The Cornea, The Lens & Refractive Surgery

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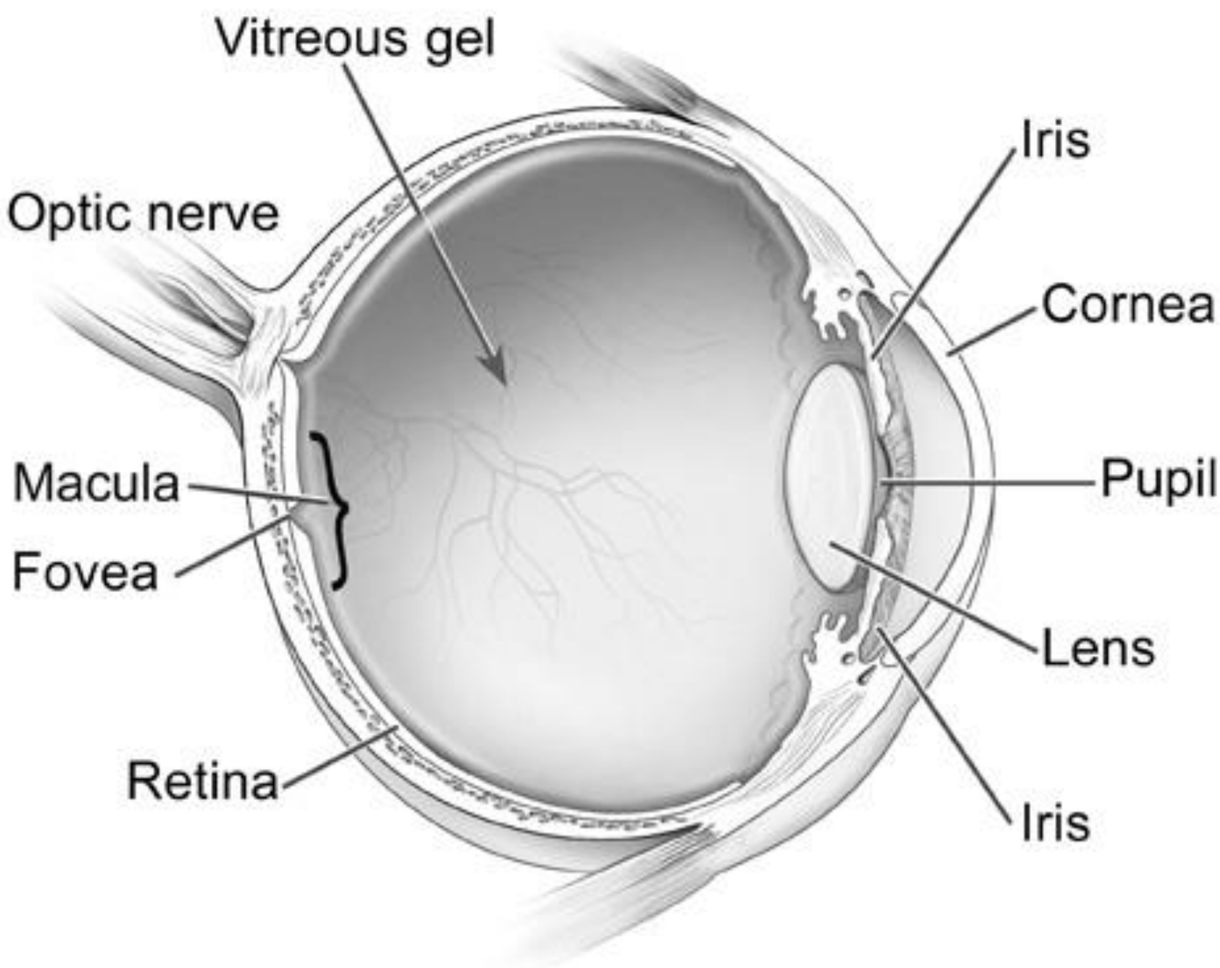

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Cornea

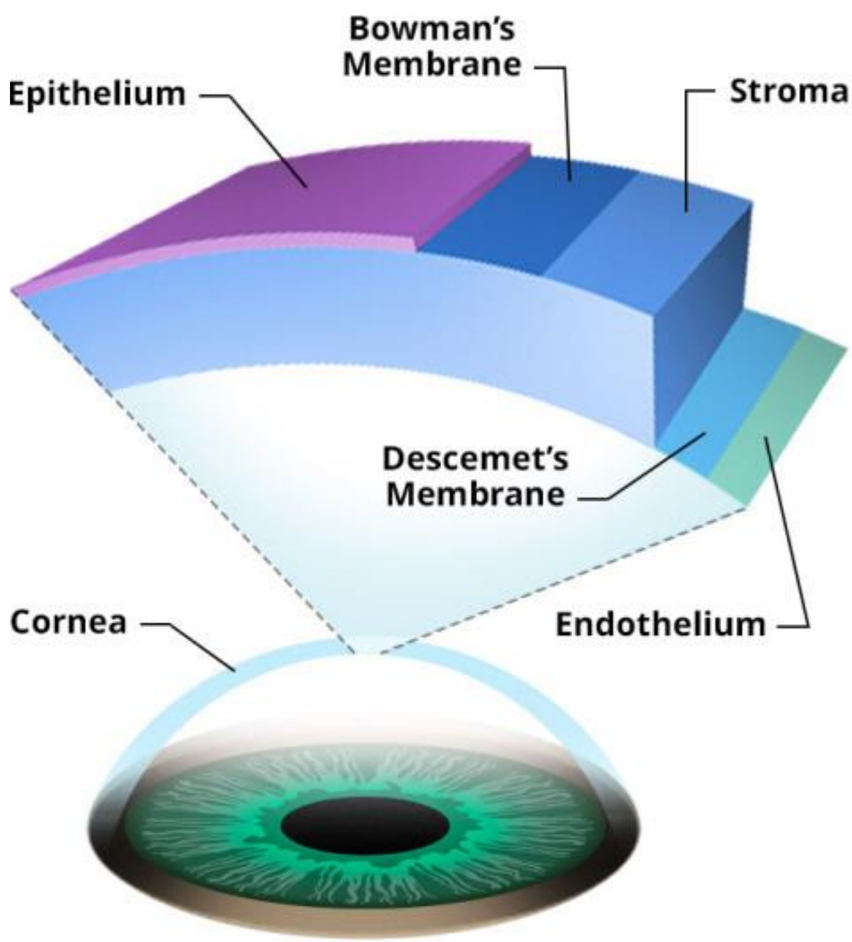
The cornea is the eye's outermost layer. It is the clear, dome-shaped surface that covers the front of the eye.

The main functions of the Cornea:

1. To shield the rest of the eye from germs, dust, and other harmful matter.
2. To act as the eye's outermost lens. It functions like a window that controls and focuses the entry of light into the eye. The cornea contributes between 65-75 percent of the eye's total focusing power.

Some facts about the cornea:

- The cornea is clear and appears to lack substance but it is actually a highly organized group of cells and proteins.
- Unlike most tissues in the body, the cornea contains no blood vessels to nourish or protect it against infection. Instead, the cornea receives its nourishment from the tears and aqueous humor that fills the chamber behind it.
- The corneal tissue is arranged in five basic layers, each having an important function. These five layers are the Epithelium, Bowman's Membrane, Stroma, Descemet's Membrane and the Endothelium.



Five Layers of the Cornea

Epithelium - the cornea’s outermost region, comprising about 10 percent of the tissue’s thickness. The epithelium functions primarily to: (1) block the passage of foreign material, such as dust, water, and bacteria, into the eye and other layers of the cornea; and (2) provide a smooth surface that absorbs oxygen and cell nutrients from tears, then distributes these nutrients to the rest of the cornea. The epithelium is filled with thousands of tiny nerve endings that make the cornea extremely sensitive to pain when rubbed or scratched. The basement membrane is the part of the epithelium that serves as the foundation on which the epithelial cells anchor and organize themselves.

Bowman’s Layer - Lying directly below the basement membrane of the epithelium is a transparent sheet of tissue known as Bowman’s layer. It is composed of strong layered protein fibers called collagen. Once injured, Bowman’s layer can form a scar as it heals. If these scars are large and centrally located, some vision loss can occur.

Stroma - Beneath Bowman’s layer is the stroma, which comprises about 90% of the cornea’s thickness. It consists primarily of water (78%) and collagen (16%), and does not contain any blood vessels. Collagen gives the cornea its strength, elasticity, and form. The collagen’s unique shape, arrangement, and spacing are essential in producing the cornea’s light-conducting transparency.

Descemet’s Membrane - Under the stroma is Descemet’s membrane, a thin but strong sheet of tissue that serves as a protective barrier against infection and injuries. Descemet’s membrane is composed of collagen fibers (different from those of the stroma) and is made by the endothelial cells that lie below it. Descemet’s membrane is regenerated readily after injury.

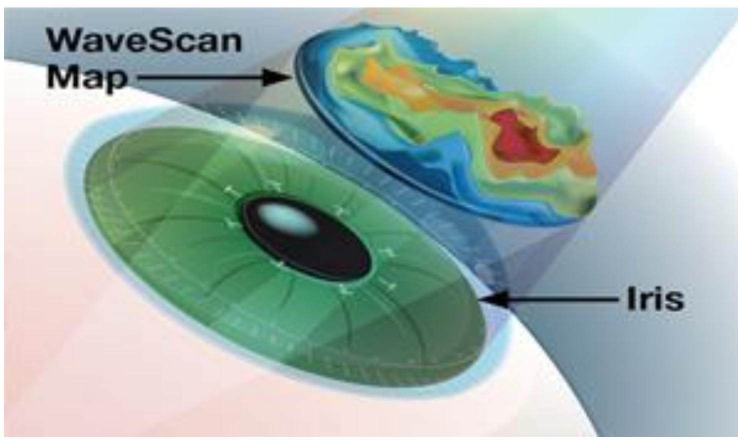
Endothelium - The endothelium is the extremely thin, innermost layer of the cornea. Endothelial cells are essential in keeping the cornea clear. Normally, fluid leaks slowly from inside the eye into the middle corneal layer (stroma). The endothelium’s primary task is to pump this excess fluid out of the stroma. Without this pumping action, the stroma would swell with water, become hazy, and ultimately opaque. In a healthy eye, a perfect balance is maintained between the fluid moving into the cornea and fluid being pumped out of the cornea. Once endothelium cells are destroyed by disease or trauma, they are lost forever. If too many endothelial cells are destroyed, corneal edema and blindness ensue, with corneal transplantation the only available therapy.

Corneal Refractive Surgery Procedures

The two main types of Corneal Refractive Surgeries are LASIK and PRK. Both procedures use a laser to reshape the cornea in order to improve the way the eye focuses light rays onto the retina at the back of the eye.

In the 1970s the excimer laser was invented, leading to the first eye surgery cases in the late 1980's. In 1999 scientists developed Wavefront Analysis. The wavefront technology maps a patient's prescription, which is as unique as a fingerprint. By programming this wavefront 'map' into the excimer laser, the laser precisely reshapes a patient's cornea, resulting in a truly customized procedure with improved results. This procedure gained U.S.FDA approval in 2002.

Wavescan - is the most up to date wavefront technology that is currently used today. In this wavefront guided technology, a very detailed three-dimensional 'map' of the patient's cornea is created that looks like a mountain range.



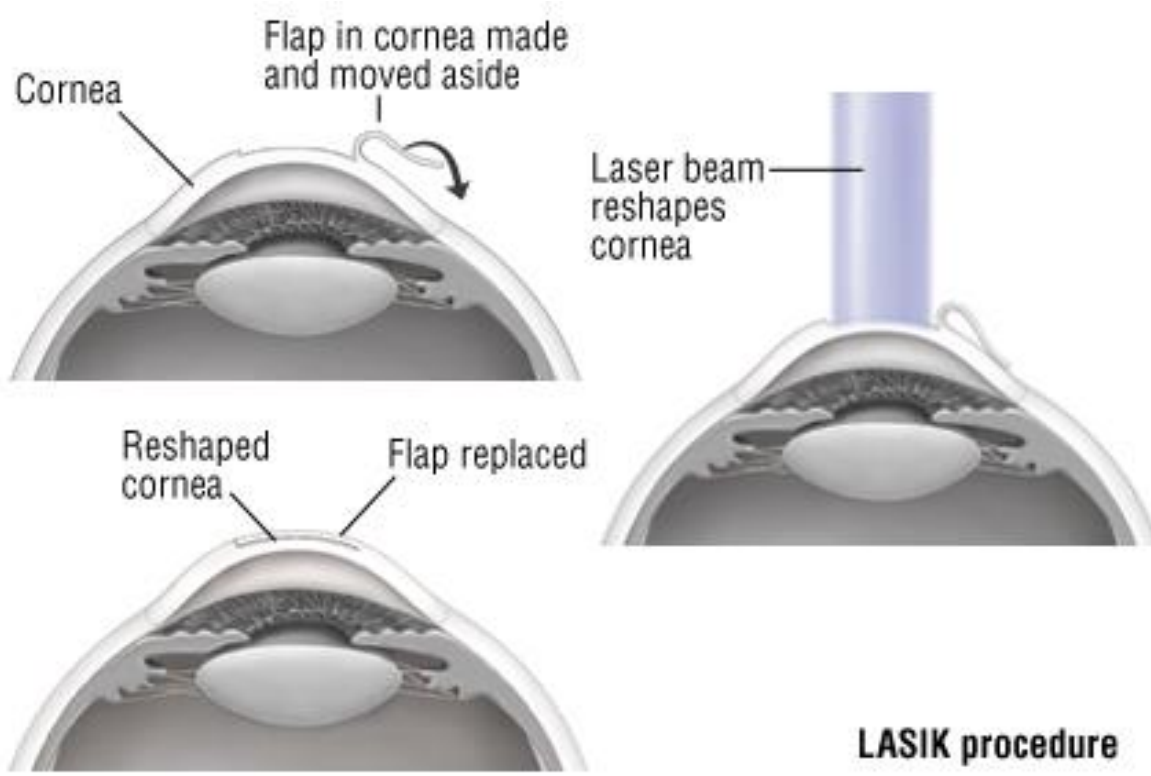
Photorefractive keratectomy (PRK) - an outpatient refractive surgery procedure used to treat all types of refractive error. In PRK the wavefront guided excimer laser is used to reshape the stroma portion of the cornea. In order to access the stroma, however, the epithelial layer must be removed. There are a handful of methods to remove this layer that surgeon may use. Once the top layer of epithelial cells are removed the wavefront guided excimer laser is used to reshape the cornea. A bandage soft contact lens is placed on the newly corrected cornea to promote epithelial healing and to protect the exposed lower layers of the cornea. The epithelium usually takes around 4 days to regrow. It may take a few days for vision to stabilize with PRK and varying levels of discomfort and pain result during the first days after surgery. The bandage lens is removed approximately 5 to 6 days after surgery.

Laser-assisted in situ keratomileusis (LASIK) - The most widely performed type of refractive surgery. LASIK is an outpatient refractive surgery procedure used to treat all types of refractive error. The difference between LASIK and PRK is that in LASIK a thin, hinged, corneal flap is created to separate the epithelium from the rest of the cornea. The epithelium is folded back and the wavefront guided excimer laser is used to reshape the remaining layers of the cornea. Once complete, the corneal flap is folded back down and placed back into position. The corneal flap sticks to the underlying tissue within two to five minutes and stitches are not needed. The patient is able to see clearly later that same day.

This corneal flap used to be created by a microkeratome – a precision surgical instrument with an oscillating blade. This technology has recently been replaced by the intralase laser.

Intralase Laser - This laser allows LASIK surgery to be performed 'blade free', allowing for more accuracy in the size and stability of the corneal flap that is created. The intralase works by using an infrared beam of light to create the flap from below the surface of the cornea. The beam of light is focused to a precise point within the stroma, where a string of tiny 2 to 3 micron bubbles is formed. Thousands of these microscopic bubbles are precisely positioned to define the flap's dimensions and distinct beveled edge, as well as location of the hinge. Bubbles are then stacked along the edge of the flap up to the corneal surface to complete the flap. The process from start to finish takes approximately 45 seconds.

LASIK provides instant gratification for patients looking for visual correction without glasses or contact lenses. A patient may not be a candidate for LASIK if they have too thin of corneas or are too Myopic or Hyperopic. LASIK does create scar tissue that will always be present on the eye and there is the risk that in extreme conditions the flap could separate from the rest of the cornea.



Lens

The lens is located just behind the cornea and the iris in the eye. The lens' job is to focus light on the retina in the back of the eye. It does this through a process called accommodation. Accommodation is made possible by the lens inside the eye and the circular muscle that surrounds the lens, called the ciliary muscle. The lens and ciliary muscle are connected by a 360-degree series of fibers (called ciliary zonules) that extend from the ciliary muscle to the thin lens capsule that encloses the lens. The ciliary muscle, ciliary zonules and lens capsule keep the lens suspended in its proper position inside the eye for clear vision.

Accommodation - in a normal eye (without presbyopia or cataracts), this dynamic process adjusts the focusing power of the eye by changing the thickness of the eye's natural lens. When the ciliary muscle is relaxed, the lens flattens to enable clear distance vision. When the ciliary muscle contracts, the lens thickens, becoming more curved for added magnification for clear near vision.

The lens also works together with the cornea to refract, or bend, light.

The lens is of ellipsoid, biconvex shape. The lens consists of the lens capsule, the lens epithelium, and the lens fibers. The lens capsule is the smooth, transparent outermost layer of the lens, while the lens fibers are long, thin, transparent cells that form the bulk of the lens. The lens epithelium lies between these two and is responsible for the stable functioning of the lens. It also creates lens fibers for the lifelong growth of the lens.

Presbyopia - (which literally means "aging eye") is an age-related eye condition that makes it more difficult to see very close. When you are young, the lens in your eye is soft and flexible. The lens of the eye changes its shape easily, allowing you to focus on objects both close and far away.

After the age of 40, the lens becomes more rigid. Because the lens can't change shape as easily as it once did, it is more difficult to read at close range. This normal condition is called presbyopia.

Since nearly everyone develops presbyopia, if a person also has myopia (nearsightedness), hyperopia (farsightedness) or astigmatism, the conditions will combine. People with myopia may have fewer problems with presbyopia.

Cataract – a clouding of the natural lens. Cataracts are the most common cause of vision loss in people over age 40 and is the principal cause of blindness in the world. In fact, there are more cases of cataracts worldwide than there are of glaucoma, macular degeneration and diabetic retinopathy combined. The lens is mostly made of water and protein and the protein is arranged in a precise way that keeps the lens clear and lets light pass through it. But as we age, some of the protein may clump together and start to cloud a small area of the lens. Over time, it may grow larger and cloud more of the lens, making it harder to see.

This clouding of the lens creates vision loss because it doesn't allow the lens to function properly. The clouding of the lens disperses the light that passes through the lens, not allowing the image to focus properly on the retina.

There are three main types of Cataracts:

1. **Subcapsular cataract -** occurs at the back of the lens. People with diabetes or those taking high doses of steroid medications have a greater risk of developing a subcapsular cataract.
2. **Nuclear cataract** forms deep in the central zone (nucleus) of the lens. Nuclear cataracts usually are associated with aging.
3. **Cortical cataract** is characterized by white, wedge-like opacities that start in the periphery of the lens and work their way to the center in a spoke-like fashion. This type of cataract occurs in the lens cortex, which is the part of the lens that surrounds the central nucleus.

Cataract Surgery

Most people are familiar with Cataract Surgery as it is the most frequently performed surgery in the United States. During surgery, the surgeon will remove the clouded lens and in most cases replace it with a clear, plastic intraocular lens (IOL). The clouded distorted vision will be gone but the patient is left with a new problem; their flexible, adjustable lens is also gone.

In the past this meant that a person would have to wear glasses to obtain 20/20 vision as the IOL in their eye no longer has the ability to change shape and perfectly position the image on the retina as it used to.

Refractive Lens Surgery

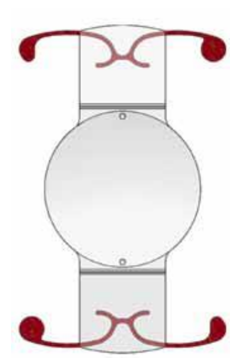
New technologies now allow the patient the option to correct their refraction when implanting an IOL. There are many IOLs available in the market today, each costing varying amounts of money and all providing slightly or significantly different results, its first important to understand the patient's visual desires after surgery. Assuming the patient desires to be out of glasses, the patient must decided whether they simply desire to be out of glasses for distance or for both near and distance. Even though there are many IOL choices, they all fall into these main categories:

Monofocal IOL – an intraocular lens with a fixed focus for one distance. The doctor can select the IOL that provides near focus, mid-distance focus or distance focus. Only one of these three can be selected and the focus will not change after surgery.

Toric IOL – premium intraocular lenses that correct astigmatism as well as nearsightedness or farsightedness. Toric IOLs can correct astigmatism because they have different powers in different meridians of the lens. They also have alignment markings on the peripheral part of the lens that enable the surgeon to adjust the orientation of the IOL inside the eye for optimal astigmatism correction.

Multifocal IOL – premium intraocular lenses that correct distance and near vision. These IOLs allow the patient to be completely glasses free or mostly free with occasional help reading small print. Multifocal lenses work by offering rings throughout the lens. Each ring is set to a specific distance or near rotating refraction. Light entering the lens is distributed through both the distance and near rings providing both images on the retina for the brain to interpret a full range of vision.

Accommodating IOL - premium intraocular lenses that corrects distance and near vision. Unlike the rings of a multifocal, accommodating lenses work by trying to emulate the natural lenses accommodation process. In an accommodating IOL, the haptics (peripheral 'legs' that secure the IOL inside the lens capsule during surgery) are designed to keep the IOL securely in place and prevent any rotational movement, but the legs are flexible in a way that allows the optical portion of the IOL to move slightly forward upon contraction of the ciliary muscle. In this fashion, an accommodating IOL can mimic the eye's natural accommodating process providing better near vision without eyeglasses than what is possible with a conventional monofocal IOL procedure. Currently the accommodating ability is far less superior then the natural lens' ability and the patient will still need reading glasses to comfortably see small print and perform other near vision tasks.



Toric-Accommodating IOL - premium intraocular lenses that corrects distance vision, near vision and astigmatism. This IOL is simply a combination of the toric and accommodating lenses; with the same accommodation process and multiple meridians to the lens.

Monovision – the process of setting your eyes at two different distances. Usually the dominant eye is set to clear distance vision and the non-dominant eye is set to clear near vision using monofocal IOLs in each eye. Your brain is able to interpret the two images and the intermediate distance in between into a full range of clear vision.

Modified monovision - Instead of using monofocal IOLs in both eyes, an experienced surgeon can pair a monofocal IOL with either a multifocal IOL or accommodating IOL in the other eye. When set correctly this can provide an even greater amount of visual freedom then what is possible from any of the above IOL options used alone.

Special Testing for Refractive Surgery

Once the appropriate lens is selected (based on the patient's visual desire) the physician must decide what power lens to implant. Selecting the correct lens power is often times the most important part to providing the patient with 20/20 vision after surgery. In order to select the correct power(s) there are numerous specialized tests that should be run using some of the most up to date measuring equipment available. Most of these tests involve measuring the patient's ocular biometry.

Ocular Biometry – the process of determining anatomical measurements of the eye, generally including the axial length (AL), Keratometry and anterior chamber depth (ACD). These measurements are crucial for the selection of the correct IOL power to achieve the desired refractive outcome after surgery.

Lenstar – optical biometry that captures seven measurements of the entire eye including lens thickness – all on the visual axis.

IOL Master – optical biometry that is part of the ZEISS Cataract Suite. It acquires a reference image in case of astigmatism during routine biometry. The image of the eye is taken along with the keraotmetry measurement.

Pentacam – a combined device consisting of a slit illumination system and a Scheimpflug camera which rotates around the eye. It takes multiple in depth measurements, eventually putting together a three-dimensional model of the entire anterior eye chamber. This information can be used to assess opacities in the cornea and in the pseudophakic lens providing a precise and complete measurement and analysis of the cornea.

Optical Coherence Tomography (OCT) - a non-invasive imaging test that uses light waves to take cross-section pictures of your retina, the light-sensitive tissue lining the back of the eye.

Optiwave Refractive Analysis (ORA) – a new tool used during Cataract Refractive Surgery that attaches to the microscope and allows continuous assessment of the patient's eye throughout the procedure. This tool provides real time measurements and analysis of the surgery allowing the surgeon to make changes and adjustments during surgery, leading to more precise outcomes.

Femtosecond Laser – A device that creates bursts of laser energy at an extremely fast rate measured in terms of a unit known as a femtosecond (one quadrillionth of a second). These ultra fast energy pulses precisely target and break apart tissue or other substances at a molecular level, without damaging adjacent areas. In refractive surgery an advanced femtosecond laser replaces or assists use of a hand-held surgical tool for the following steps in cataract surgery:

1. The corneal incision
2. The anterior capsulotomy
3. Lens and cataract fragmentation

Use of a laser can improve the precision, accuracy and reproducibility of each of these steps, potentially reducing risks and improving visual outcomes of cataract surgery.

Refractive Lens Surgery without a Cataract

Clear Lens Exchange (CLE) - As its name suggests, CLE is simply exchanging your natural clear lens for an IOL; its cataract surgery without having a cataract. Though most lens surgeries are done to remove cataracts, a patient may choose to have a lens surgery to correct their myopia, hyperopia or presbyopia, even without having Cataracts.

Phakic IOLs - clear implantable lenses that are surgically placed either between the cornea and the iris or just behind the iris, without removing your natural lens. These implantable lenses function like contact lenses with the obvious difference that they work from within your eye instead of sitting on the surface of your eye.

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