Application of Femtosecond Laser in Cataract Surgery

Essay
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in Ophthalmology

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Last but not least, sincere gratitude to Soul of My Parents for their spiritual support.

AIM OF THE WORK

The goal of this essay is to highlight the application of femtosecond laser in cataract surgery and to focus on the advantages and disadvantages of its usage.

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Femtosecond lasers first became available for refractive surgery in 2001, when they were introduced for the purpose of flap creation in laser in-situ keratomileusis (LASIK) **(Salomao and Wilson, 2010)**.

A new and very important application for the FSL is the lens **(Teuma et al., 2009)**, has shown the efficiency of the technology to obtain precise capsulotomies, with the desired size as centred as the surgeon wants, allowing the photoablation of the nucleus, fragmenting it in a variety of different patterns that allows, ideally, the aspiration of the nucleus and cortex material without using phaco energy, or at least reducing it to very small periods **(Nagy et al., 2009)**.

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Capsulotomy

Studies have shown that the size of the capsulorhexis is important to optimize positioning and intraocular lens (IOLs) performance

The capsulotomy construction is extremely important for estimating effective lens position (ELP).

Inaccurate prediction of the ELP has been identified as the biggest source of error in IOL power calculations **(Norrby, 2008)**. A difference of only 1mm in lens position can lead to an approximately 1.25 diopter change in refractive error (**Sanders et al., 2006)**.

Predictable and controlled IOL placement can be achieved more often when the capsulotomy incision is precisely sized and centered using a femtosecond laser system

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View from the Catalys near-infrared video system of a precisely sized, shaped and positioned laser capsulotomy.

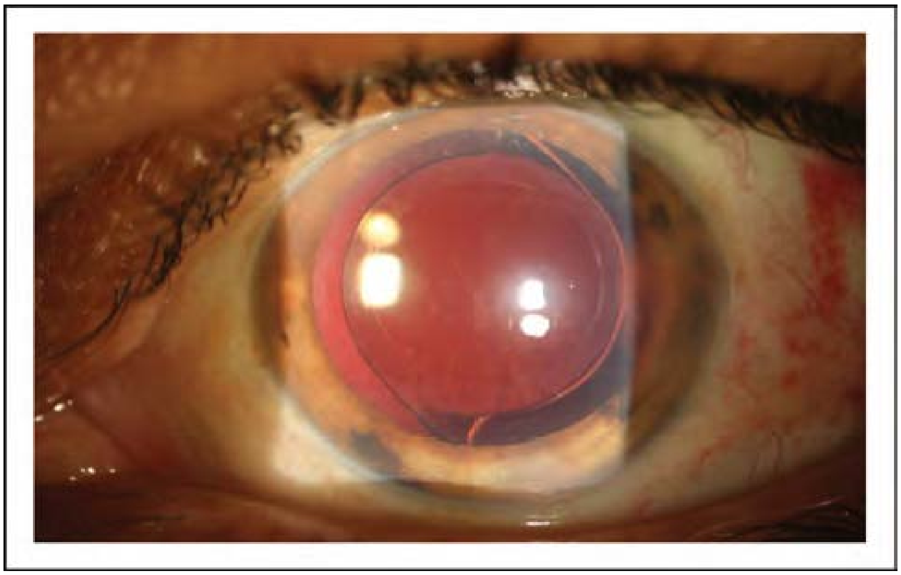


Figure (5.2): Intraocular lens with laser capsulotomy **(He et al., 2011)**.

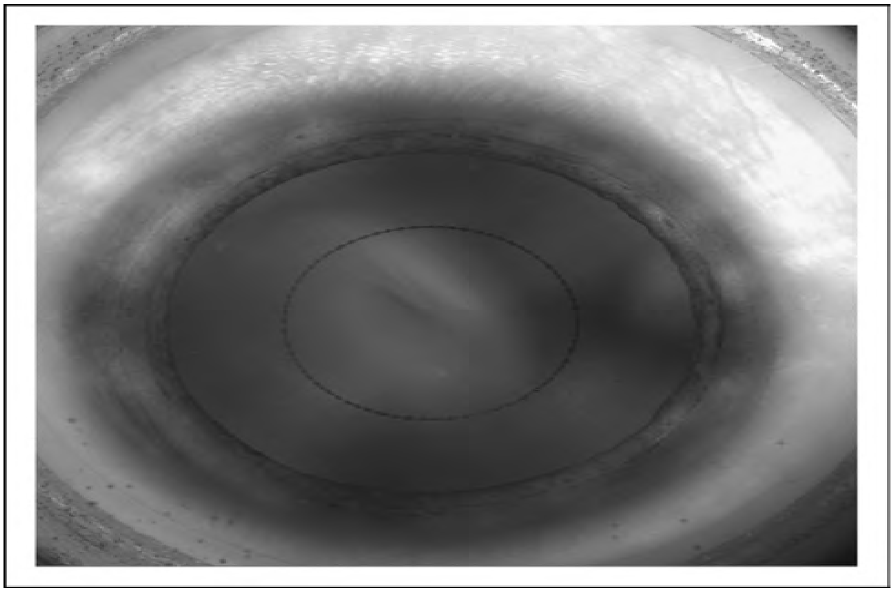
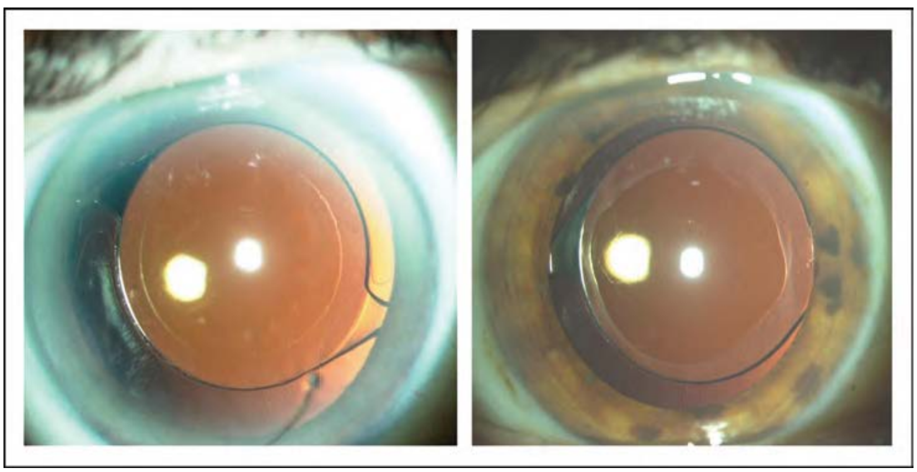


Figure (5.1): Laser capsulotomy **(He et al., 2011)**.



(a) **(b)**

Figure (5.3): 1 Month postoperative. Laser versus Manual. (a) Slit lamp view at 1-month postoperation of the laser capsulotomy and intraocular lens. (b) Slit-lamp view at 1-month postoperation of a manual capsulorhexis and intraocular lens **(He et al., 2011)**

The goal of femtosecond laser technology is to perform accurate and predictable capsulorhexis; the capsulotomy is currently evaluated by comparing its size, shape, and centration when created with the laser technique versus those from a manually created capsulorhexis.

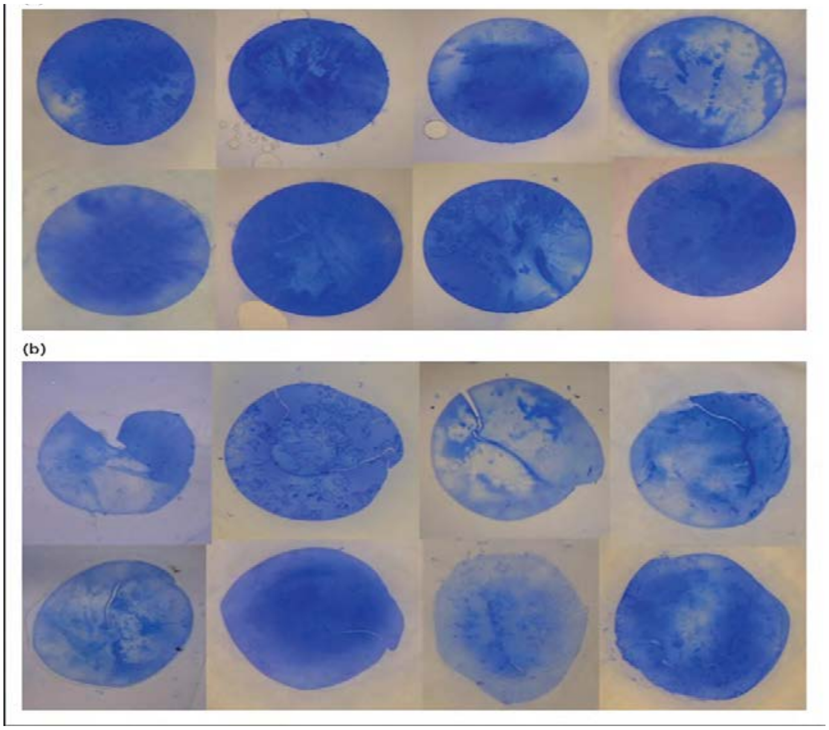


Figure (5.11): Capsule discs

Laser versus manual. Excised capsule tissue disk samples demonstrating repeatability of size and shape with (a) the laser system as compared with (b) manual samples.

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Lens fragmentation

emtosecond lasers can be used to segment the nucleus, allowing the surgeon to skip the difficult sculpting and chopping steps

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 **(Johansson et al., 2009)**.

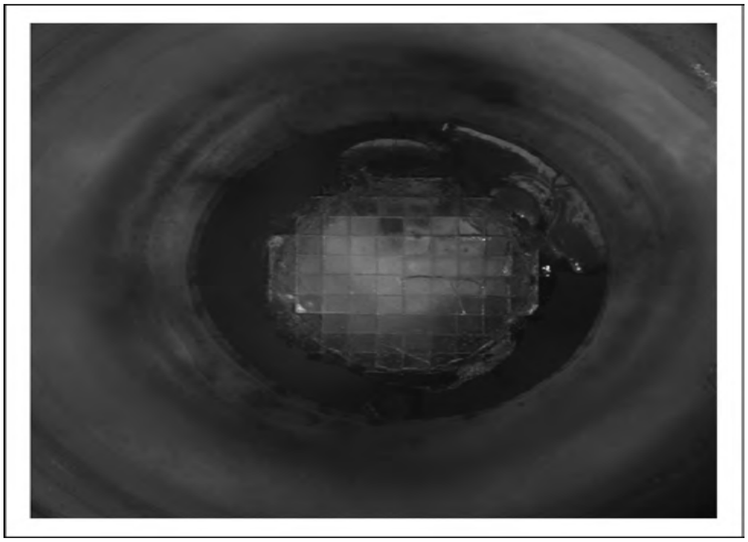

Figure (5.4): Laser lens fragmentation **(He et al., 2011**

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Relaxing incisions

The cataract laser systems can perform corneal or limbal relaxing incisions (LRIs) to correct up to 3.5 diopter of astigmatism, flattening the steepest meridian of the cornea, eliminating a source of refractive error

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Planning

For the capsulotomy, the planning parameters include the size, shape, and desired center for the incision

These can be customized for lens density and matched to the surgeon's preferred technique, reducing phacoemulsification time and energy

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Engagement

Prior to delivering the laser, a patient's eye must be stabilized relative to the optical system of the laser

An ideal interface would pull a tight vacuum over an annulus design for retention and stability without distorting the eye and causing IOP increase 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.

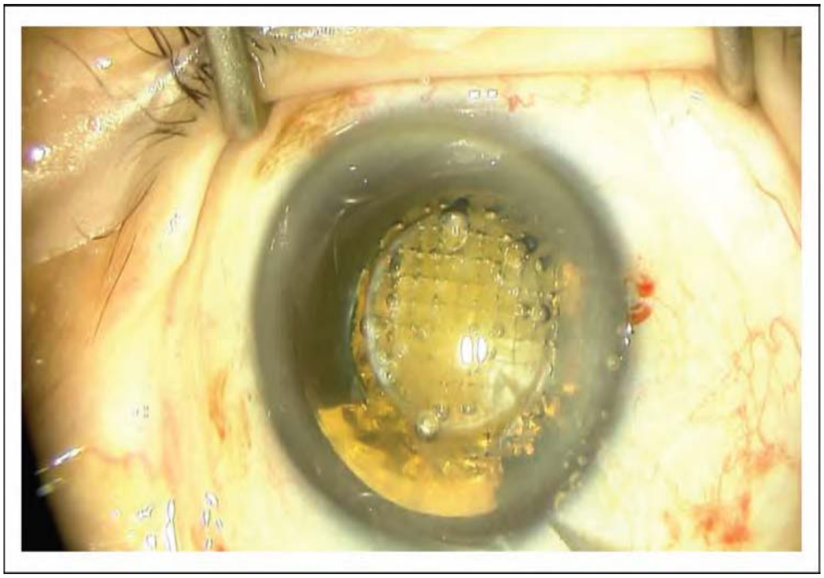

Figure (5.5): Laser cataract surgery **(He et al., 2011).**

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Visualization and customization

Anterior segment imaging with Fourier-domain optical coherence tomography (FD-OCT) now allows for real-time, high-resolution measurements of lens position, corneal thickness, iris boundaries, and iridocorneal angle. Although visualization of the ciliary body is limited by the pigmentation of the iris, this technology offers several advantages including non contact application, accuracy in the presence of corneal opacity, ease of use, and high-resolution profile imaging **(Doors et al., 2010)**.

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Comparison between the 3 United States-based laser systems

Although all three systems have demonstrated a level of capsulotomy precision beyond the manual technique, the accuracy and degree of precision of the three systems is not uniform. A summary follows of the early clinical data from 2010 on the size, shape, and position of the capsulotomy and ease of lens fragmentation. Corneal incision data are still limited **(He et al., 2011)**.

Figure (4.2): LenSx Laser System.
http://www.devicelab.com/portfolio/laser-eye-surgery-system.php (retrieved in July 2011).

Figure (4.3): LensAR Laser System.
http://www.bleckdesigngroup.com/medicalproductdesign/ (retrieved in July 2011).

Figure (4.4): Optimedica Laser System.

http://www.bleckdesigngroup.com/medicalproductdesign/ (retrieved in July 2011).

Table (5.1): Capsulotomy Size Accuracy: Comparative View

	OptiMedica (Lane et al., 2010)	LensAR (Nichamin et al., 2010)	LenSx (Nagy et al., 2010)
Manual (mean ± SD)	0.339 ± 0.248 mm	0.46	10% < 0.25mm
Laser (mean ± SD)	0.027 ± 0.025mm	0.18	All < 0.25 mm

All companies found that the laser capsulotomy was more precise than manual capsulorhexes. OptiMedica reported 0.027mm (SD, 0.025mm) of intended diameter for laser capsulotomy compared with 0.339mm (SD, 0.248mm) for manual capsulorhexis **(Lane et al., 2010)**.

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Table (5.2): Capsulotomy Shape Accuracy: Comparative View

	Measurement Technique	Laser (mean ± SD)
OptiMedica (Lane et al., 2010)	Circularity	0.942 ± 0.040
LensAR (Nichamin et al., 2010)	Consistency of shape (squared residuals)	0.003
LenSx (Nagy et al., 2010)	Roundness	Significantly rounder

For capsulotomy shape, each company used different measurement techniques, so a comparison is not easily assessed

OptiMedica measured circularity as a function of capsulotomy diameter and area with 1 being perfectly circular. OptiMedica laser capsulotomies measured 0.942 (SD, 0.040) **(Lane et al., 2010)**. LensAR used a residuals analysis technique to determine consistency of shape, result was 0.003 for the laser capsulotomies and 0.02 for the manual capsulorhexis **(Nichamin et al., 2010)**. LenSx laser capsulotomies were 'significantly rounder' than manual continuous circular capsulorhexis **(Nagy et al., 2010)**.

For capsulotomy position, OptiMedica reported centration within 86µm (SD, 51µm) of intended placement **(Lane et al., 2010)**, whereas LenSx IOL centration was significantly better in laser group as compared with manual **(Fig. 5.12) (Nagy et al., 2010)**. LensAR has not reported on centration. In this study, centration was measured only for the laser capsulotomy arm because the center of manual discs was not consistently discernible **(He et al., 2011)**.

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Lens fragmentation

By pre segmenting the nucleus and using laser patterns to soften harder cataracts, laser fragmentation has been shown to reduce the amount of ultrasound energy from the phacoemulsification probe

Table (5.3): Reduction in Phaco Energy required to remove the Crystalline Lens

	All Lenses	Grade 4 Lenses only
OptiMedica (Talamo, 2010)	38% reduction in CDE	40% reduction in
LensAR (Fishkind et al., 2010)	> 35% reduction in CDE	41.6% reduction in CDE
LenSx (Slade et al., 2010)	54% reduction in average phaco power	

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LIMITATION OF FEMTOSECOND CATARACT SURGERY

The major risks involved in femtosecond cataract laser surgery are loss of suction during the procedure and displacement of the laser pulses. This can lead to posterior capsular rupture

Displaced laser pulses could also damage the iris, causing hemorrhage in the anterior segment, or damage the corneal endothelium

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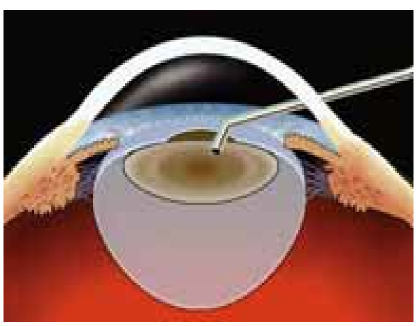
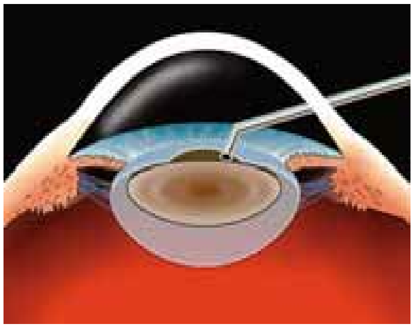
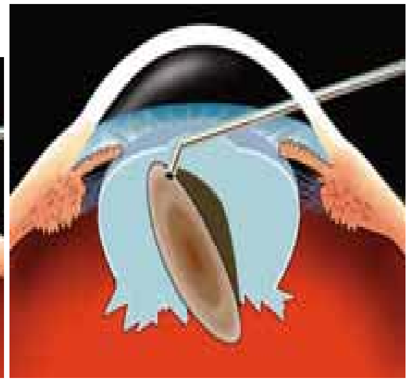
Gerard in 2011, showed results over 200 cases done by six surgeons. One surgeon had two cases of capsular block syndrome (CBS), which resulted in nuclear displacement requiring vitrectomy and a second procedure to remove the lens

Intraoperative CBS occurs during rapid hydrodissection using a large amount of BSS





The nucleus occludes the anterior capsular opening created by the continuous curvilinear capsulorhexis as a result of capsular blockage, and the trapped BSS expands toward the posterior capsule, which the fluid inflates completely and pushes anteriorly. The anterior chamber becomes shallow, and the IOP rises, the posterior capsule ruptures, and the nucleus luxates into the vitreous cavity. The BSS that flows into the vitreous cavity through the ruptured posterior capsule may also contribute to an anterior shifting of the capsular bag **(Miyak, 2005)**.

Complex cataract cases, such as those with very opaque nuclei, corneal opacity or edema, conjunctival bleb due to previous filtration surgery and poor iris dilation are the contra-indications for the procedure
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Economics:

Expenses may increase for both cost per case (i.e. cost of laser and related disposables) and increased surgical time, which will in the short term reduce the number of cases that a surgeon or operating room can perform on any given day.
in the long run, as was true for phacoemulsification and all-laser LASIK surgery, improved results will ultimately drive the acceptance (or rejection) of femtosecond laser cataract technology.

THANK YOU

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