

## Quest to Create a Perfect Capsulorhexis

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**Received:** April 27, 2017; **Published:** May 03, 2018

Continuous curvilinear capsulorhexis (CCC) in the anterior capsule is an extremely important and critical step in modern refractive cataract surgery [1]. A good and optimum sized capsulorhexis is important not only for a smooth phacoemulsification surgery, but also to ensure optimum positioning of the IOL. Several techniques are used to make a CCC including needle cystotome, Utrata capsulorhexis forceps, micro-incision capsulorhexis forceps, femto-second laser, and Zepto nano pulse precision capsulotomy [2-10]. However, the accuracy of a CCC created using the manual methods (needle cystotome, capsulorhexis forceps, etc.) depend on the ophthalmic surgeon's skill and surgical experience, and the CCC is not always uniform and reproducible [10]. Moreover, creating a perfectly centered, adequate sized (5 - 5.5 mm) capsulorhexis in white mature intumescent cataracts cases remains a challenge and it is not uncommon to have "run-away rhexis" in these difficult cases, when done manually.

In the continuous quest to create a "perfect" capsulorhexis, many techniques/devices have been introduced to improve the accuracy of CCC. Corneal and anterior capsular markers as well as dyes to stain the anterior capsule (e.g. trypan blue) are the most frequently used aids to achieve a good CCC. Different Image Guided Systems (e.g. Alcon Verion imaging system and Zeiss Callisto Eye System) have been developed in the last few years to help surgeons by projecting a circular template of a pre-determined size on the anterior capsule intra-operatively [10]. Femto-second laser assisted capsulotomy has been shown to be very precise and predictable, and is much better centered than manual capsulorhexis. However, femto second laser is not commonly used by ophthalmologists due to high cost of the equipment. Creating a "perfect" CCC may become easier with some of the newly available (and less expensive) devices for capsulorhexis that include Zepto precision pulse capsulotomy, CAPSULaser, and Aperture continuous thermal capsulotomy [9,10].

**Zepto-Rhexis:** A novel capsulotomy method and technology called precision pulse capsulotomy (PPC) has recently been developed by Mynosys Cellular Devices; Fremont, Calif., USA [3,4]. The trade named "Zepto" received USA Food and Drug Administration clearance in June 2017 and currently it is distributed and marketed in India by Care Group, Vadodara, India. Both the small size of the instrument and the several millisecond speed of capsulotomy creation inspired the name of the device. Precision nano pulse capsulotomy device is a relatively inexpensive and disposable capsulotomy device that uses low energy pulses to create a precise central capsulorhexis, independent of pupil size, corneal clarity, or lens density. Zepto capsulotomy device can be very helpful in white cataract cases, small pupils, sub-luxated cataract cases, and infantile cataracts, where a successful capsulorhexis is difficult, and an inadequate capsulorhexis may preclude premium intraocular lens (IOL) implantation. Inserted through a clear corneal incision of 2.75 mm (now also with 2.2 mm), the device uses a gentle suction to create a uniform capsular contact. Capsulotomies are performed using a disposable hand-piece with a soft collapsible tip and circular nitinol cutting element. Electrical nano pulses are delivered to a nitinol (Nickel Titanium) ring to create the capsulotomy instantaneously and simultaneously along all 360°, with no cautery or burning of tissue. Vaporization of water molecules trapped between the capsule and nitinol edge causes the stretched capsular membrane to split circumferentially all at once [3,4]. A clear central window in the silicone shell surrounding the nitinol ring permits patients to fixate on the microscope light and allows the surgeon to center the capsulorhexis under direct visualization through the microscope. This device can create a capsulorhexis of 5.2 mm (or 4.8 mm) in size, irrespective of lens density, pupil size, or corneal clarity.

Our center was among the first centers in India to use the Zepto nano pulse capsulotomy system. So far we have done 20 eyes with excellent results and without any complication. Based on our experience, Zepto nano pulse capsulotomy system has several advantages over a femto-second laser: it is significantly cheaper, (which is even more important in developing countries), results in a stronger capsulotomy, provides fewer logistical challenges, and reduces overall surgical time [8,9].

In spite of the many advantages, Precision nano pulse capsulotomy device also has some limitations. One of the limitations is the need to insert the device in the anterior chamber. There are concerns about possible endothelial cell loss in cases with shallow anterior chamber. Live rabbit studies done by researchers showed no issues with inflammation or endothelial cell loss [4]. In addition, thermocouple probe measurements confirmed that there is negligible temperature change within the anterior chamber associated with PPC. Insertion of this device should be done very carefully in cases of nano ophthalmos and phacomorphic glaucoma with very shallow anterior chamber. Preoperative injection of intravenous mannitol with or without pars plana vitreous tap may be helpful in these difficult cases to deepen the anterior chamber. We recommend the frequent use of chondroitin sulfate based OVD (Viscoat, Alcon Fort Worth, USA) to coat the corneal endothelium to minimize endothelial cell loss during insertion or removal of the hand-piece from the anterior chamber. Like with any machine dependent procedure, there are other potential problems while using the Zepto PPC device. These include inability to open the device, suction loss, incomplete CCC, and difficulty in folding the device. However, we have not seen any of these complication(s). This new technique helps to achieve a perfect sized and well centered CCC in difficult cataract cases, enabling the implantation of premium IOLs. The well sized and central rhexis ensures the correct effective lens position (ELP) in these cases, which is very crucial for premium IOLs.

**Upcoming devices-CAPSULaser and Aperture CTC:** Two devices in the pipeline for achieving a perfect CCC include the CAPSULaser and Aperture CTC. The CAPSULaser (CAPSULaser; Los Gatos, Calif. USA) relies on continuous thermal energy to create capsulotomies. After dilating the pupil and making side-port incisions, the surgeon stains the anterior capsule with trypan blue to create a selective target for the laser. According to the manufacturer, the CAPSULaser, can be adjusted to select diameters from 4.5 to 7 mm. Unlike femto-second laser, this laser is continuous rather than pulsed and is scanned in a single circular pattern to create the continuous curvilinear capsulotomy.

A CAPSULaser capsulotomy may be stronger and more elastic than those made by manual CCC or by femto-second laser because its energy denatures the collagen. In the region of irradiation, the laser energy facilitates the molecular phase change of the capsular collagen IV to elastic amorphous collagen. As the collagen undergoes this phase change it creates the capsulotomy with a rim that has a high degree of elasticity and tear strength associated with the amorphous collagen and this strengthens the capsulotomy. Since the CAPSULaser uses low levels of continuous energy to make capsulotomies, the device momentarily raises the temperature of the iris, corneal endothelium and retina by less than 0.2°C as measured by infrared imaging and thermocouple. The CAPSULaser attaches to a standard surgical microscope, and has a small console, so it is quite portable, and doesn't disturb the patient work flow [9].

The Aperture continuous thermal capsulotomy (ApertureCTC) is being developed by International Biomedical Devices (Charleston, S.C., USA). This allows uniform contact with the anterior capsule. The manufacturer adds that the ApertureCTC can cut a capsulotomy rapidly, with repeatable size, shape and centration. The device consists of a console that provides constant, safe, low-level energy to the cutting parts of the capsulotomy tip of the hand-piece, which is designed to look and feel like the one used in phaco. The ApertureCTC hand-piece is used with disposable steel rings ranging from 4.5 to 6.5 mm in diameter. This ring attaches to the tip of a 1.2-mm hand-piece and retracts at the sides to fit through a small incision. After introducing into the anterior chamber, the ring is expanded to its original position. The ring delivers thermal energy to the capsular membrane and captures the circular cap for removal. As the ring is retrieved, it automatically captures and removes the perfectly circular cap. The disposable tip is discarded after the case, and the reusable hand-piece is sterilized in standard fashion. This is a non-laser based system, which provides continuous low-level thermal energy to create a well-centred capsulorhexis under direct visualization through the microscope [9].

In summary, a precise, optimum sized, and centrally placed capsulorhexis is crucial for in-the-bag implantation of premium IOLs. An adequate overlap of the capsulorhexis edge all around the optic of the IOL also ensures the correct effective lens position of the IOL. Manual capsulorhexis is extremely good in most cases and has strong edges. Femto-second laser can help to achieve capsulorhexis in difficult cases, but is associated with very high cost (machine and disposables). The size of the femto-second laser machine and the need for imaging and docking create logistical workflow issues and limit its utility for eyes with small pupils. At present, new devices are being designed to assist in the safe, fast, and repeatable creation of consistently strong and circular capsulotomies with less expense than that associated with femto-second lasers. All devices and instruments to facilitate capsulorhexis are useful, and the surgeon should choose the one that suits him/ her. As cataract surgery evolves into becoming a refractive surgery, the quest to achieve a perfect capsulorhexis becomes more important. In this ongoing journey, we have many devices from femto-second lasers, precision nano pulse technology to metallic thermal instruments to create perfectly round, consistent, central capsulotomies. This enables the best results of premium IOLs even in more difficult cataract cases, as these instruments give better capsulorhexis and effective lens position predictability and thus better outcome after refractive cataract surgery.

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**Volume 9 Issue 6 June 2018**

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