converging power. Thus, RK can be used to treat myopia. Note that because incisions cannot produce overall steepening of the central cornea, RK cannot be used to treat hyperopia. Note also that RK is considered obsolete at this juncture, and is thus no longer performed in the US.
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Refractive Surgery Overview

Radial keratotomy

Figure 2: Incisions
Images A through E: Example of eye with 4, 8, 12, 16, and 20 incisions.
A set of incisions oriented radially (**radial keratotomy**, RK) will flatten the central cornea, and thereby reduce its converging power. Thus, RK can be used to treat **myopia**. Note that because incisions cannot produce overall **steepening** of the central cornea, RK cannot be used to treat hyperopia.
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OTOH, *peripheral* incisional procedures to offset refractive error are an important and oft-used surgical technique.
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OTOH, peripheral incisional procedures to offset astigmatic refractive error are an important and oft-used surgical technique.
Specifically, this refers to **AK** and **LRI**

OTOH, *peripheral* incisional procedures to offset *astigmatic* refractive error are an important and oft-used surgical technique.
Refraction Surgery Overview

Both AK and LRI incisions are placed on the steep meridian of the cornea, in pairs located on opposite sides of the cornea. AK incisions are made in the paracentral cornea, whereas LRI are made at the limbal cornea.
Both AK and LRI incisions are placed on the steep meridian of the cornea, in pairs located on opposite sides of the cornea. AK incisions are made in the paracentral cornea, whereas LRI are made at the limbus (as their name implies).
Refractive Surgery Overview

AK incisions

LR incisions

Limbal Relaxing Incisions
Refractive Surgery Overview

Both AK and LRI incisions are placed on the steep meridian of the cornea, in pairs located on opposite sides of the cornea. AK incisions are made in the paracentral cornea, whereas LRI are made at the limbus (as their name implies). Both techniques have the effect of flattening the meridian in which they’re placed, but through a process called *coupling*, steepening the meridian 90 deg away.
Both AK and LRI incisions are placed on the steep meridian of the cornea, in pairs located on opposite sides of the cornea. AK incisions are made in the paracentral cornea, whereas LRI are made at the limbus (as their name implies). Both techniques have the effect of flattening the meridian in which they’re placed, but through a process called *coupling*, steepening the meridian 90 deg away.
Refractive Surgery Overview

Corneal Coupling Effect

Before Corneal Incisions

After Corneal Incisions

Coupling
Refractive Surgery Overview

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Specifically, this refers to AK and LRI, which are incisional procedures to offset astigmatic refractive error, as an important and oft-used surgical technique. Both AK and LRI incisions are placed on the steep meridian of the cornea, in pairs located on opposite sides of the cornea. AK incisions are made in the paracentral cornea, whereas LRI are made at the limbus (as their name implies). Both techniques have the effect of flattening the meridian in which they're placed, but through a process called coupling, steepening the meridian 90 degrees away.

The most common indication for AK is correction of astigmatism in an eye that is s/p penetrating keratoplasty. LRI are typically placed at the time of cataract surgery to correct corneal astigmatism in hopes of producing better UCVA post-op.
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Refractive Surgery Overview

Refractive Surgery

Intraocular
- Pseudophakic
- Phakic IOL

Corneal
- Incisional
  - RK
  - AK
  - LRI
- Laser
  - PRK
  - LASEK
  - Epi-LASIK
  - LASIK
  - SMILE

Other

These are the ‘other’ procedures covered in the BCSC book
Refractive Surgery Overview

Refractive Surgery

- Intraocular
  - Pseudophakic
  - Phakic IOL

- Corneal
  - Incisional
    - RK
    - AK
    - LRI
  - Laser
    - PRK
    - LASEK
    - Epi-LASIK
    - LASIK
    - SMILE
  - Other
    - Conductive Keratoplasty (CK)
    - Small Aperture Inlay (SAI)
    - Corneal Reshaping Inlay (CRI)
    - Corneal CROSS Linking (CXL)
    - Intrastromal Corneal Ring Segments (ICRS)

These are the ‘other’ procedures covered in the BCSC book.
Refractive Surgery Overview

Refractive Surgery

Intraocular
- Pseudophakic
- Phakic IOL

Corneal
- Incisional
- Laser
- Other
  - RK
  - AK
  - LRI
  - PRK
  - LASEK
  - Epi-LASIK
  - LASIK
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These three treat presbyopia
Refractive Surgery Overview

Refractive Surgery

Intraocular
- Pseudophakic
- Phakic IOL

Corneal
- Incisional
- Laser
  - RK
  - AK
  - LRI
  - PRK
  - LASEK
  - Epi-LASIK
  - LASIK
  - SMILE

Other

These three treat presbyopia

- Conductive Keratoplasty
- Small Aperture Inlay
- Corneal Reshaping Inlay

Corneal CROSS Linking
Intrastromal Corneal Ring Segments
Refractive Surgery Overview

Refractive Surgery

Intraocular
- Pseudophakic
- Phakic IOL

Corneal
- Incisional
  - RK
  - AK
  - LRI
- Laser
  - PRK
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  - LASIK
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- Other
  - Conductive Keratoplasty (CK)
  - Small Aperture Inlay (SAI)
  - Corneal Reshaping Inlay (CRI)
  - Corneal CROSS Linking (CXL)
  - Intrastromal Corneal Ring Segments (ICRS)

These three treat presbyopia

These two treat keratoconus
Refractive Surgery Overview

- **Refractive Surgery**
  - Intraocular
    - Pseudophakic
    - Phakic IOL
  - Corneal
    - Incisional
      - RK
      - AK
      - LRI
    - Laser
      - PRK
      - LASEK
      - Epi-LASIK
      - LASIK
      - SMILE
    - Other
      - Conductive Keratoplasty (CK)
      - Small Aperture Inlay (SAI)
      - Corneal Reshaping Inlay (CRI)
      - Corneal CROSS Linking (CXL)
      - Intrastromal Corneal Ring Segments (ICRS)

**These three treat presbyopia**

**These two treat keratoconus**
Refractive Surgery Overview

Refractive Surgery

Intraocular

Corneal

Pseudophakic

Conductive Keratoplasty (CK)

Small Aperture Inlay (SAI)

Corneal Reshaping Inlay (CRI)

Corneal CROSS Linking (CXL)

Intrastromal Corneal Ring Segments (ICRS)

In CK, a thermal probe is used to produce a set of focal corneal scars. The scars produce local corneal steepening, thereby increasing convergence and improving vision at near.

Flattening v steepening

Convergence v divergence
In **CK**, a thermal probe is used to produce a set of focal corneal scars. The scars produce local corneal steepening, thereby increasing convergence and improving vision at near.
Refractive Surgery Overview

CK probe

CK in action

CK scars
Refractive Surgery Overview

In **CK**, a thermal probe is used to produce a set of focal corneal scars. The scars produce local corneal steepening, thereby increasing convergence and improving vision at near.

The **SAI** is a [small aperture inlay](https://example.com) that is implanted in [where?] the cornea. Its central [describe it—size, shape] produces a [effect to improve near vision]

**Small Aperture Inlay** — **SAI**

**Conductive Keratoplasty** — **CK**

**Corneal Reshaping Inlay** — **CRI**

**Corneal CROSS Linking** — **CXL**

**Intrastromal Corneal Ring Segments** — **ICRS**
In **CK**, a thermal probe is used to produce a set of focal corneal scars. The scars produce local corneal steepening, thereby increasing convergence and improving vision at near.

The **SAI** is a tiny donut-shaped disc that is implanted in the central corneal stroma. Its central aperture produces a pinhole effect to improve near vision.
Refractive Surgery Overview

Made from Polyvinylidene Fluoride (PVDF)

The KAMRA inlay

Contact lens
Refractive Surgery Overview
In **CK**, a thermal probe is used to produce a set of focal corneal scars. The scars produce local corneal steepening, thereby increasing convergence and improving vision at near.

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Like the SAI, the **CRI** is a tiny device implanted in the central corneal stroma. However, its mechanism of action is different—it is a tiny disc with a central 'bump' that increases the curvature of the overlying corneal surface, which in turn increases corneal convergence and thus improves near vision.
In **CK**, a thermal probe is used to produce a set of focal corneal scars. The scars produce local corneal steepening, thereby increasing convergence and improving vision at near.

The **SAI** is a tiny donut-shaped disc that is implanted in the central corneal stroma. Its central aperture produces a pinhole effect to improve near vision.

Like the SAI, the **CRI** is a tiny device implanted in the central corneal stroma. However, its mechanism of action is different—it is disc-shaped with a central ‘bump’ that increases the curvature of the overlying corneal surface, which in turn increases corneal convergence and thus improves near vision.
Refractive Surgery Overview

CRI
Refractive Surgery Overview

Refractive Surgery

Intraocular
- Pseudophakic
- Phakic IOL

Corneal
- Laser
  - PRK
  - LASEK
  - Epi-LASIK
  - LASIK
  - SMILE
- Incisional
  - RK
  - AK
  - LRI

Other

Corneal CROSS Linking

CXL involves the induction of a chemical reaction that strengthens the bonds between corneal stroma fibrils. The result is a stabilization of the keratoconus process.
Refractive Surgery Overview

Refractive Surgery

Intraocular
- Pseudophakic
- Phakic IOL

Corneal
- Incisional
  - RK
  - AK
  - LRI
- Laser
  - PRK
  - LASEK
  - Epi-LASIK
  - LASIK
  - SMILE
- Other

**CXL** involves the induction of a chemical reaction that strengthens the bonds between corneal stroma fibrils. The result is a stabilization of the keratoconus process.
Refractive Surgery Overview

BEFORE CXL: LESS CROSSLINKING
= WEAKER CORNEA

AFTER CXL: MORE CROSSLINKING
= STRONGER CORNEA

CXL concept
Refractive Surgery Overview

1. We remove the Epithelium

2. Riboflavin (Vitamin B2) eye drops are applied onto the cornea

3. 1 minute later, the solution is irrigated or washed away by the surgeon

4. An ultra-violet light (UVA) illuminates the Riboflavin solution for the corneal cross-linking procedure

CXL: Process
Refractive Surgery Overview

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Refractive Surgery Overview

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Other

CXL involves the induction of a chemical reaction that strengthens the bonds between corneal stroma fibrils. The result is a stabilization of the keratoconus process.

ICRS employs segments of PMMA. These segments are placed in the peripheral corneal layer, where they produce local flattening and steepening.
Refractive Surgery Overview

Refractive Surgery

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- Other

CXL involves the induction of a chemical reaction that strengthens the bonds between corneal stroma fibrils. The result is a stabilization of the keratoconus process.

ICRS employs semicircular segments of PMMA. These segments are placed in the peripheral corneal stroma, where they produce local flattening.
Refractive Surgery Overview

Intrastromal ring segments
Refractive Surgery Overview

Intrastromal ring segments *in situ*
Refractive Surgery Overview

Intrastromal ring segments placed for KCN