Cipla

Surgical Insights

Femtosecond Laser Cataract Surgery

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Femtosecond
Laser Cataract Surgery

Cataract surgery has evolved tremendously since it was first performed. With the advent of multifocal and accommodating intraocular lenses (IOL) and patients pursuing surgery earlier with less tolerance for visual impairment, cataract surgeons are facing increasingly high patient expectations for refractive outcome. Today, the goal of cataract surgery is to achieve near emmetropia.[2] Just as phacoemulsification improved outcomes compared with extracapsular cataract extraction (and extracapsular techniques improved on intracapsular surgery), a laser too offers an opportunity to meet better patients' expectations.[1]

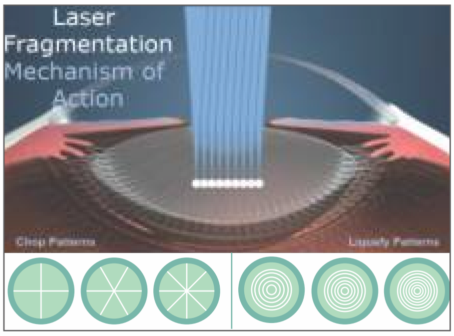
Femtosecond lasers (FSL) first became available for refractive surgery in 2001, when they were introduced for the purpose of flap creation in laser in-situ keratomileusis (LASIK). Since then, use of femtosecond lasers has been expanded to other corneal surgeries and most recently has been applied to cataract surgery.[2]

FSL was approved in 2010 for cataract surgery.[3] Just as for LASIK, femtosecond laser technology can deliver remarkable gains in reproducibility, centration, and safety in cataract surgery, delivering the necessary accuracy and precision to improve beyond current clinical outcomes.[2]

Femtosecond lasers: Mechanism of action

FSL causes tissue disruption with its near-infrared scanning pulse focused to 3 μm with an accuracy of 1 μm.[3] Photodisruption is essentially induced by vaporization of target tissues, which occurs through the following steps:

- The focused laser energy increases to a level where a plasma is generated;
- The plasma expands and causes a shock wave, cavitation, and bubble formation;
- And then the bubble expands and collapses, leading to separation of the tissue[3].



The FSL uses ultrafast pulses in the range of 10^{-15} seconds and due to its decreased energy requirements for tissue destruction, it causes reduced unintended destruction of surrounding tissues.[2] As the laser's near-infrared wavelength is not absorbed by optically clear tissue, it can be focused precisely at different depths within the anterior chamber.[2] The waves are known to dissipate approximately 100 μm from the lens tissue target.[3]

Can Femtosecond Laser improve cataract surgery?

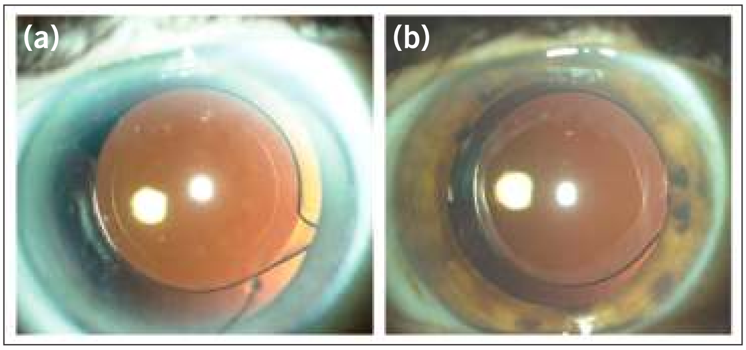
Importance in Capsulorhexis

One way in which femtosecond lasers may help ophthalmologists meet patients' expectations for postsurgical vision is that the technology can create a predictable and reproducible capsulorhexis. Whether the capsulorhexis is perfectly centered on axis, is a crucial determinant of the effective lens position, which, in turn, will affect the performance of the IOL[1]. A small capsulorhexis (<5.5mm) has been linked to anterior capsule fibrosis and hyperopic shift with a single-piece aspheric IOL. However, when the capsulorhexis is too large and there is insufficient overlap of the IOL by the capsule, there can be increased rates of tilt, decentration, and posterior capsular opacification, sometimes even requiring lens exchange.[2]

Creating precise and predictable capsulotomies should reduce the occurrence of aforementioned complications.[2] Early reports and presentations indicate that femtosecond laser technology improves surgeons' ability to increase their odds of achieving the intended refractive outcome via a more precise capsulorhexis.[1] Predictable and controlled IOL placement can be achieved more often when the capsul otomy incision is precisely sized and centered using a femtosecond laser system.[2]

In the human trials, laser capsulotomies were more than 12 times and four times more precise in terms of size and shape, respectively, than manual capsulorhexes, which was highly statistically significant ($P < .001$).[4]

Laser vs. Manual.
(a) Slit lamp view at 1-month postoperation of the capsulotomy and intraocular lens.
(b) Slit-lamp view at 1-month postoperation of a manual capsulorhexis and intraocular lens



Lens fragmentation

Femtosecond lasers can be used to segment the nucleus, allowing the surgeon to skip the difficult sculpting and chopping steps that most frequently lead to complications. Additionally, patterns of cuts can be placed on the nucleus to soften harder cataracts. These treatments could reduce the amount of ultrasound energy from the phacoemulsification probe, thereby diminishing the risk of capsule complications and corneal endothelial injury. There may be added safety benefits from reducing the number of instruments used, intraocular movements, and manipulations of the lens. Finally the treatments may be optimized for the irrigation/aspiration phacodynamics to reduce flow, trampolining, and iris prolapse.[2] In theory, this application should result in more efficient, safer surgery compared with manual removal of the lens.[1]

Surgical view after laser cataract surgery. Minimal petichae and subconjunctival hemorrhages are visible following use with the liquid optics interface.

Relaxing incisions

Femtosecond lasers can also be used to cut incisions intended for astigmatic correction, an important consideration given that a large portion of the cataract population has between 0.50 to 0.75 D of corneal astigmatism or more.[1] The cataract laser systems can perform corneal or limbal relaxing incisions (LRIs) to correct up to 3.5 D of astigmatism, flattening the steepest meridian of the cornea, eliminating a source of refractive error. Unlike with classic limbal relaxing incisions cut with a manual knife, however, surgeons have the option of making intracorneal laser arcuate incisions at the time of cataract surgery and opening them only if needed during the postoperative healing period.[1] Improved accuracy afforded by the femtosecond laser could improve the reliability of outcomes of laser LRIs compared with manual LRIs.[2]

Clear corneal incisions (CCI)

The self-sealing CCI is the preferred method of access into the anterior chamber for the superior visual outcomes and faster recovery it offers. However, there is an increased incidence of endophthalmitis with CCIs. Laser-made wounds may show less features of damage and faster healing, either by virtue of the wound properties or from reductions in the mechanical stresses during the operation.[2]

A femtosecond laser can be combined with optical coherence tomography. Real-time imaging allows the surgeon to use femtosecond laser technology to create accurate, predictable, and reproducible corneal incisions and limbal relaxing incisions.[1]

There are four primary steps for the laser cataract surgery procedure: Planning, engagement, visualization & customization, and treatment[2]

1. Planning

Prior to cataract surgery, individual variations in pupil dilation, lens thickness, corneal thickness, and other anatomy can be measured. After initial planning, adjustments can be made in real time using drag and drop user interfaces with incision overlays on video and cross sectional images.[2]

Planning parameters	
Capsulotomy	• Size, shape, and desired centre for the incision • The primary driver of the capsulotomy planning is the intraocular lens
Lens fragmentation	• Depth and diameter of cut, and pattern • These can be customized for lens density and matched to the surgeon's preferred technique • Reduces phacoemulsification time and energy
Relaxing incisions	• Traditional nomograms are used
Clear corneal incisions	• Location, depth, and architecture of incisions

2. Engagement

Prior to delivering the laser, a patient's eye must be stabilized relative to the optical system of the laser.[2] The cornea is applanated with a docking system that involves a contact lens with a circumferential suction skirt distributing pressure evenly on the cornea.[3] The interface would have a liquid between the laser system and eye, preventing corneal folds that occur with suction, and allowing for a tight laser focus, thus, minimizing energy, reducing cavitation bubble size, and optimizing treatment results.[2]

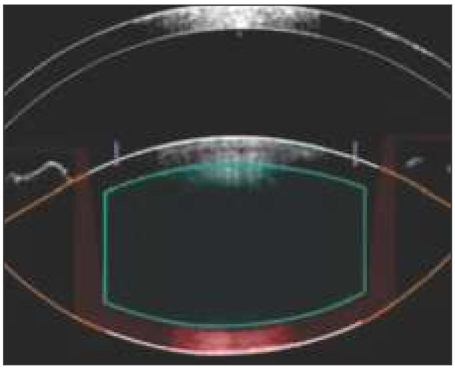
All currently available laser systems have appeared to be effective in stabilizing the eye and minimizing intraocular pressure (IOP) rise, however, the method and device for docking appears to be an area of differentiation for each platform.[2]

3. Visualization and customization

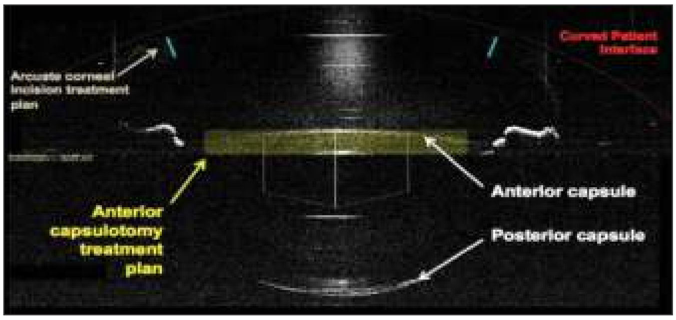
Once docking is complete, anterior segment imaging is then performed.[3] The image guidance system is a critical part of laser cataract surgery as it determines the location and dimension of ocular structures (cornea, iris, and anterior and posterior capsule) and guides the surgeon in customizing the placement of laser incisions and lens fragmentation zones.[2] It is also crucial that specific boundaries are mapped, including the iris and the posterior surface of the lens.

Pre-programmed corneal incisions for temporal wound, paracentesis, and any optional LRIs can be adjusted at this point to surgeon preference. The treatment plan is customized according to the patient's ocular anatomy and the orientation of the eye.[4] The pattern is then centered and the laser is activated.[3]

LenSx and OptiMedica laser systems use Fourier-domain optical coherence tomography (FD-OCT) for three-dimensional, high-resolution viewing of ocular structures. LensAR system uses a three-dimensional confocal structured illumination- scanning transmitter very similar to Scheimpflug technology.[2]



Detected surfaces (white), treatment area (purple and green), and safety zones (red) with image guidance system



Integrated online OCT imaging for planning and monitoring the procedure

4. Treatment

The final step of laser cataract surgery is the treatment. The laser spot pattern for a single incision is applied from posterior to anterior. This maintains a precise focus, avoiding scatter of the laser beam and also reduces the amount of radiation reaching the retina.[2] Usually, laser-assisted capsulotomy is performed, followed by lens fragmentation. This sequence is justified because lens fragmentation causes release of gas bubbles, which can distort the anatomy and affect capsulotomy planning.[3] The laser incisions are usually completed in approximately 30 to 60 seconds, depending on the desired cuts and their parameters. The capsulotomy takes 2 seconds to complete.[4]

Benefits[4]

- Safety and reproducibility
- Femtosecond laser should eliminate capsular tears due to the creation of an irregular capsulorhexis, thereby reducing the risk of breaking the posterior capsule and losing vitreous
- Laser procedure should lessen the occurrence of corneal burns and decrease damage to the corneal endothelium by reducing or eliminating the use of ultrasound energy
- May lower the rate of endophthalmitis through the creation of highly precise, reproducible, self-sealing corneal incisions
- Greater safety would increase predictability throughout the surgical procedure.
- OCT will allow ophthalmologists to visualize the entire anterior segment before and during the procedure
- A precisely created capsulorhexis will lead to a better-centered IOL and improved overlap of the lens by the capsular edge
- One of the most attractive facets of laser cataract surgery is its ability to address pre-existing astigmatism at the time of the lens' removal, because a large proportion of patients present with at least mild corneal cylinder
- Surgeons will now be able to treat this error, due to the precise axial placement, depth, and location of the limbal and peripheral corneal relaxing incisions

Limitations[3]

- Persistent epithelial defects from the trauma of docking into an optical system, in an otherwise routine cataract surgery
- Contraindications: Similar to FSL refractive surgery
  - Patients with deep set orbits/ tremors or dementia(do poorly with the initial docking of the lens that requires patient cooperation)
  - Anterior basement membrane dystrophy, corneal opacities (such as arcus senilis, corneal dystrophies, and trauma- or contact lens induced scars), ocular surface disease, pannus with encroaching blood vessels, or recurrent epithelial erosion syndrome
  - Additionally, the level of increase in IOP induced by the docking device has not been adequately quantified in published studies. This may be a significant contraindication for patients with glaucoma, optic neuropathies, or borderline endothelial pathology
  - Diabetics may have undiagnosed epithelial disease making them prone to epithelial defects
  - Patients with poor dilation would be poor candidates (eg. posterior synechiae, intraoperative floppy iris syndrome suspects, or those on chronic miotic medications)
  - Additionally, having a stable, stationary lens is needed for precise laser mapping and execution. Patients with phacodonesis and zonular dialysis, or even those with risk factors such as pseudoexfoliation syndrome or trauma, may not be ideal candidates.
- Cost- The laser machines with integrated OCT or Scheimpflug technology will add considerable cost to a currently standard procedure.

Indian Experience[5]

A randomized controlled study was performed at a tertiary care centre in India, which compared femtosecond laser assisted cataract surgery and conventional phacoemulsification with respect to the visual outcome and patient preference at 3 weeks.

The study included 32 eyes (16 patients) that underwent cataract surgery of both eyes at an interval of one week. All patients were randomised to undergo femtosecond laser assisted cataract surgery in one eye and the fellow eye was subjected to conventional phacoemulsification.

At day 1 and week 3, eyes that underwent femtosecond assisted cataract surgery had significantly better uncorrected visual acuity (UCVA), whereas the best corrected visual acuity (BCVA) was comparable with both techniques ($P>0.05$) at week 3. With femtosecond laser, there was significantly less surgically induced astigmatism contributing to the better UCVA.

The factor influencing patient preference in most cases was the patient's perception of a bladeless laser procedure. At 3 weeks, 56% patients preferred the femtosecond eye, 19% patients preferred the conventional phacoemulsification eye while 25% patients had no preference.

The study authors concluded that refined cataract surgery with enhanced visual outcomes could be offered by femtosecond laser. Pre-operative counselling and the perception of a "bladeless laser" procedure were important contributors to the patient preference towards femtosecond laser procedure.

Future applications

Compared with traditional techniques, laser cataract surgery offers the possibility of greater control and precision as well as a higher level of safety and standardization in anterior capsulotomies.[4] With its improved precision and accuracy, it may allow better preservation of the biomechanical properties of the lens capsule, enabling the creation of better accommodative IOLs.[2] The automation inherent in femtosecond technology brings reproducibility and consistency.[4]It has the potential to improve the predictability of the capsulotomy, arcuate and cataract incisions, and the effective lens position as well as to reduce the amount of energy used inside the eye to fragment the lens.[1]

Femtosecond lasers have also been investigated to restore accommodation to an aging, stiffening lens by separating collagen fibrils, or increasing the flexibility of the lens with incisions that act as gliding planes.[2]

There are also many groups attempting to use the femtosecond laser to reverse some of the accumulated damages contributing to cataracts and presbyopia. Throughout all applications, the new femtosecond laser systems usher in the future of cataract surgery and bring us one step closer to an ideal surgery that corrects cataract, astigmatism, and presbyopia.[2]

Adapted from:

1. *Advanced ocular care November/December 2011:39-40*
2. *Curr Opin Ophthalmol 2011;22:1-10*
3. *Middle East Afr J Ophthalmol. 2011 Oct-Dec; 18(4):285–291.*
4. *Advanced ocular care April 2011:31-38*
5. *http://www.escrs.org/milan2012/programme/free-paper-details.asp? id= 14066 & day=0 Last accessed on 4th July 2013.*