Original Article

Evaluation of change in the orientation of intraocular lens in the bag using intraoperative spectral-domain optical coherence tomography before and after capsular tension ring implantation

Naren Shetty, Reshma Ranade, Akash Jain, Raghav Narasimhan, Yash Patel, Rudy Nuijts[1], Rohit Shetty

Purpose: The purpose is to study the change in the contact of the IOL with the posterior capsule using intraoperative SD-OCT before and after implantation of the CTR post implantation of the IOL in the capsular bag. **Methods:** A total of 51 eyes of 51 patients with senile immature cataract underwent topical phacoemulsification procedure with implantation of an extended depth of focus intraocular lens by a single experienced surgeon. The Rescan 700 SD-OCT system was used for intraoperative imaging. These patients were imaged using intraoperative SD-OCT after implantation of the IOL and before and after implantation of appropriate size of CTR. The vertical height between posterior surface of the lens capsule and the posterior surface of the IOL was measured and compared across 3 CTR sizes. **Results:** The vertical height between the posterior surface of the lens capsule and the posterior surface of the IOL reduced significantly post CTR implantation (*P* value < 0.001) in all three groups. The change in height after CTR implantation was seen highest with the CTR size 13 mm and lowest with CTR size 11 mm. **Conclusion:** Significant improvement of contact between the IOL and the posterior capsule was shown after implantation of the CTR. Larger the size CTR, more the contact of the IOL with the bag was shown.

Key words: Capsular tension ring, intraoperative OCT, IOL stability

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In phacoemulsification surgery with premium IOL, IOL stability and centration are of paramount importance. IOL stability is critical for achieving postoperative emmetropia. A major determinant of IOL stability is the accurate prediction of the postoperative IOL position in relation to the posterior capsule.[1]

Spectral-domain optical coherence tomography (SD-OCT) provides high resolution, real-time, and cross-sectional *in vivo* imaging of the eye.[2] It has been used to evaluate IOL position in relation to the posterior capsule.[3] Since, a standard diameter of the IOL is used for implantation, contact between the optic and the posterior capsule may be variable, impacting the IOL stability and the refractive outcome.

Capsular tension rings (CTRs) are intraocular capsular support devices introduced by Legler and Witschel[4] and Nagamoto *et al*.[5] which redistribute the tension from areas of intact zonules to strengthen those having weak or missing zonules bringing the posterior capsule close to the IOL.[6,7] Several studies report the use of CTR to improve IOL centration by symmetrically stretching the capsular bag.

To achieve circumferential support and to ensure uniform stretch of the capsular bag, the terminal ends of the CTR should overlap.[8] Capsular bag sizes depend on the axial length and the corneal white-to-white (WTW) diameters.[9] Vass *et al*.[10] studied the correlation between axial length, corneal diameter, and other biometric variables.

Choosing appropriate size of the CTR based upon the axial length is well documented in literature.[11] Though previous studies[10] evaluated the correlation between the WTW diameter and other biometric variables and the capsular bag, there is a knowledge gap with respect to choosing the CTR size using the corneal horizontal WTW. Additionally, the effect of CTR in changing the contact of the IOL with the posterior capsule and its documentation using intraoperative SD-OCT has not been studied. Because the corneal horizontal WTW diameter was used to choose the appropriate size of the CTR in our patients, validation using intraoperative SD-OCT becomes necessary.

We intend to study the change in the contact of the IOL with the posterior capsule using intraoperative SD-OCT before and after implantation of the CTR. The authors believe that it can profoundly impact and bring about a paradigm shift in our current practice of premium IOLs by proposing the use of CTR to mitigate the rising concerns about their postoperative

Cataract and Refractive Lens Services, Narayana Nethralaya, Bengaluru, Karnataka, India, [1]University Eye Clinic Maastricht, Maastricht University Medical Center, Maastricht, The Netherlands

Correspondence to: Dr. Naren Shetty, Cataract and Refractive Lens services, Narayana Nathralaya Superspecilaty Eye Hospital, 121/C Chord Road, Near Iskcon Temple, 1st R Block, Rajaji Nagar, Bengaluru – 560 010, Karnataka, India. E-mail: Narenshetty. 27@gmail.com

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short and long-term stability and thereby ensure an optimal visual outcome.

Methods

The prospective single center study was conducted at our center according to the tenets of the Declaration of Helsinki and approval by the Institutional Ethics Committee. A total of 51 eyes of 51 patients diagnosed with senile immature cataract undergoing topical phacoemulsification procedure with implantation of an extended depth of focus intraocular lens by a single experienced surgeon were included in the study. Patients with mature, black, or brown cataracts and other ocular co-morbidities such as zonular dehiscence, glaucoma, and retinal disorders were excluded from the study. All patients were informed of the details and possible risks of the surgery and a written informed consent was obtained. All consenting patients underwent complete preoperative work-up including refraction, dilated slit lamp examination, retina evaluation. Preoperative Biometry was performed using partial coherence interferometry by IOL Master 700 (Carl Zeiss Meditec, AG). Patients with normal axial length in the range of 22 mm to 25 mm were included, and the rest were excluded.

Surgical technique

All surgeries were performed by a single experienced surgeon under topical anesthesia with 0.5% proparacaine hydrochloride. Standard phacoemulsification procedure with 2.8 mm self-sealing clear corneal incisions at 200 degrees in the right eye and 20 degrees in the left eye with paracentesis incisions located 2 clock hours away on either side were made. A continuous curvilinear capsulorhexis approximately 5 mm in size was fashioned to ensure a 1 mm overlap of the rhexis margin over the implanted IOL. Phacoemulsification was performed using the Centurion Gold phacomachine (Alcon Laboratories, USA) with surgeon specific parameters which were kept fixed for all cases. The intraoperative IOP was set at 22 mmHg for all cases to achieve a more physiological environment. The non-gravity based active fluidics system of the Centurion Gold Phacoemulsification Systems ensured the maintenance of the IOP of 22 mmHg throughout the procedure.[12,13] An extended depth of focus IOL (AcrySof® IQ Vivity™, Alcon Laboratories, Inc) was implanted in the capsular bag using an IOL delivery system, with the haptics oriented horizontally for all the patients. The AcrySof® IQ Vivity™ IOL is a single piece hydrophobic acrylic IOL with an optic diameter of 6 mm and an overall length of 13 mm. Thorough wash of the viscoelastic agent (2% hydroxypropyl methyl cellulose (Appavisc PFS®, Appasamy Associates) was performed after implantation of the IOL to prevent any barrier between the optic of the IOL and the posterior capsule. After the implantation of the IOL and capturing the SD-OCT scans, a capsule tension ring (Endocapsular ring, Care group, Gujarat, India) of appropriate size 11, 12 and 13 mm uncompressed diameters, (Styles ECR 11, ECR 12 and ECR 13) based on the horizontal WTW measurement was implanted in the bag under irrigation. ECR 11 was used in patients with WTW between 11–11.5 mm, ECR 12 was used for those with WTW 11.5 to 12 mm, and those with WTW >12 mm were implanted with ECR 13.

Intraoperative OCT imaging

After IOL implantation, Rescan 700 (Zeiss Meditec, Germany) integrated with the surgical microscope (Opmi Lumera 700) was used for capturing scans. The Rescan 700 (Zeiss Meditec, Germany) is SD-OCT device with a wavelength 840 nm, a scanning speed 27,000 A-scans per second, providing a A-scan depth of 2 mm and an axial resolution of 5.55 µm in tissue. The RESCAN 700 also provides Z-tracking and focus control for stabilization of the image and quality check. Adjustment and capture of the intraoperative SD-OCT images were performed by a single experienced observer. The alignment of the iris and the IOL at a horizontal plane or close to a horizontal plane was ensured to confirm the visibility of the capsular bag and IOL. Two intraoperative SD-OCT images, with a scan size of 8 mm, were captured, the first scan showing the IOL in the bag, and posterior capsule was stored for comparative analysis. A total of three scans showing the IOL and posterior capsule were captured to ensure repeatability. A CTR (Endocapsular ring, Care group, Gujarat, India) of appropriate size (11 mm 12 mm and 13 mm uncompressed diameter) based on the horizontal WTW measurement was implanted. Intraoperative OCT scan with the same parameters was captured after CTR implantation. Intraoperative SD-OCT scanning was performed using the video and snapshot modes.

OCT standardization

Scans captured were standardized. They all were a two line raster scan of size 8 with OCT depth of 2.9 mm. The scanning area was centered to the purkinje image from the anterior corneal surface and the IOL reflection. Resizing intraoperative SD-OCT scans from 512 pixels * 1024 pixels (standard image size from Rescan 700) to 600 pixels * 200 pixels or 900 pixels * 200 pixels were optimum, because this size corresponds to the dimensions of the real-time intraoperative SD-OCT scans, which are equal to 6.0 mm * 2.0 mm or 9.0 mm * 2.0 mm (6000 mm * 2000 mm or 9000 mm * 2000 mm).

Height calculation

The scans were exported as video files, and screenshots of OCT scans before and after the CTR implantation were taken from the recorded videos [Figs. 1 and 2]. A custom-built software was made using LabVIEW (v18) to calculate the vertical height between posterior surface of the lens capsule and the posterior surface of the IOL (axial height in pixels). The software reads both before and after CTR implantation scans and showed them side by side. The pre-processing steps involved cropping of the screenshots to view only the horizontal and vertical OCT scans, conversion to grayscale and thresholding to reduce noise. The posterior of the IOL was manually selected by the trained clinician and the program automatically detected the posterior of the lens capsule on the vertical axis using peak detection. The vertical height difference was then calculated from the detected surfaces and represented in pixels.

Statistical analysis

All parameters were summarized as mean ± standard deviation [Table 1]. Paired sample *t*-test was used to determine statistical significances between the vertical height before and after CTR implantation. A *P* value less than 0.05 was considered statistically significant. MedCalc v20.015 (MedCalc Inc., Ostend, Belgium) software was used for statistical analyses.

Results

A total of 51 eyes of 51 patients were included in the study. The mean age of the 23 men (45%) and 28 women (55%) was

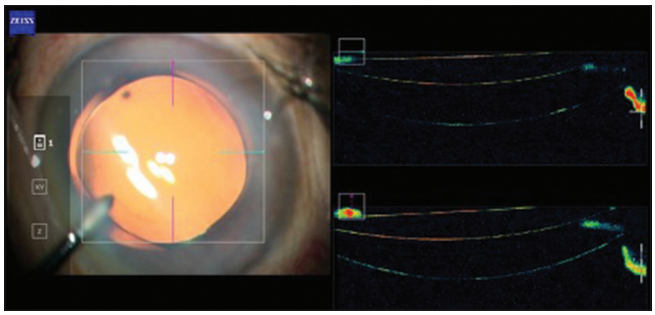

Figure 1: Intraoperative OCT before CTR

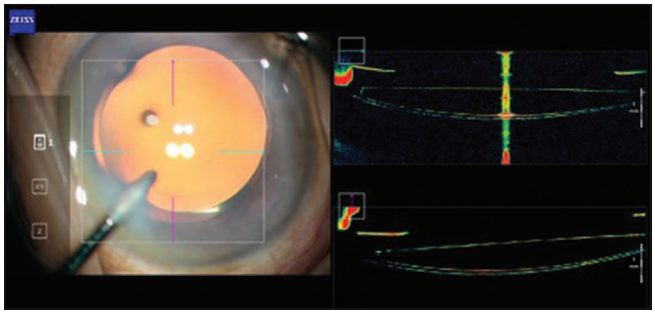

Figure 2: Intraoperative OCT after CTR

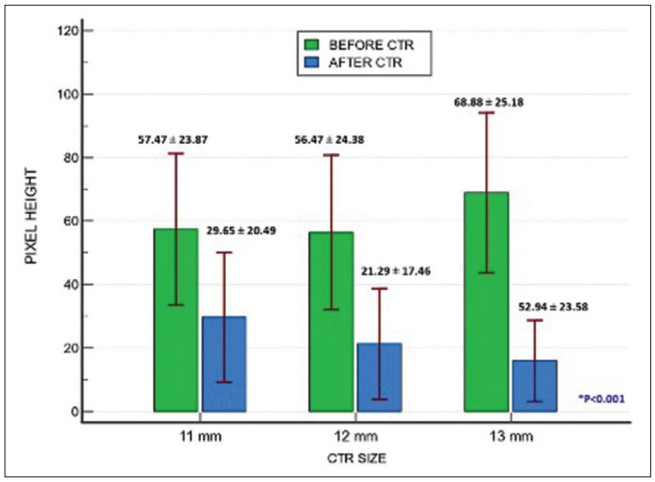

Figure 3: Mean vertical height before and after CTR for different CTR sizes

64.7 years (range 48 to 86 years). All these patients underwent the standard clear corneal phacoemulsification procedure with extended depth of focus IOL implantation (AcrySof® IQ Vivity™, Alcon Laboratories, Inc) performed by a single surgeon with surgeon specific parameters kept constant across all procedures. The mean AL was 23.30 ± 0.63 mm (range 22.17 to 24.61 mm). The mean horizontal WTW was 12.02 ± 0.42 mm (Range 11 mm to 12.8 mm), and the mean IOL power was 21.68 D ± 1.54 (range 18 D to 24.50 D). All eyes achieved a mydriasis of >6 mm, and the edge of the optic was visible in all cases. All surgeries were uneventful and had well-centered IOL.

CTR sizes 11, 12, and 13 were used in 17 patients in each group. In those implanted with CTR size 11 mm, the mean vertical height in pixels between posterior surface of IOL to the posterior capsule before CTR implantation was 57.47 ± 23.87 pixels which reduced to 29.65 ± 20.49 pixels after implantation of CTR. In those implanted with CTR size 12 mm, the mean pre-CTR vertical height was 56.47 ± 24.38 pixels which reduced to 21.29 ± 17.46 pixels. Similarly, in those where CTR size 13 was implanted, mean pre-CTR vertical height was 68.88 ± 25.18 pixels which reduced to 15.94 ± 12.77 pixels after CTR implantation.

Table 1: Mean vertical height before and after CTR and mean change in height after CTR, for different CTR sizes. All parameters are represented as mean±standard deviation

CTR Size	Before CTR	After CTR	Change in height after CTR implantation	P*
11 mm	57.47±23.87	29.65±20.49	27.82±16.79	<0.001
12 mm	56.47±24.38	21.29±17.46	35.18±16.70	<0.001
13 mm	68.88±25.18	15.94±12.77	52.94±23.58	<0.001

*Paired *t*-test

The change in height after CTR implantation was seen highest with the CTR size 13 mm and lowest with CTR size 11 mm [Fig. 3].

Discussion

Intraoperative SD-OCT can be a brilliant tool to document the positioning of the IOL in relation to the posterior capsule. Lytvynchuk *et al*.[3] have evaluated the position of IOL with intraoperative SD-OCT. The role of CTR in distributing the tension of the zonules, maintaining the shape of the bag and increasing the attachment between the posterior capsule, and the IOL surface has been well documented in literature.[12] Axial length determines the appropriate size of CTR for implantation.[13] Previous studies[10] have also studied the correlation between the WTW diameter and other biometric variables with the capsular bag. However, the role of horizontal WTW as a lone factor for determining the CTR size has not been explored. Moreover, there are no studies evaluating the impact of different CTR sizes on the contact between the posterior capsule and the IOL using intraoperative SD-OCT. To the best of our knowledge, ours is the first study to evaluate the change in the contact of the IOL with the posterior capsule before and after CTR implantation using intraoperative SD-OCT.

We used our custom nomogram to choose size of the CTR based on the horizontal WTW. ECR 11 was used in patients with WTW between 11–11.5 mm, ECR 12 was used for those with WTW 11.5 to 12 mm, and those with WTW >12 mm were implanted with ECR 13. We compared the mean vertical height between posterior surface of the lens capsule and the posterior surface of the IOL before and after CTR implantation for different CTR sizes. We found that the height reduced significantly post CTR implantation (*P* value < 0.001) in all three groups. The change in height after CTR implantation was found to be the highest with the CTR size 13 mm and lowest with CTR size 11 mm. Our data set consisted of patients showing a normal distribution of axial length between 22–25 mm and WTW between 11–12.8 mm. Though we found that the mean reduction in vertical height between the IOL and posterior capsule was statistically significant with all 3 CTR sizes, the

decrease in the height was found to be the highest with CTR size 13 mm. This suggests that in normal eyes with axial length of 22–25 mm and horizontal WTW between 11–12 mm, using a CTR size of 13 mm would be more beneficial.

Posterior capsule opacification (PCO) is a common postoperative complication.[14] It is affected by the IOL material, IOL design, postoperative inflammation, surgical technique, apart from several ocular and systemic associations.[15–18] Previous studies[19,20] found that IOLs with square-edged design impede migration of lens epithelial cells and reduce PCO formation. Increased contact between the IOL optic and the posterior capsule prevents PCO formation. To address the latter, Lytvynchuk *et al*.[3] studied the contact between the IOL's square edge and the posterior capsule. They found that the contact was only partial in 57.53% of eyes, while evaluating two groups implanted with Acrysof IQ SN60WF IOL (Alcon Laboratories, Inc) and Tecnis IOL (Johnson and Johnson, Inc). Since the authors noted a partial contact between the posterior capsule and the IOL in a majority of the eyes, our study additionally considered using CTR to reduce the space between the IOL and posterior capsule.

Moreover, our study stands unique in the fact that we used the corneal horizontal WTW diameter alone for choosing the size of CTR. Since we used our nomogram for implanting the CTR, its validation using intraoperative SD-OCT was necessary.

The size of the capsular bag is determined by axial length, age, and individual characteristics.[21,22] In most of the patients undergoing cataract surgery, an IOL of a standard size is implanted irrespective of the size of the capsular bag or the axial length. Improper size of IOL and variable capsular bag size leads to residual refractive errors, IOL displacement, or tilt postoperatively. The distance between IOL and the posterior capsule depends on axial length, the condition of the vitreous and zonular fibers, capsular bag size, IOL design, and even the intraocular pressure at the end of phacoemulsification.

Theoretically, contact between the posterior capsule and the IOL can be improved by implanting an IOL customized as per the capsular bag. However, this may not be practically possible across case scenarios.[23,24] An alternative, therefore, could be CTR implantation to increase apposition and reduce space between the posterior capsule and IOL. Intraoperative SD-OCT has been used previously to demonstrate the gap between the IOL and posterior capsule at the end of the phacoemulsification procedure without using a CTR.[3] However, to the best of our knowledge, there is a lacunae in literature with respect to evaluating the effect of CTR in changing the contact of the IOL optic with the posterior capsule using intraoperative SD-OCT.

Though we evaluated the effect of CTR in improving the contact between the IOL and the posterior capsule intraoperatively, longitudinal studies to study its role in long-term stability, tilt, or decentration need to be done. All the patients in our data set underwent implantation of extended depth of focus IOLs along with appropriate size CTR implantation. We included those patients with an EDOF IOL implantation primarily because the centration and postoperative stability of these IOLs are crucial to ascertain optimal refractive outcomes. Lee *et al*.[25] have concluded that CTR implantation can lead to reduced postoperative IOL movements and that eyes with both an IOL and a CTR had significantly less IOL decentration and tilting in comparison with the eyes with an IOL only. However, they analyzed the role of CTR with the implantation of a PMMA IOL *in vitro* using porcine eyes with the Miyake technique. In our study, we assessed the effect of CTR on the contact between the IOL and the posterior capsule in EDOF IOLs *in vivo* using intraoperative SD-OCT in human eyes.

Inoue *et al*.[26] analyzed the degree of toric IOL misalignment by attempting to differentiate between an intraoperative positioning error and a postoperative rotational error. The authors found that greatest IOL rotation occurred within 1 hour after surgery and that IOL orientation was highly stable after the first postoperative day. They concluded that postoperative rotational stability plays an important role in obtaining satisfactory corrective effects of toric IOL implantation. Our data set consisted of patients undergoing non-toric EDOF IOL implantation only. A limitation of our study is that we assessed the contact between the posterior capsule and the IOL intraoperatively alone. Though our study is an indirect evidence that greater contact and reduced space between the optic of the IOL and the posterior capsule may lead to postoperative IOL stability and lesser chances of IOL rotation, further studies using toric IOLs and validation of stability and centration in these patients with postoperative follow-ups are crucial.

Capsular bag distension syndrome (CBDS) is a rare complication after cataract surgery. It is characterized by distension of the capsular bag and accumulation of the fluid behind the IOL. Saccadic eye movements, retained viscoelastic behind the IOL, retained cortical matter in the capsular bag contribute to pathogenetic mechanisms in CBDS.[27–29] The role of improved apposition of IOL with the posterior capsule as a deterrent for CBDS has not been studied. We hypothesize that a reduction in space between IOL and the capsule may reduce the chances of CBDS. However, further longitudinal studies are required to prove the same. CTR implantation itself can have complications like capsular bag tear, zonular dialysis, retained cortex, etc.

Another limitation of our study is that we only included eyes with an axial length between 22 and 25 mm and horizontal corneal diameter between 11 and 12.8 mm which is considered to be the normal range. Analysis of short eyes and long eyes is essential to establish the results more conclusively.

Conclusion

Our data suggests that greater contact between the IOL and the posterior capsule could be achieved after CTR implantation. We suggest that the resultant IOL stability leads to lesser chances of postoperative IOL rotation, IOL tilt, or decentration and hence optimal visual outcomes. This becomes crucial in patients undergoing premium IOL implantation like toric, extended depth of focus, or trifocal IOLs where centration and stability are necessary. Our paper substantiates the need for CTR implantation, especially in these premium IOL designs.

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