Current Practices in Ophthalmology
Series Editor: Parul Ichhpujani

Parul Ichhpujani *Editor*

Current Advances in Ophthalmic Technology

Springer

Current Practices in Ophthalmology

Series Editor

Parul Ichhpujani
Department of Ophthalmology
Government Medical College and Hospital
Chandigarh, India

This series of highly organized and uniform handbooks aims to cover the latest clinically relevant developments in ophthalmology. In the wake of rapidly evolving innovations in the field of basic research, pharmacology, surgical techniques and imaging devices for the management of ophthalmic disorders, it is extremely important to invest in books that help you stay updated. These handbooks are designed to bridge the gap between journals and standard texts providing reviews on advances that are now part of mainstream clinical practice. Meant for residents, fellows-in-training, generalist ophthalmologists and specialists alike, each volume under this series covers current perspectives on relevant topics and meets the CME requirements as a go-to reference guide. Supervised and reviewed by a subject expert, chapters in each volume provide leading-edge information most relevant and useful for clinical ophthalmologists. This series is also useful for residents and fellows training in various subspecialties of ophthalmology, who can read these books while at work or during emergency duties. Additionally, these handbooks can aid in preparing for clinical case discussions at various forums and examinations.

More information about this series at http://www.springer.com/series/15743

Parul Ichhpujani
Editor

Current Advances in Ophthalmic Technology

Springer

Editor
Parul Ichhpujani
Department of Ophthalmology
Government Medical College and Hospital
Chandigarh
India

ISSN 2523-3807 ISSN 2523-3815 (electronic)
Current Practices in Ophthalmology
ISBN 978-981-13-9794-3 ISBN 978-981-13-9795-0 (eBook)
https://doi.org/10.1007/978-981-13-9795-0

© Springer Nature Singapore Pte Ltd. 2020
This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
The publisher, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Contents

About the Editor

Parul Ichhpujani is currently an Associate Professor in the Department of Ophthalmology at Government Medical College and Hospital, Chandigarh, India, where she is chiefly responsible for glaucoma and neuro-ophthalmology services. She completed her glaucoma training at the Advanced Eye Centre, Postgraduate Institute of Medical Education and Research, Chandigarh, India, and in a subsequent Clinical Research fellowship, under Dr. George L Spaeth, at Wills Eye Institute, Philadelphia, USA. She currently serves on the Education Committee of the World Glaucoma Association and is the Associate Managing Editor of the *Journal of Current Glaucoma Practice*, the official journal of the International Society of Glaucoma Surgery. She was ranked among the Powerlist 2015 for the "*Best 40 ophthalmologists under 40.*"

An avid researcher, Dr. Ichhpujani has coauthored three books: *Pearls in Glaucoma Therapy*, *Living with Glaucoma*, and *Smart Resources in Ophthalmology*; and has edited another five: *Expert Techniques in Ophthalmology*, *Glaucoma: Basic and Clinical Perspectives*, *Manual of Glaucoma*, *Clinical Cases in Glaucoma: An Evidence Based Approach*, and *Glaucoma: Intraocular Pressure and Aqueous Dynamics.* She has contributed several research articles and book chapters in national and international books and serves as a reviewer for many ophthalmology journals.

Newer Technologies for Cataract Surgeries

1

Roberto Bellucci

1.1 Introduction

Cataract surgery is the surgical procedure most frequently performed worldwide, with increasing incidence in developing and developed countries [1]. Despite the high efficiency and safety that is associated with the current level of surgery, the evolution of technology is offering new devices and machinery that are innovating many aspects of the procedure. As a result, the commonly performed phacoemulsification with monofocal intraocular lens (IOL) implantation is now regarded as the "basic" surgery, while the implementation of the newer modalities is considered "high technology" surgery. In this chapter we will try to review the most known innovations, which either are already implemented or will be implemented in the next 1–2 years, about the preoperative, the intra-operative, and the postoperative of cataract surgery.

1.1.1 Implementation of OCT Technology into Cataract Surgery

Since its introduction in 1991, optical coherence tomography (OCT) has revolutionized ophthalmic imaging [2]. OCT is based on low-coherence interferometry (LCI), also known as optical coherence domain reflectometry (OCDR), white light interferometry (WLI), partial coherence interferometry (PCI), and optical low-coherence reflectometry (OLCR).

Fourier-domain optical coherence tomography (Fourier-domain OCT) has changed the whole ophthalmic care. Posterior segment OCT is now an essential part of the retinal diagnostic processes, while anterior segment OCT (AS-OCT) has been extensively used for the anterior segment evaluation of non-operated as well as operated eyes.

R. Bellucci (✉)
Department of Ophthalmology, University Hospital, Verona, Italy

P. Ichhpujani (ed.), *Current Advances in Ophthalmic Technology*,
Current Practices in Ophthalmology, https://doi.org/10.1007/978-981-13-9795-0_1

Spectral-domain OCT (SD-OCT) uses a broadband near-infrared superluminescent diode with a wavelength of approximately 840 nm as a light source, along with a spectrometer as the detector. Swept-source OCT (SS-OCT) uses a tunable swept laser, currently with a center wavelength of approximately 1050 nm, with a single photo detector (instead of the CCD cameras) [3]. SS-OCT imaging is faster than SD-OCT imaging (double scan speed), which allows for denser scan patterns and larger scan areas for a given acquisition time. In addition, the longer wavelength of the SS-OCT enhances light penetration and is safer for the eye, thus allowing the use of higher laser power. The higher power combined with the reduced sensitivity roll-off improves the likelihood of detecting the inherently weaker signals from deeper layers [3]. Both types of OCT have been implemented in ocular biometers and have been used for specific purposes both before and after cataract surgery.

1.1.1.1 OCT for Ocular Biometry

The development of partial coherence interferometry (PCI) about 20 years ago has stimulated the production of a variety of different ocular biometers, with the purpose of measuring with increased precision the different anatomical parts of the eye involved in IOL power calculation. More recently, OLCI and OLCR have been extensively used to measure anterior chamber depth, axial length, and lens thickness, all parameters useful for IOL power calculation. Unlike classic interferometry, where ambiguity of the measurement result often exists, these technologies can provide an unambiguous (i.e., absolute) measurement result relatively easily. When implemented using optical fiber, low-coherence interferometers/reflectometers can perform remote measurements whose results are independent from external disturbances.

The newer OCT-based machines have been demonstrated to provide similar results as the PCI-based machines in cataract eyes, with small differences that were statistically but not clinically significant [4–7]. The same small differences were found with the SS-OCT-based machines [8–14]. However, being more powerful the SS-OCT was able to measure a higher percentage of eyes than the previous technology [8, 9, 11–13], and the measurement precision was better than with previous technology in long eyes [14, 15]. In addition SS-OCT can give an image of the impact area, namely the fovea, thus indicating both the precision of the alignment and the anatomy of the central retina [16].

SS-OCT can also measure the corneal curvature accurately [17], and its ability to visualize a 3-D image of the crystalline lens and of the anterior segment of the eye is stimulating new studies on IOL power calculation [18]. Other machines incorporate a Scheimpflug camera or a Placido disk to measure the corneal curvature and the corneal diameter, and new studies will clarify the differences in the results, if any.

Several comparisons between OCT-based and Scheimpflug-based machines in measuring anterior chamber parameters have been carried out. The two methods offered good repeatability in the study by Sel et al. [19]. The measurement of anterior chamber depth was found similar by Nakakura et al. [20] and by Wang et al. [21], with minor differences that however were statistically significant. Differences in anterior segment parameters were also found by Özyol and Özyol [22], who concluded that the SS-OCT and the Scheimpflug camera that he used are not interchangeable.

1.1.1.2 Anterior OCT in the Preoperative

Besides ocular biometry, AS-OCT can be employed in the preoperative diagnosis of several anatomical conditions, thus helping the surgical planning. SS-OCT has been used to identify eyes at risk for acute angle-closure glaucoma among those presenting with mature cataracts [23], to check lens and cataract shape and position [24–26], and especially to control the status of the posterior lens capsule [27, 28]. The ability of OCT to visualize the posterior lens capsule is of utmost importance in posterior polar cataracts, which are often associated with anatomical distortion of Berger's space [29, 30]. Unfortunately, this is not always possible in the preoperative with current machines, and ecography is often required [31].

1.1.1.3 Intra-Operative Use of OCT

Imaging of the anterior segment by integrated OCT is an essential part of femtosecond laser-assisted cataract surgery (FLACS) and will be discussed in the dedicated section. Surgical microscope-integrated OCT was found beneficial during cataract surgery by Das et al. [32]. They qualitatively assessed the wound morphology in clear corneal incisions, and identified subclinical Descemet's membrane detachments (DMDs), tears in the inner or outer wound lips, and wound gaping at the end of surgery. Intra-operatively, segregation of the true posterior polar cataracts from suspected cases could also be done. The depth of grooving could also be easily evaluated, and the final position of the implanted IOL checked. In another study, Hirnschall et al. [33] demonstrated that the intra-operative measurement of anterior chamber depth (ACD) after capsular tension ring implantation was more precise in predicting the final ACD after IOL implantation than the preoperative ACD measurement. Similar results were obtained by Lytvynchuk et al. [34]. The value of intra-operative OCT in evaluating the posterior capsule in posterior polar cataracts was confirmed by Tassignon and Ní Dhubhghaill [35], who could confirm the absence of Berger's space and the previously suggested anatomic distortion in those eyes.

1.1.1.4 Anterior Segment OCT in the Postoperative Course

AS-OCT helps obtain preoperative and postoperative quantitative data regarding anterior chamber configuration. In their study, Kim et al. [36] were able to demonstrate the anterior chamber angle widening (from 24° to 35°) and the ACD increase (from 2.75 ± 0.43 to 4.14 ± 0.31 mm). Nagy et al. [37] also reported similar results after FLACS. A few studies on corneal incisions found epithelial imperfections in more than 36% of eyes [38], lower posterior wound gape with higher posterior wound retraction of femto incisions [39], and inadequate precision of the location of femto arcuate incisions [40]. The corneal epithelium returned to its preoperative status after 4 weeks according to the OCT study of Kannellopoulos and Asimellis [41], and the capsular bag collapsed earlier onto single-piece acrylic IOLs than onto three-piece acrylic IOLs or three-piece silicone IOLs [42]. Later on after surgery anterior SS-OCT was used to diagnose the appearance and the grade of capsular block syndrome [43], and to evaluate the position and tilt of the IOL [44]. In this regard, a tendency has been established to measure the pseudophakic ACD typical of specific IOLs, in order to improve the relevant IOL power calculation [45]. A Scheimpflug camera can also be used for these purposes [46–49], which allow quicker personalization of the "A" constant as compared with the methods based on refraction shift.

1.1.2 Automation in Cataract Surgery

The tendency of modern medicine to deliver to machines part of the surgical maneuvers and the availability of more precise devices and lasers to do so have opened the way to automation in ophthalmic surgery and in cataract surgery in particular. Currently, machines are used to perform corneal incisions, capsulotomy, and lens fragmentation, but specific projects are being carried out to implement true robotic surgery in this area.

1.1.2.1 Femtosecond Laser-Assisted Cataract Surgery

Femtosecond Laser

The femtosecond laser (FSL) is a solid-state laser that produces infrared light pulses with a wavelength of 1030–1060 nm, and a duration of 300–800 fs. The energy range per pulse is typically 5–10 microjoules (μJ) [50]. The photodisruptive effect is achieved when the FSL beam is sharply focused and generates plasma within the affected tissue. This plasma rapidly expands as an acoustic shock wave, displacing the surrounding tissue. Cooling of plasma results in formation of cavitation bubbles. Photodisruption occurs at the laser's focal point without any thermal effect or collateral tissue damage [51].

The FSL can create tissue separation and precise cuts within the cornea, lens capsule, and crystalline lens [50]. Important features of any femtosecond laser are the repetition rate and the numerical aperture. Higher repetition rates result in less energy required to obtain the same tissue effect. The numerical aperture indicates how much concentrated energy is at the impact area. A larger numerical aperture causes less dispersion of the laser beam and thus better focussing and/or smaller spots. This results in improved precision of the cut depth and lower energy, to provide the same tissue effect. Therefore, corneal treatments require a larger numerical aperture (with a lower energy level), while vice versa holds true for the crystalline lens [50, 52].

Models Available

At present there are five FSL systems available worldwide for cataract surgery (FLACS): LenSx Laser System (Alcon, Fort Worth, TX), LENSAR (LENSAR Inc, Orlando, FL), CATALYS Precision Laser System (Abbott Medical Optics, Abbott

Table 1.1 Some features of the femtosecond lasers currently available for cataract surgery

Characteristic	LenSx	LENSAR	CATALYS	Victus	LDV-8
Company	Alcon	LENSAR	J&J	B&L	Ziemer
Docking	Cushion	Fluid	Fluid	Fluid[a]	Fluid[a]
Imaging	SD-OCT	Scheimpflug	SD-OCT	SS-OCT[b]	SD-OCT
Integrated bed	No	No	Yes	Yes	No[c]
Pulse energy (μJ)	<15	<15	<10	<10	<2.5
Pulse duration (fs)	600–800	400–600	400–600	300–600	200–350

Adapted from Grewal et al. [53]. *J&J* Johnson & Johnson, *B&L* Bausch & Lomb

[a] Direct contact employed for corneal incisions; fluid interface available for capsulotomy and lens fragmentation

[b] On-line OCT imaging of the laser activity

[c] Movable laser

Park, IL), Femto LDV platform (Ziemer Ophthalmic Systems, Port, Switzerland), and Victus Femtosecond Laser Platform (Bausch and Lomb, Rochester, NY) [53]. They are all categorized as class 3B Lasers, and are also available in the USA except for the Femto LDV platform. They differ in several physical and clinical aspects (Table 1.1), of which a few are relevant for the clinician. A suction clip that is separate from the laser head may facilitate docking with anxious patients. Eye docking should avoid corneal folds that may lead to capsulotomy bridges, and therefore some fluid or a cushion contact lens is used between the eye and the plastic patient interface. Eye imaging that is used for treatment planning should detect any eye tilting to avoid a possible posterior capsule cut by the laser. On-line imaging of the laser activity allows direct observation of any inconvenience or complication. Control of horizontal and vertical eye micromovements during laser activity may help in avoiding suction or pressure loss [53].

Clinical Applications

The FSL can perform three steps of cataract surgery: capsulotomy, lens fragmentation, and creation of corneal incisions.

Capsulotomy A round, well-centered, and precise diameter capsulotomy can be easily obtained if the cornea is transparent and without docking folds [50, 53], and even in eyes with a very shallow anterior chamber [54]. Because the cut is obtained by aligning small gas bubbles, some of which can be misplaced due to ocular micromovements, the obtained capsulotomy is considered less resistant than manual capsulorhexis. However, anterior tears do not develop during normal surgical maneuvers but only from tags or uncut bridges [55]. The precision and repeatability of the laser capsulotomy has stimulated the design of new intraocular lenses for anterior capsular rim fixation [56]. All the IOLs currently available can of course be implanted, and early results indicate more precise IOL positioning after femtosecond laser than after manual capsulotomy, with lower tilt [57].

Lens Material Fragmentation This is the second objective of the femtosecond laser activity. This is obtained by aligning the small bubbles to form cut patterns of different shape: cross, circular, dice, and a mixture of them are the most popular (Fig. 1.1). The fragmentation reduces the amount of ultrasound energy required for complete cataract removal, even approaching zero in some studies [58]. However, the gas bubbles that develop and merge inside the lens may hit the posterior capsule causing its oscillation and even its rupture if excessive or much too close (Fig. 1.2). The Z8 laser makes the exception because the small amount of energy

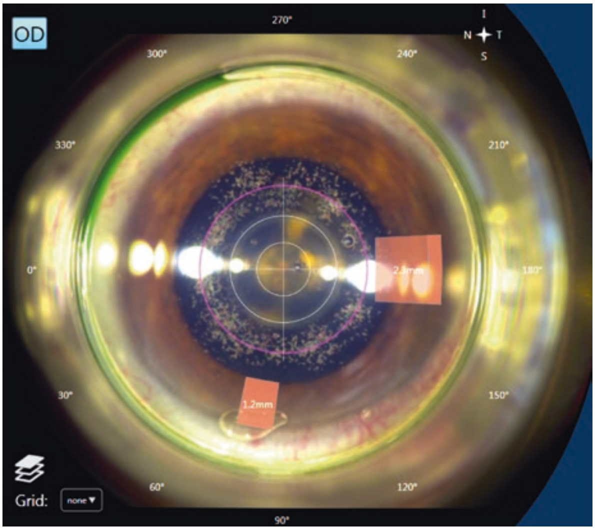

Fig. 1.1 Fragmentation pattern in femtosecond laser cataract surgery

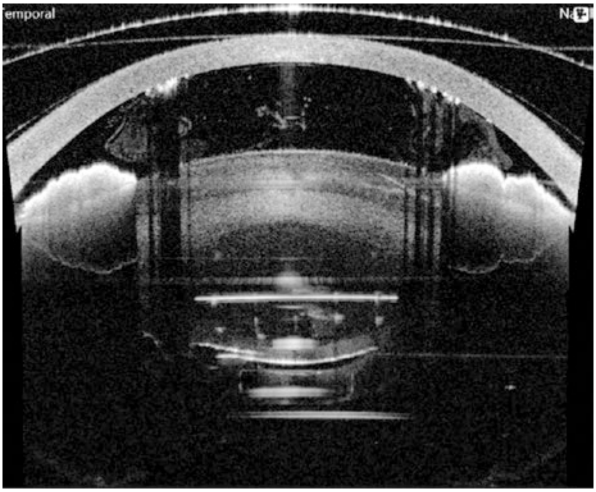

Fig. 1.2 A gas bubble is developing in the posterior cataract pushing backwards the posterior cortex and capsule

employed does not produce large gas bubbles, and therefore it does not increase the lens volume. For this reason lens fragmentation precedes capsulotomy with this laser. After laser lens fragmentation, hydrodissection has to be gentle because of the retained gas, and is poorly successful because the injected solution will follow the laser channels instead of separating the lens capsule [59, 60]. Even hard cataracts can be fragmented if they retain some transparency, while white cataracts cannot be fragmented: the femtosecond energy is light and therefore it is sensitive to transparency, while the ultrasound energy is mainly mechanical and it is sensitive to hardness.

Corneal Incisions Corneal incisions are then performed by the laser, again in a very precise and reproducible manner. The location of the incisions is selected by the surgeon with reference to the angles displayed by the laser camera. The width, length, and shape of the incisions can also be selected, taking care to avoid opaque parts of the peripheral cornea, namely the gerontoxon. With the femtosecond laser we can consider for the first time the corneal thickness in planning the cataract incisions, and exactly place the internal incision border that is important for the astigmatic outcome [61]. Many studies have been dedicated to the analysis of laser wound healing in comparison with blade wound healing, with minor advantages demonstrated for the former [53, 54, 57, 58].

Results and Complications

Since the first report by Nagy et al. [62], several studies have been carried out to verify the advantages of FLACS over phacoemulsification. Many of them were performed with early laser models, and their results are no longer valid [63]. More recent papers report information that is useful for a first evaluation of the impact of FLACS on cataract surgery. It is certain that by FLACS we reduce the amount of ultrasound energy required for cataract removal [54, 58]; however, this reduction is not always associated with lower endothelial cell loss [58]. All the parameters related with the capsulotomy are better with FLACS, but the prostaglandin release is by far lower with phacoemulsification [64, 65]. One distinct advantage of FLACS over conventional surgery is the ability to perform capsulotomy and lens fragmentation in difficult conditions like shallow anterior chamber and subluxated cataracts [66]. Also the mechanical stress for the zonula is lower than in phacoemulsification, although the effects in the long term have still to be investigated. As for the refractive outcome, available data report similar results with FLACS and with previous techniques [67, 68] with the exception of astigmatism when arcuate incisions are performed with the laser [69], but randomized clinical trials are still required in this area.

A recent analysis found the capsule complication rate of FLACS to be similar as that of phacoemulsification, and better with unexperienced surgeons [70]. The overall laser-related complications are decreasing in parallel with the improvements made by the industry in the machines, and with the increasing experience of the surgeons in machine programming [71]. The surgeon's related complication rate is already lower with FLACS than with conventional phacoemulsification [72].

Future Directions

At the moment the standardization of the capsulotomy appears the most important contribution of FLACS to cataract surgery. By producing the same capsulotomy in the operated patients, we will shorten the evaluation period of new intraocular lenses, and will promote the development of new devices to be implanted at surgery like special IOLs, capsular rings, glaucoma shunts, and so on. New studies on capsular bag filling will become possible [70]. The laser capsulotomy can also be applied to cut anterior capsule phimosis, avoiding the anterior tear typical of the manual maneuver [73].

The fragmentation ability will be used to modify the power of IOLs "in vivo," to adjust for minor refractive errors or to implement/remove multifocal designs [74]. IOL optics can be cut "in vivo" to facilitate removal [75]. New types of surgical procedures for the anterior segment will be developed, which involve transparent or semi-transparent tissues or devices.

1.1.2.2 Automation in Capsulotomy

Precision Pulse Capsulotomy

In the search for devices to produce a perfect capsulotomy that may be simpler than femtosecond lasers, Mynosys (Fremont, California) has developed a novel capsulotomy method and technology called Precision Pulse Capsulotomy (PPC), and trade named Zepto-Capsulotomy.

A small console drives the active part, a disposable handpiece with a nanoengineered capsulotomy tip consisting of a circular nitinol ring 5.0–5.5 mm in diameter, covered by a thin soft and clear silicone suction cup. A retractable metal push rod elongates the superelastic nitinol ring and the suction cup into a narrower profile that can be inserted through a 2.2 mm or larger clear corneal incision into a viscoelastic-filled anterior chamber [76]. After retracting the push rod, the compressed tip resumes its circular shape and is positioned onto the anterior capsule surface. Slight suction is needed to appose the anterior capsule against the bottom edge of the nitinol ring, and a rapid series of electrical pulses 4 ms in duration is used to create the capsulotomy (Fig. 1.3). The electric pulses produce phase transition

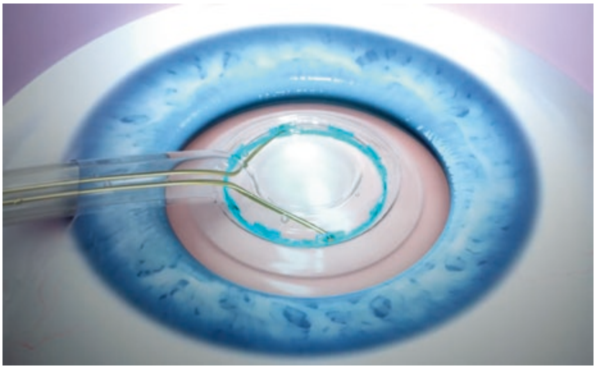

Fig. 1.3 The tip of the Zepto capsulotomy device

of the water molecules trapped between the capsule and the nitinol edge, causing mechanical cleavage of the stretched capsular membrane circumferentially all at once. The other structures of the anterior chamber remain protected by the silicone cup and by the viscoelastic substance [76]. Unlike the sequential circular path of a manual capsulorhexis (CCC) or FSL capsulotomy, the PPC technology mechanically and simultaneously cuts all 360° of the apposed anterior capsule without cauterizing it.

Zepto capsulotomy strength was tested by Thompson et al. [77]. In their study on cadaver eyes the force to break the Zepto capsulotomy was three- to fourfold the force required to break femto or manual capsulotomy [77]. Early clinical experience with Zepto capsulotomy has been promising, with no inconveniences reported by Thompson et al. in 38 eyes [78], and by Pandey and Sharma in 3 eyes [79]. More recent studies point out some difficulties of the learning curve, with 4% of failures in the Hooshmand et al. study on 52 eyes [80], and 5% of failures out of the 123 eyes reported by Kelkar et al. [81]. Additional studies are being carried out with this device that might provide perfect capsulotomies at a fraction of the cost of a femtosecond laser. In a recent paper, Thompson [82] described a method to anchor the IOL on the patient visual axis by using Zepto capsulotomy.

Aperture CTC

Aperture CTC (continuous thermal capsulotomy) (International BioMedical Devices, Mt. Pleasant, South Carolina) is similar to Zepto but employs a stainless steel double ring that forms a perfect circle. On activation heat is produced creating the capsulotomy. This device is still under investigation [83].

CAPSULaser

CAPSULaser (Los Gatos, California) is a laser device that fits onto the bottom of the operating microscope. The machine can produce perfect circular capsulotomies 4.5–6.0 mm diameter in 0.1 mm steps, with a double border that ensures good resistance to stretching [84]. The laser is activated after capsule staining with a new formulation of trypan blue (Fig. 1.4). In unpublished clinical studies, CAPSULaser demonstrated superior consistency compared to manual in creating a capsulotomy that is 100% free-floating and provides 100% 360° IOL coverage, according to the producer. After being around for some years now, the CAPSULaser has received the CE mark and is available for clinicians.

1.1.2.3 Robotic Surgery

A robotic system is being developed for automated cataract extraction to reduce common complications in cataract surgery such as posterior capsule rupture, incomplete lens removal, and corneal incision leakage [85].

The IRISS (intraocular robotic interventional surgical system) has an OCT that scans the eye and provides data for both the preoperative planning and the intraoperative intervention, along with a robotic surgical system. Image-based techniques were used to automatically align active instruments to the corneal incisions, to define an insertion trajectory, and to design a flower-shaped trajectory with safety

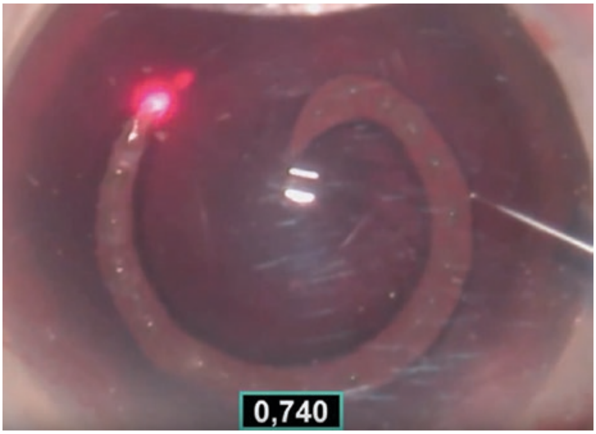

Fig. 1.4 The capsulotomy of CAPSULaser

margins to aspirate lens matter. Engineers have demonstrated that the OCT-guided system has sufficient capability to perform automated cataract extraction. This robot was tested on 30 pig eyes, efficiently removing the cataract in 25. In the remaining five cases, the system left small particles of lens matter behind the iris, suggesting the need for echography. In this study, none of the eyes had posterior capsule rupture, indicating that robotic semi-automatic cataract surgery is feasible in the near future [85].

1.1.3 Novelties in Phacoemulsification and IOL Implantation

1.1.3.1 Feed-Back Control of Irrigation

One of the major problems of phacoemulsification fluidics is the stabilization of the anterior chamber volume and pressure during the various phases of the procedure. Several studies have been carried out to find effective solutions that have been implemented into the more recent machines. We know that the volume of the aspiration line should be as low as possible, that small pumps with low hysteresis are better than large pumps, that both fluid and air venting should be available, and that small phacoemulsification needles are associated with lower anterior chamber oscillation, but involve the problem of clogging.

So far irrigation has been only dependent on sleeve size and on bottle height, with 1.3 ratio between height in centimeters above the eye and intraocular pressure in mmHg. Whenever more irrigation was required, the surgeon asked the nurse to rise the bottle, and to lower it if the anterior chamber was becoming much too deep. Sometimes this could be obtained by foot pedal. This method had several inconveniences. The response was much too slow, depending on how quick the nurse was in executing the surgeon’s instructions, and especially the extra irrigation required to balance post-occlusion surge could not be obtained. To avoid any anterior chamber collapse many surgeons selected to keep the bottle excessively high, 90–120 cm above the eye level, resulting in an intraocular pressure increase of up to 90 mmHg,