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FEMTOLASER CATARACT SURGERY

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Chapter 4

Quick Overview on Femtosecond Laser for Cataract Surgery

P Crozafon

In 1978, the question was: "Is phacoemulsification the future of cataract surgery?"

Over the last 30 years, more than 50 million eyes have undergone phaco surgery!

In 1984, the cost of a phaco machine was 100.000 € and the cost of a phaco tip was 100 €.

In the beginning of 2012, the question was: "Is femtophaco surgery the future of cataract surgery?"

After 1 year of practicing femto laser-assisted cataract surgery with the LenSx® system, my answer is "YES! This is the future of cataract surgery."

Just two points:

- The surgical-induced astigmatism (SIA) of my patients treated with femtophaco is only 0.03 D and 47% of whom are totally emmetropic postoperative at 0 D with 93% within ± 0.50 D.
- This allows me to use advanced technology intraocular lenses (IOLs) in almost 70% of my cases.

General Considerations

Laser-tissue interaction occurs in different forms:

- Photocoagulation which produces heat
- Photodisruption which produces rupture
- Photoablation which produces chemical breakdown of tissues
- Photodynamic which enhances the pharmacological action.

A variety of short pulsed lasers are utilized:

- Nanosecond: Billionths of a second in traditional yttrium-aluminium-garnet (YAG) lasers.
- Picosecond: Trillionths of a second in some early YAG-lasers.
- Femtosecond: Quadrillionths of a second in refractive and cataract lasers.

Femtosecond laser pulses have a specific laser-tissue interaction in which the plasma effect within protein tissue provides a method to cut and dissect tissue.

These lasers produce ultrashort pulses with energy (work done) and power (rate that work is done).

- Energy (Joules) = Power × Time
- Power (Watts = Joule × Second) = Energy × Time
- Femtosecond laser generates a photodisruption effect in a precise spot inside the cornea, the capsule or the lens, where a pulse of laser energy is focused and delivered.
- Microplasma is generated, vaporizing a sphere with a diameter of approximately 1 µm of tissue.
- Photodisruption produces an expanding bubble of gas and water.
- The gas and water produced by photodisruption create a cleavage plane in the tissue.

These lasers work only if the tissues for the most part are "clear".

Major Variables of Femtosecond Laser Cataract Systems

- Graphic user interface
- Imaging technique
- Patient interface (PI)
- Available incision patterns
- Nuclear softening

Currents Systems

- LenSx® (Alcon LenSx Inc, Fort Worth, TX)
- Victus™ (Bausch & Lomb/Technolas Perfect Vision GmbH, Munich, Germany)
- LensAR (LensAR Inc, Winter Park, FL)
- Catalys® Precision Laser System Abbott (Illinois, USA)
- IntraLase (AMO, Santa Ana, CA)
- LDV (Zeimer, Port, Switzerland)

The LenSx is the most diffused system (more than 300 machines, 1,000 surgeons and more than 10,000 procedures performed at this writing).

Imaging Methods

- Optical coherence tomography (OCT):
  - LenSx®
  - Victus™
  - Catalys® precision laser system
- Optical (modified Scheimpflug)
  - LensAR
- Rangefinder (attenuated 1,053 nm pulses)
  - IntraLase

Patient Interface

Ideally, the PI should allow a clear optical path for focused laser delivery, a minimal increase of intraocular pressure (IOP) and stability of the globe relative to the optical system.

- Curved applanation lens:
  - LenSx®
  - Victus™
- Liquid
  - LensAR
  - Catalys® precision laser system
  - IntraLase

The Application of Femtosecond Laser in Cataract Surgery

Typical cataract surgery involves (Fig. 1):

- Primary and secondary (smaller) incisions (1)
- Capsulorhexis (2)
- Lens fragmentation (3)
- Phacoemulsification
- Intraocular lens insertion
- Incision closure.

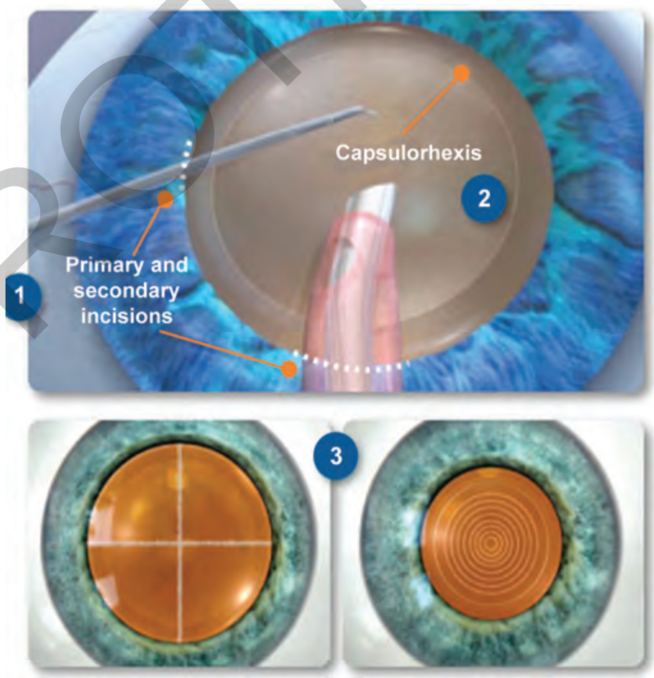


Fig. 1 Applications of femtosecond laser in cataract surgery

Setting the Laser

The surgeon can choose the steps he would like to use for each patient (Fig. 2).

Fig. 2 Selection of treatments

Setting Anterior Capsule Treatment

The surgeon must specify (Fig. 3):

- Diameter of capsulotomy
- Upper and lower deltas
- Energy level
- Tang spot separation
- Layer separation.

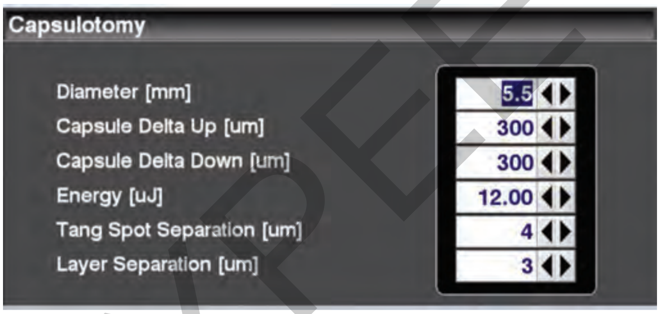


Fig. 3 Setting anterior capsule treatment

Personal Preferences

- Diameter: 5.2 mm
- Delta up: 400 µm
- Delta down: 350 µm
- Energy: 15 mJ
- Spot separation: 4 µm
- Layer separation: 3 µm

Motives for These Preferences

- A 5.2 mm diameter rhexis reduces the stress that can occur on the capsulotomy while perfectly covering a 6 mm diameter IOL.
- Setting the upper and lower deltas close to 400 µm allows a more complete rhexis in case of tilting.

Setting Nucleus Treatment

The surgeon must specify (Fig. 4):

- Pattern of chops and cylinders
- Number of chops or cylinders
- Length of chops or diameter of cylinders
- Anterior and posterior lens offsets
- Energy level
- Spot separation
- Layer separation
- Primary incision angle offset from the chop incision.

Fig. 4 Setting nucleus treatment

Personal Preferences

Lens Method—Chop

- Number of cuts: 3
- Length of cuts: 4.8 mm
- Anterior offset: 500 µm
- Posterior offset: 800 µm
- Energy: 15 mJ
- Spot separation: 10 µm
- Layer separation: 10 µm

Lens Method—Cylinder

- Number of cylinders: 4
- Diameter of cylinders: 2.5 mm
- Anterior offset: 500 µm
- Posterior offset: 800 µm
- Energy: 15 mJ
- Spot separation: 10 µm
- Layer separation: 10 µm

Motives for These Preferences

Lens Method—Chop

- A 4.8 mm diameter chop reduces the risk of capsule tag extensions that can occur if the cavitation bubbles push on the periphery of the anterior capsule
- Three chops reduce the size of each slice and ease the emulsification in reducing rhexis stress.

Lens Method—Cylinder

- A maximum diameter of 2.5 mm with four cylinders allows a very efficient softening of the nucleus central core which eases each quadrant aspiration.

Setting Primary Incision Treatment

The surgeon must specify (Fig. 5):

- Number of planes: Single plane, two plane or three plane primary incision

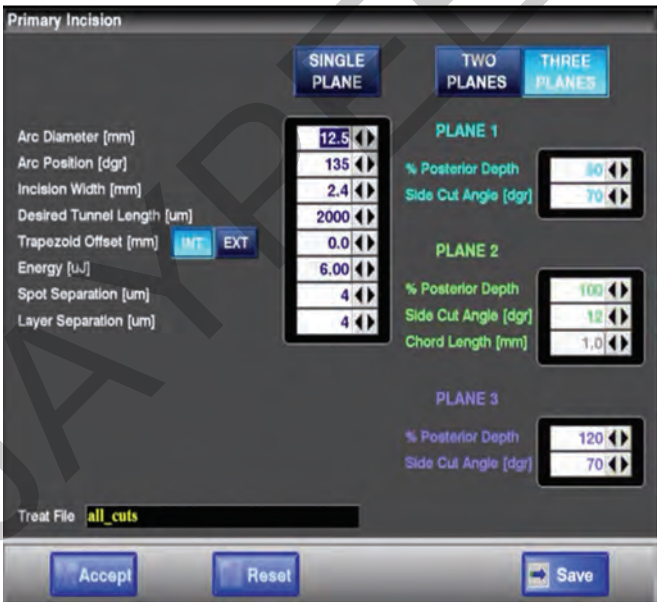


Fig. 5 Setting primary incision treatment

- For each plane of multiple plane incisions:
  - Percentage of posterior depth
  - Side cut angle
- Arc position of the primary incision
- Desired tunnel length
- Trapezoid offset: external or internal
- Energy level
- Tang spot separation
- Layer separation

Personal Preferences

Primary Incision

- Incision width: 2.2 mm
- Internal trapezoid offset: 0.2 mm
- Three planes: at 140°
- Plane 1: 62% 90°
- Plane 2: 103% 11°
- Plane 3: 134% 90°
- Energy: 5.5 mJ
- Spot separation: 4 µm
- Layer separation: 4 µm

Secondary Incision

- Incision width: 1.2 mm
- Internal trapezoid offset: 0.2 mm
- One plane: at 5°
- Energy: 5.5 mJ
- Spot separation: 4 µm
- Layer separation: 4 µm

Motives for These Preferences

- A trapezoid internal offset of 0.2 mm reduces the stress due to the lateral movements of the US probe and reduces the SIA

Docking with the Patient Interface with Suction Ring and Tubing

Preparation

- Dedicated room in preoperative zone (for better temperature and hygrometry settings)
- Treatment is performed on the surgical bed
- No gel topical anesthesia with polyvidone preparation
- Horizontal toric marks are done before entering the laser room

Fig. 6 LenSx® patient-interface

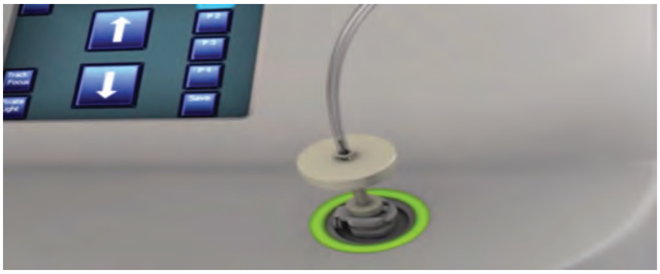


Fig. 7 Connection of the suction tube

- Cautious and meticulous docking for a planocapsular OCT and no tilting of the lens.
  LenSx® patient-interface with connection of the suction tube is represented in (Figs 6 and 7, respectively).

Checklist of Key Points

1. Connect PI to suction port and gantry.
2. Set up lid retractor and position patient's head.
3. Focus video monitor and apply focus tracking.
4. Lower the gantry.
5. The assistant says "contact".
6. Dock and verify applanation pressure (green zone).
7. The surgeon says "apply suction".
8. Limbus centration and incisions peripheral positioning.
9. Capsulorhexis centration.
10. Scan OCT.
11. Check delta up and down with capsular circular OCT and accept.
12. Check deltas up and down with lens linear OCT and accept.
13. Check incisions' scans and accept.
14. The surgeons say "verify settings".
15. The surgeons say "apply laser treatment" and press footswitch.
16. The surgeon checks that there is no suction loss during laser emission which is done following this order: capsulorhexis, lens fragmentation, incisions Laser treatment duration is around 1 minute.
17. End of treatment: release footswitch and suction tube.
18. Remove lid retractor.
19. Move patient to the Operatory Room and start surgery within 15 minutes.

LenSx Lasers Optical Coherence Tomography

The system I am most familiar with is the LenSx® laser system. This system is capable of taking a single OCT snapshot or live continuous OCT images. The live OCT imaging can be used as an aide while docking, but is not required. This function will be reviewed later. First, the standard surgical OCT images that are used to confirm cut positions, etc. are shown in the Figure 8. The Line Scan is a 180° image or cross section. The relevant ocular structures are represented on the right.

The circle scan is a 360° image which has been "unrolled" (Fig. 9). The degree marks above act as an aide to understand the orientation of each part of the scan. It shows the same structures as the line scan but requires some practice before it can be comfortably interpreted.

With live OCT, the default is a circle scan. It helps to identify tilt during the docking procedure and only occurs prior to suction being engaged. Once suction is engaged, live OCT stops and becomes a single circle OCT. Optical centration is confirmed during docking via the live video monitor.

The live circle OCT is centered on the optical center and follows the diameter of the capsulotomy or lysis pattern if caps are not enabled (Fig. 10).

Here are some examples to help interpret the live circle OCT (Figs 11A to F):

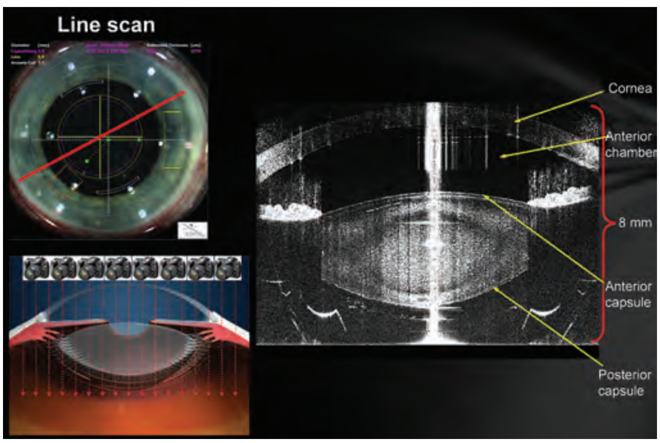


Fig. 8 Standard surgical optical coherence tomography (OCT) images

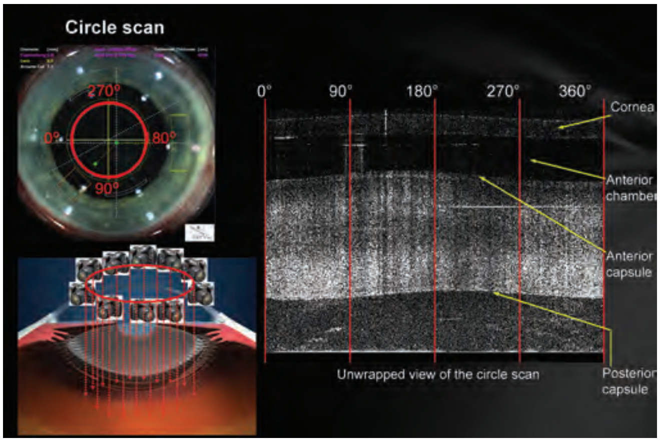


Fig. 9 Circle scan optical coherence tomography (OCT) image

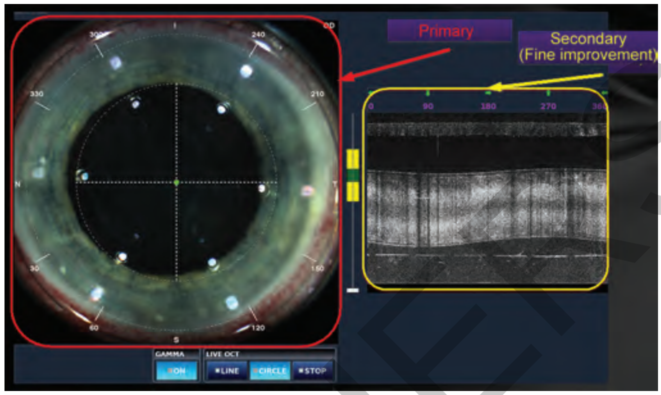
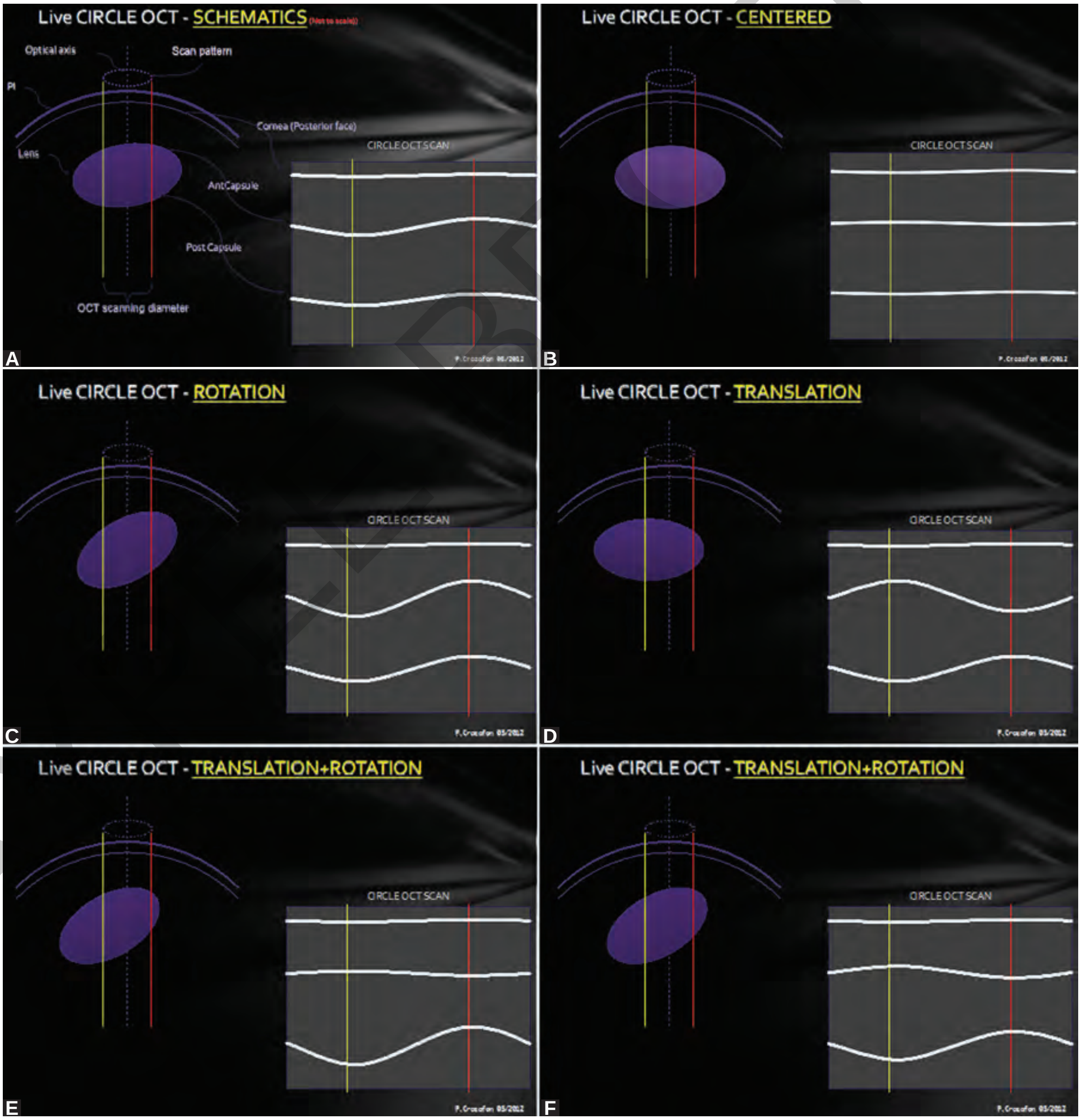


Fig. 10 Docking with live circle optical coherence tomography (OCT)

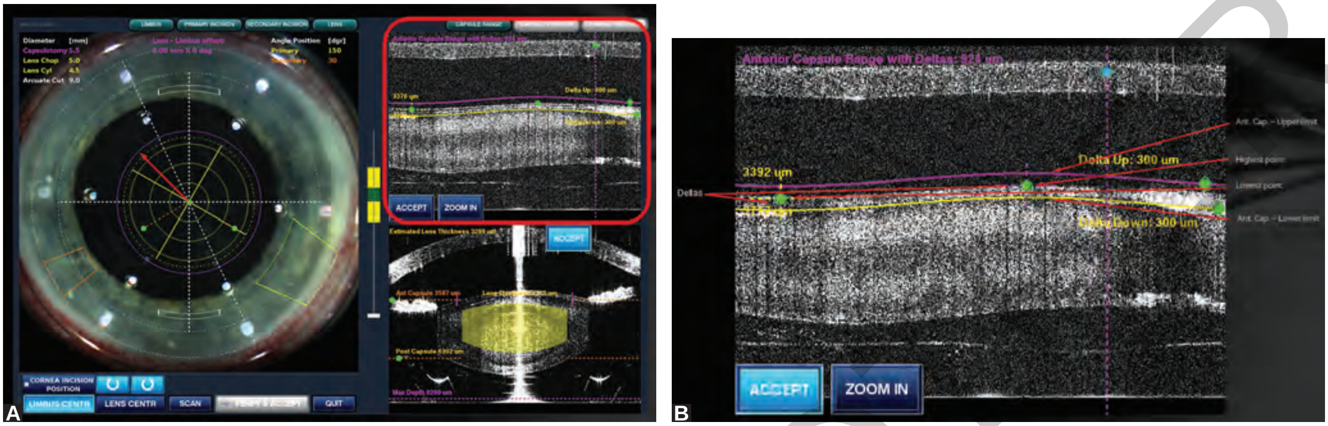


Figs 11A to F Examples of live circle optical coherence tomography (OCT): (A) Schematics; (B) Centered; (C) Rotation; (D) Translation; (E) Translation-rotation; (F) Translation-rotation

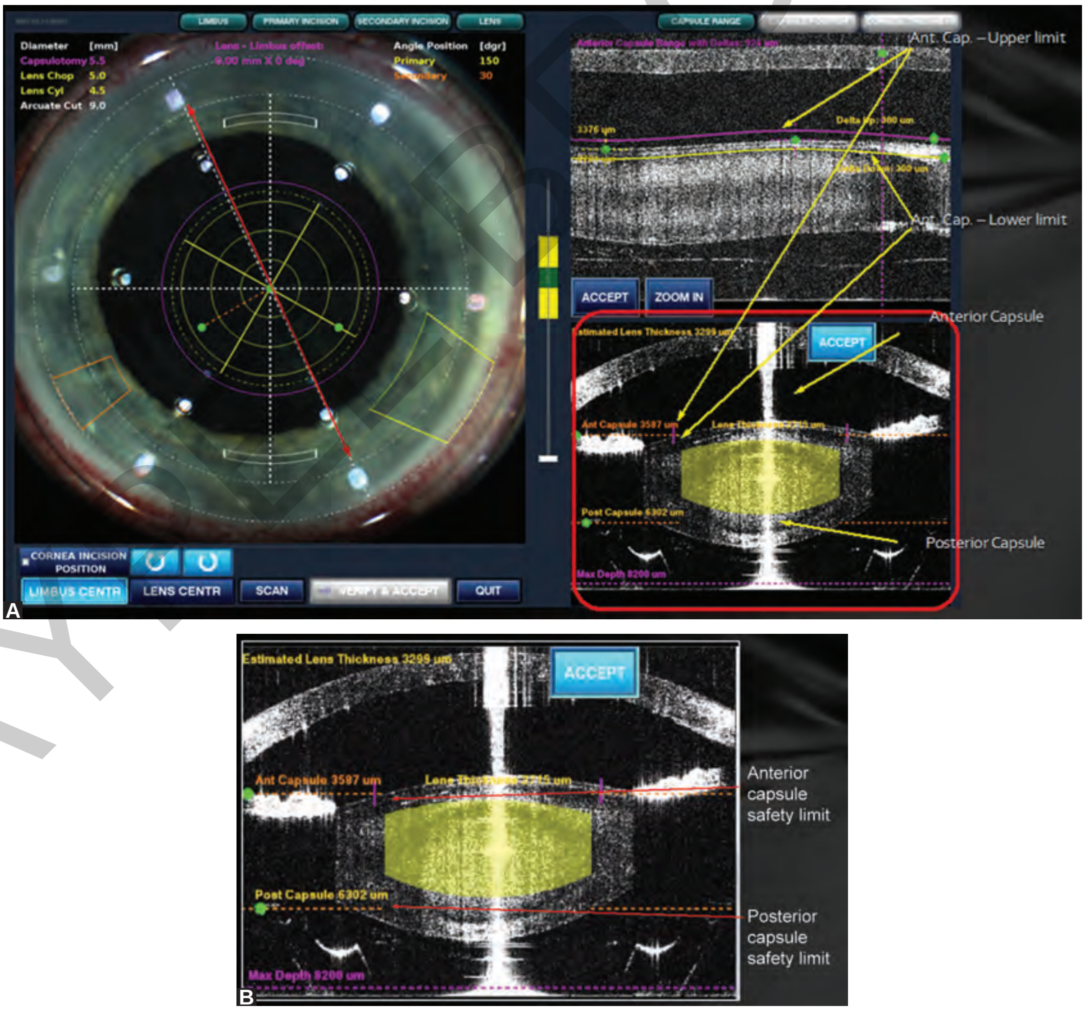
Setting the Capsulotomy

The centration and diameter of the capsulotomy (purple circle) using the live video monitor on the left must be confirmed (Figs 12A and B).

Once that is confirmed, the top right displays a circle scan of the anterior capsule, allowing the confirmation of the placement of our capsulotomy incision, ensuring that the laser treatment starts below and ends above the capsule.



Figs 12A and B Capsulotomy: single circle optical coherence tomography (OCT)



Figs 13A and B Lysis: Single line optical coherence tomography (OCT)

It is possible to zoom in for a closer view to confirm the set limits before you proceed.

The solid line indicates the upper and lower limits of where the laser treatment will occur. The dotted cross hair identifies the highest and the lowest points of the anterior capsule. The dotted vertical line is aligned with the highest point of the posterior capsule.

Setting the Lysis

As previously mentioned, the vertical dotted line must be aligned to the highest point of the bottom wave which identifies the tilt axis. That axis of tilt is where the line scan or cross-section OCT is imaging, as seen on the bottom right in the Figure 13A.

The line scan is a fixed 12 mm wide scan.

The capsulotomy depth is indicated with the purple sign, which must intersect the anterior capsule without touching the iris.

The depth of the lysis cut must be confirmed by placing the top control point at the lowest point of anterior surface of the capsule and the bottom control point at the highest point of the posterior surface of the capsule.

Again, the solid lines indicate the limits of the laser cut; the dotted lines include selected offsets or "buffer zones" which are safety zones to ensure that the posterior capsule or the capsulotomy sites are not damaged (Fig. 13B).

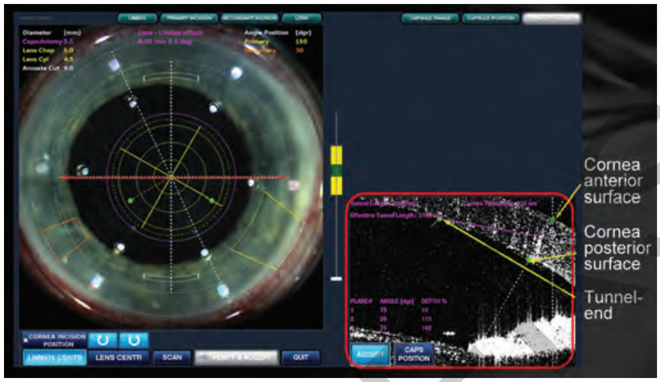


Fig. 14 Primary cornea incision: Single line optical coherence tomography (OCT)

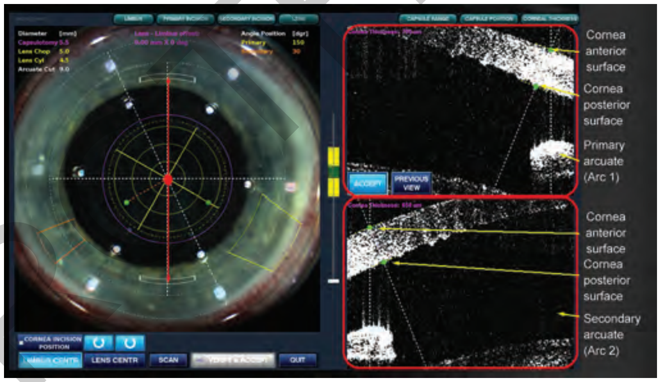


Fig. 15 Arcuate cornea incision: Single line optical coherence tomography (OCT)

Setting the Primary Corneal Incision

Once caps and lysis are confirmed, the corneal incisions must be confirmed starting with the primary incision. The limbal placement of the corneal incisions must first be confirmed using the live video monitor.

Although the angles and general shape of the primary incision (Fig. 14) have been programmed, the depth and shape of it can still be modified and confirmed using the control points. Attention must be paid to the tunnel length, keeping it around 2,000 μm (2 mm). The maximum length allowed is 3,000 μm and the maximum depth is 150% of the total estimated corneal thickness.

The same process applies for the arcuate incisions (Fig. 15), identifying the anterior and posterior corneal surfaces. The laser will automatically adjust to the programmed depth percentage based on the surgeon's preferred nomograms. If the corneal thickness varies between two arc positions, the system will default to the "lesser" of the two.

FEMTOLASER
CATARACT SURGERY

Cataract Surgery has seen incredible changes in the last 100 years. Femtosecond Laser-assisted Cataract Surgery is the latest innovation in the field of Anterior Segment Surgery, a technique that allows surgeons to achieve amazing refractive results.

This textbook is addressed to all Surgeons, Phacoemulsification Experts and young Ophthalmologists, as a guide to the new experiene with Femto-cataract. The first part will explain how we went from Reclinatio, through ICCE, ECCE and Phacoemulsification, to Femto-cataract surgery, the physics of the Femtosecond Laser and the environment of Femto-cataract Laser.

LenSx (Alcon), Victus (Bausch & Lomb), Lens AR (Topcon), Catalys (Abbott) and LDV Z8 (Ziemer) are the Femto-cataract Lasers actually in commerce. In the second part, we will explore the technique and surgery of all 5 devices. The authors, pioneers of the technique, will share their knowledge and experience, describing tricks for the learning curve, complicated cases and showing general advantages and disadvantages of the technique.

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