The Role of Femtolaser in Cataract Surgery

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Abstract

Femtolasers were recently introduced into the surgery of the crystalline lens after having great success in corneal surgery. The most important indications and features are: perfectly centred and sized capsulotomy, liquefaction of softer lenses, fragmentation of harder lenses to help chopping of the cataractous lens without phaco energy, and lastly to create corneal wound in any position and size and also to control pre-operative astigmatism using arcuate incisions in the desired depth within the cornea. As a result of controlled steps in cataract surgery wide acceptance and spread is to be expected.

Keywords

Femtolaser, refractive cataract surgery, capsulorhexis, liquefaction, fragmentation, corneal wound

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Femtolasers are operating with a high energy level and very short pulses (in the femtosecond range). The usual wavelength is 1.063 nanometers (nm) and neodymium (Nd):玻璃 is the active laser medium – this wavelength operates in the near-infrared range of electromagnetic spectrum. The depth of the femtolaser effect can be precisely controlled and focused within the eye, therefore, a very precise cut can be achieved. During application within the cut, microplasm is created in the order of 1.0 micrometer (μm). The surgeon may observe in the operating microscope a fine line, consisting of whitish gas bubbles within the cut plane. The laser impulses can be placed in any plane, therefore horizontal, perpendicular and any kind and size of cut can be created. This feature can be very well used in corneal surgery and during the surgery of the crystalline lens. Until recently, femtolasers were only used for corneal surgery, but based on the technical development carried out by researchers within LenSx-Alcon, the femtolaser surgery of the crystalline lens has been approved by the US Food and Drug Administration (FDA) in 2010 for capsulorhexis, lens fragmentation and liquefaction and for creating corneal wound, and lastly for creating arcuate incisions to control pre-operative astigmatism (see Figure 7). The first human treatment in the world was performed in August 2008 at the Semmelweis University, Budapest, by Dr Zoltan Z Nagy.1

It is still debated as to what the most important advantages of femtolaser refractive cataract surgery over manual phacoemulsification are. The most important features can be seen below, but in summary, based on the experiences of previous years, one can conclude: the exact diameter and central position of capsulorhexis, sparing of phacoemulsification energy, compact corneal wounds in the desired position and size, so much higher predictability in refractive outcome compared with traditional phacoemulsification, and the surgeon is able to control with micrometer exactness are all critical steps of cataract surgery.2-5 These issues came into focus with the invention of premium lenses, which dictate more precise steps in surgical cascade. For example, if capsulorhexis is larger than the desired 5 mm or it is decentred, shift of the implanted posterior chamber lens may result in causing myopic/hyperopic refractive change, increase in higher order aberration, causing glare and halo effect.6-10 As ophthalmologists operate on younger and younger patients, quality of vision and the ability to perfectly see for far and short distances will exert tremendous pressure on ophthalmologists. These surgical requirements can be achieved only with perfect technology.

Treatment Patterns

For the treatment of the crystalline lens the surgeon may choose a cylindrical pattern or a cross pattern treatment. Cylindrical pattern means concentric rings starting from the back of the crystalline lens (about 400 μm away from the posterior capsule towards the anterior capsule). The surgeon controls the position of the laser beam within the crystalline lens. The cylindrical pattern is recommended up until grade 2.0 according to the Lens Opacities Classification System (LOCS). The aim of this is to liquefy the central lens material and then the surgeon is able to aspirate the lens material using only the irrigation and aspiration (I&A) programme of the phacoemulsification machine. This is meant for refractive lens exchange, especially in younger patients with high myopia and hyperopia or in patients where the restoration of the accommodation is needed.

The cross pattern is recommended in harder nuclei up until +4.0 grade according to the LOCS system. The four cuts (to form four quadrants within the lens) is compulsory; the surgeon may of course choose six or eight cuts (cake pattern). The four cuts are very useful to ‘crack’ the nucleus without using any phaco energy (no need to make a groove with the phaco head using ultrasound energy) at the beginning of the surgery. After this, the phacoemulsification runs a similar way as during traditional phacoemulsification. Recently, the hybrid pattern has also been used for harder nuclei (i.e. in the central
3.5 mm zone a liquefaction is used parallel with the fragmentation). During the first-step, the surgeon removes the central part and then chops the lens more easily. The last pattern became popular quickly.

At the creation of the corneal wound, one can use any parameters: different wound structure (uniplanar, biplanar, multiplanar), the length and the width of the wound, moreover the position of the wound can also be customised (upper or temporal incisions, etc.) for the convenience of the surgeon.

It is very important to note that the corneal wound is a self-sealing type, so it does not open upon creation. The surgeon may perform it within the operating room (OR) or outside it, and it may be performed hours before surgery. It is an important factor, because if the femtolaser were to be used by many surgeons in different ORs it is recommended for it to be set up in a separate laser room in order to use it effectively.

Indications, Inclusion and Exclusion Criteria
Indications for lens liquefaction:

- refractive lens exchange, mainly for high myopia and high hyperopia;
- cataract grading maximum 2.0 according to the LOCS system, or age up to 50 years; and
- traumatic cataract (lens just started to get opaque) age below 50 years.

Indications for lens fragmentation:

- cataract up to 4.0 grade, and above 1.5 grade;
- no age limit, but in younger patients usually liquefaction is better; and
- traumatic cataract, when the nucleus seems harder.

Contraindications:

- non-dilating pupil;
- non-cooperating patients;
- brown or black cataract (only relative, due to the low water content of the crystalline lens, but good for capsulorhexis); and
- white cataract (only relative contraindication because for capsulorhexis the method is perfect, but cuts cannot be made within the white lens material).

Sequence of the Femtolasar Procedure

- patient selection;
- consenting;
- patient head positioning;
- drop anaesthesia;
- capsulorhexis;
- lens liquefaction or fragmentation;
- corneal wound; and
- astigmatism correction (arcuate incisions in 80 % depth).

Patient Selection and Preparation

It is very important that the patient should be cooperative and have a positive attitude, should understand the importance of laser treatment and accept the possible problems using this technology. The ideal patient can tolerate some pressure feeling during the treatment, not be too anxious and be able to look into the fixating light of the operating microscope or in the patient interface (PI), able to rest for a couple of minutes, and has no cataract (refractive lens exchange) or has a nuclear cataract grading <4.0 according to the LOCS system. Besides slit lamp examination, the use of Pentacam® is recommended, because the density of the crystalline lens can be pre-operatively assessed easily. Also the surgeon can gain important information about the anatomical data of the eye. The measurement of the lens density is also possible with the inbuilt ocular coherence tomography (OCT), but it is recommended only when there is no Pentacam available. The femtolaser refractive cataract surgery is usually performed in drop anaesthesia because the patient needs to fixate on a special light during the docking procedure.

Laser Docking and Coupling

The femtolaser treatment is performed in a supine position. It is important to achieve a resting position and the eye should be horizontal. If it is not achieved, there might be a tilt of the eye and a tilt of the crystalline lens, which might cause inconsistencies in rhesis and fragmentation.

Image-guided Alignment of Laser Treatment

One of the most important features of the commercially available femtolasers is the inbuilt OCT imaging system. It is very useful to plan all treatment details based on the OCT imaging to have a safe distance from posterior and anterior capsule and to achieve a perfect corneal wound. The OCT examination is being performed after having centred the eye. After inserting the PI, the computer projects circles and lines (limbal area, capsulotomy and corneal wounds) on the surface of the
Figure 2: The OCT Image of the Anterior Segment of the Eye

The OCT image of the anterior segment. The OCT identifies the anterior and posterior capsule, and measures the density of the crystalline lens. The surgeon plans the corneal cuts on the screen.

Figure 3: Operating Microscope and OCT Image of the Treated Eye

Image-guided treatment

The proprietary image-guided system allows the surgeon to take a pre-operative OCT image and position the planned incisions and photodisruption patterns on the patient's eye. The blue and yellow overlays represent the lens photodisruption and capsulotomy patterns. The red represents the corneal incisions. Size and position of all patterns can be pre-programmed and adjusted for ultimate surgeon-control.

Figure 4: The Corneal Wound Created by the Femtosecond Laser

Intact wound

The femtosecond laser created corneal wound is self-sealing. It can be opened with a blunt spatula.

Figure 5: Different Stages of Capsulotomy

The steps in femto rhesis from left to right: creating femto rhesis (under the microscope of the femtolaser), rhesis as can be seen in the main OR with the operating microscope, after the removal of the crystalline lens and after implantation of the foldable posterior chamber lens. Note the precise centration and perfect round shape of the rhesis.

The surgeon controls the central position of the projected circles and lines and then performs the first OCT measurement. As the first step, the surgeon identifies the anterior capsule and plans the capsular treatment. During the second step, the surgeon identifies the anterior and posterior capsule and manually sets the machine where the cuts within the lens should be. During the third OCT measurement, the corneal cuts are planned and can be modified. After accepting the treatment parameters, all data are transferred to the computer of the femtolaser and in a couple of seconds, the treatment can be started by pressing down the treatment pedal. The Whole femtolaser treatment usually does not exceed 50 seconds.

Laser Steps

The laser steps are the following:

- cut in the anterior capsule (capsulorrhexis);
- cut in the lens (cylindrical or cross pattern); and
- cut in the cornea (uniplanar, biplanar, multiplanar or arcuate).

Important Steps During Cataract Surgery

As a first step, the surgeon identifies the corneal wounds and opens them with a blunt spatula (see Figure 4). Thereafter the anterior chamber should be filled with viscoelastic material. The deepest cut within the lens should be sought for identified and, if possible, lifted with a rhesis needle (cystotome) or rhesis forceps. The contour of the femtolaser cut should be meticulously followed and the round shape anterior capsule can be removed by this way. Pulling out with abrupt hand movement can cause anterior tear, which might lead to anterior and posterior capsular damage. Small tags can occur especially during the learning curve. After removing the capsule, a slow hydrodissection should be performed. It should be carried out slowly and softly because gas bubbles may appear within the crystalline lens after fragmentation, with slow hydrodissection, the gas exits through the anterior capsule without a problem. With abrupt hydrodissection a blockage syndrome may result.
in causing a rupture of the posterior capsule. With a cautious technique this can be avoided in 100% of cases. After successful hydrodissection the surgeon enters the eye with the phaco head and the chopper. It is advised to grab the lens near to the perpendicular fragmentation line with 300 millimetre of mercury (mmHg) and to chop it into two pieces with the chopper. Later to turn the lens and to repeat the movement with the other fragmentation line. Having four quadrants of the nucleus, they can be easily removed using minimal phacoemulsification energy and time, so the cumulative dissipation energy (CDE) can be minimised. After nucleus removal the cortex should be removed with the I&A method, similarly to manual phacoemulsification. The posterior chamber lens implantation is similar to previous surgical techniques (see Figure 5). At the end of surgery the wound should be checked, most of the cases do not require hydration because the wound itself is self-sealing (see Figure 6). If there was rupture or other surgical trauma that case might require hydration. According to the European Endophthalmitis Study, intracameral antibiotics might be used to avoid post-operative intraocular complications.

In case of softer lenses after removing of the anterior capsule, hydrodissection is usually not required and the central nucleus can be easily aspirated by using only the I&A tip. Anterior chamber depth should be closely monitored and maintained during surgery especially with high myopes and sometimes hyperopes to ensure safety. It is especially important in younger patients operated in drop anaesthesia. They can be anxious and exerting pressure with the speculum, consequently causing higher intraocular pressure.

Figure 6: The OCT image of the corneal wound two weeks after surgery

The corneal wound is well apposed from inside and outside following cataract surgery (OCT image).

Conclusion

Femtolaser treatment of the crystalline lens increases safety, efficacy and predictability of the surgery. Surgical skill and wisdom are still needed to avoid possible complications, which might arise during lens surgery. During well-prepared surgeries (thoughtful patient information and selection, proper PI insertion, well-designed and performed capsulotomy, lens fragmentation/liquefaction, and corneal wound and astigmatism correction) the safety of refractive cataract surgery increases and all advantages of the premium lenses can be achieved and benefited to our patients. Pricing is an important factor as to how quick the procedure will spread, but with the ageing population and the increasing number of cataract, lens surgeries, wide acceptance and use is expected in the near future.