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Automated precision pulse capsulotomy vs manual capsulorhexis in white cataracts: reduction in procedural time and resource utilization

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Purpose: To compare the utility of precision pulse capsulotomy (PPC) with manual capsulorhexis for capsulotomy in white cataracts.

Setting: Hospital-based academic practice.

Design: Retrospective analysis of surgical case records and surgical videos from a single surgeon.

Methods: Cases involving intumescent and nonintumescent white cataracts were identified. Capsulotomy outcomes, surgical outcomes, procedural time, and resource utilization, as well as patient demographic and health data, were analyzed and subjected to statistical testing.

Results: 15 cases of white cataract (10 intumescent and 5 nonintumescent) performed using continuous curvilinear capsulorhexis (CCC) were compared with 20 cases (9 intumescent and 11 nonintumescent) performed using PPC. The cases covered a period of 14 months before and 30 months after surgeon adoption of PPC. There were no significant differences between the 2 groups in patient age, sex, ethnicity, ocular history, medical history, and medications. PPC resulted in complete capsulotomies without tags or tears and intracapsular intraocular lens implantation with 360-degree capsular overlap in all 20 cases. There was 1 CCC case resulting in the Argentinian flag sign. Compared with CCC, PPC white cataract cases also demonstrated significant advantages in capsulotomy time, reduced use of trypan blue and ophthalmic viscosurgical device, and less overall procedural time.

Conclusions: PPC is a safe and highly effective method to create consistent capsulotomies in both intumescent and nonintumescent white cataracts. The use of PPC provides benefits of significant reductions in capsulotomy time, overall procedural time, and resource utilization, resulting in a streamlined treatment of these complex cataract surgery cases.

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Online Video

The challenges of capsulorhexis in cases with white cataract are well recognized. These include poor visibility because of the lack of a red reflex, egress of the liquified cortex and the presence of elevated intralenticular pressure leading to a transcapsular pressure gradient that can result in uncontrolled capsular extensions and further surgical complications. These surgical complications can add surgical time and prevent planned intraocular lens (IOL) placement. Surgeons typically adopt several strategies to treat white cataracts. These include the staining of the capsule with trypan blue dye to allow the capsular tissue to stand out in contrast from the opaque lens. In addition, the anterior chamber pressure is iatrogenically elevated to counter the raised intralenticular pressure, decreasing the transcapsular pressure gradient with the hope of mitigating the risk of capsular extension during capsulorhexis. This is generally accomplished with the introduction of additional high-molecular-weight cohesive ophthalmic viscosurgical device (OVD) before capsulorhexis, instead of the traditional dispersive or even low-molecular-weight cohesive OVD that is usually used at the beginning of surgery. Before capsulorhexis, a needle decompression of the capsule is often performed to attempt to release pressure. Alternatively, a decompression step using the phacoemulsification probe may also be used. Another method is to make an initial minirhexis that is smaller than an ideal rhexis, followed by enlargement to a normal size.[1] One other recent approach that has been proposed is the use of a femtosecond laser to assist in the creation of the capsulotomy for intumescent white cataract.[2–4] However, this method can result in capsular tags and extensions likely resulting from released cortical

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milky material interfering with the laser path.[5,6] The current treatment of white cataracts therefore requires the surgeon to modify routine cataract surgery with additional steps and necessitates the utilization of additional surgical resources. Despite the incorporation of these mitigating steps, surgical treatment of white cataracts still has a high rate of complications and has been found to be the leading cause of dropped nuclei during cataract surgery.[7]

Recently, PPC was introduced for the automated creation of a round, precise capsulotomy during cataract surgery.[8–12] PPC involves the use of a handpiece with a capsulotomy tip composed of a suction cup and an embedded nitinol capsulotomy ring element. The tip is folded and inserted into corneal incisions 2.2 mm or greater and is reexpanded to its original circular shape once introduced inside of the eye. Suction is delivered through the suction cup to secure the capsulotomy ring against the capsule, and energy is delivered to create the entire perimeter of the capsulotomy at the same time. PPC has been used successfully not just in routine cataract surgery but also in pediatric cataract surgery and in challenging cases with corneal opacities, small pupils, zonular pathologies, and trauma.[11–15] The learning curve has been reported to be favorable, and the experience of 4 surgeons has been described.[11]

Several device operating principles underlying PPC creation suggest that this technology may also be useful in cases of white cataract. This includes the technology's ability to function in the presence of poor capsular visibility, the near-instantaneous (4 milliseconds) creation of the whole capsulotomy to rapidly release intralenticular pressure, and the demonstrated added capsular edge strength resulting from PPC's unique cutting effect.[9]

In this study, we investigated the hypothesis that PPC can be used in cases of white cataract to compensate for poor capsular visibility because of the loss of the red reflex and to provide a quick, consistent, and reliable method of safe capsulotomy creation in cases of intumescent white cataract. In addition, we wished to examine whether the use of PPC resulted in less procedural time and less utilization of surgical disposables such as trypan blue dye and high-molecular-weight cohesive OVD that are normally used as mitigation strategies in these challenging cases.

METHODS

Data Collection

Cataract surgeries conducted at the Denver Health Medical Campus from the period January 2018 to September 2021 were reviewed to select only those which had the term "white cataract" associated with medical charts. Cases with posterior synechiae, phacodonesis, violated capsule, cataract postvitrectomy, ruptured globe, and penetrating keratoplasty were excluded. The dataset also excluded cases performed primarily by resident surgeons. All cases performed by the author (C.I.) that involved the removal of a white cataract were included for analysis. Of the 35 cases identified, the capsulotomy was performed using CCC in 15 cases, whereas 20 cases used precision pulse capsulotomy (PPC) (Zepto, Centricity Vision, Inc.). Patients did not pay for, nor did they receive any financial consideration for the use of PPC during cataract surgery. These cases occurred over the period spanning 14 months immediately before the surgeon's adoption of PPC, a 4-month transition period during which both CCC and PPC were used for capsulotomies, followed by a 26-month period after PPC was adopted into the surgical routine and used exclusively.

Recorded Data

The data obtained from each case included patient demographic information, relevant medical history, primary diagnosis, associated diagnoses, date of surgery, and laterality of the operated eye. The existence of comorbidities including glaucoma, diabetes mellitus, diabetic retinopathy, uveitis, and dry eye disease was noted. Medications including any eyedrops, tamsulosin, the use of blood thinners, and hypertension medications were also noted.

Preoperative data included uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), intraocular pressure (IOP), axial length, contralateral axial length, anterior chamber depth (ACD), and contralateral ACD. Visual acuities were determined using the Snellen chart. Intraoperative data included the use of trypan blue, OVD use, capsulotomy time, phacoemulsification method, cumulative dispersed energy, use of intraocular epinephrine, surgical complications, and type of lens implant. Postoperative data included UDVA, CDVA, and AC cells at 1 day, 1 week, 1 month, and 3 months after surgery. IOP was also obtained at 1 day, 1 week, and 1 month postoperatively.

Surgical videos were obtained for 23 of the 35 cases (7 CCC and 16 PPC) and were used to determine the time required for capsulotomy completion (see below), the roundness of the capsulotomy, and whether there was a complete overlap between the capsulotomy and the IOL implant. The time required for trypan blue use was determined as the interval from the introduction of the cannula containing trypan blue into the eye to the removal of the cannula after rinsing out of trypan blue from the eye. All CCC cases and PPC cases that used trypan blue were analyzed. Capsulotomy completion time was determined as the interval from the entry of the capsulorhexis instrument or the tip of the PPC device into the anterior chamber to the time the capsulorhexis instrument or the tip of the PPC device exited from the anterior chamber.

Analysis

The recorded data were compared between CCC and PPC cases. Statistical analysis included comparisons between CCC and PPC groups using descriptive statistics. Categorical data between CCC and PPC groups were tested using the chi-square test, whereas the testing of means between CCC and PPC groups was performed using the appropriate t test.

Visual acuities based on the Snellen chart were converted into logMAR scores for statistical analysis.[16] Visual outcomes at 1 week, 1 month, and 3 months were analyzed using descriptive statistics and were also tested using mixed-effects analysis of variance and exploration of the existence of the interaction between treatment type and time.

The roundness of each CCC and PPC was quantified as a roundness index defined as the ratio of the surface area of the CCC or PPC to the area of a circle whose diameter is equal to the maximum diameter of the capsulotomy (Computational Modelling of Biomechanics and Biotribology in the Musculoskeletal System [Second Edition], 2021). Surgical videos were imported into Adobe Premiere Pro video editing software (v. 14.0; Adobe, Inc.). Individual still frames from each surgical video that best showed the PPC and CCC capsulotomy at the time of surgery were chosen. Capsulotomy images were imported into Adobe Photoshop (v. 22.1.0) to manually trace the perimeter of the capsulotomy. The surface area of the capsulotomy was then derived using PowerPoint software (v. 16.0; Microsoft Corp.) as the number of pixels enclosed by the perimeter tracing. The greatest diameter of each capsulotomy was selected using the line measurement function of the software. A circle of the corresponding diameter was created and converted into the surface area expressed as pixel units. The ratio of the number of pixels from the capsulotomy (surface area) to the number of pixels of the circle (surface area) was obtained as the roundness index. The roundness index therefore describes how close each capsulotomy is to a perfect circle. The roundness index of a perfect circle is equal to 1.

RESULTS

CCC and PPC Group Demographics

There were no significant differences in the patient demographic data from the CCC and PPC groups. The CCC group consisted of 7 female and 8 male patients, whereas the PPC group consisted of 11 female and 9 male patients (P = .49, chi-square test). No differences were found by ethnicity analyzed as groups consisting of White or Caucasian, Black or African American, Asian, and others (P = .62, chi-square test). The mean age of the CCC group was 55.9 ± 10.1 years and was not significantly different from that of the PPC group that had a mean of 57.7 ± 10.3 years (P = .61, t test; F tested for equal variance).

Clinical Data for CCC and PPC Groups

No difference was observed in the ACD of CCC cases (mean 2.54 ± 0.35 mm) and PPC cases (mean 2.87 ± 0.57 mm) (P = .075, t test). No significant differences were observed in the preoperative IOP between the CCC (15 ± 8.4 mm Hg) and PPC groups (14 ± 3.2 mm Hg) (P = .77, t test, unpaired, unequal variance). No differences were noted in the occurrence of glaucoma, diabetes mellitus, and dry eye disease between the 2 groups. There was no difference in the use of medications (tamsulosin, antihypertensives, blood thinners, and eyedrops) between groups.

CCC in Intumescent and Nonintumescent White Cataracts

CCC was used to create the capsulotomy in 15 cases with white cataract. Five cases were classified as nonintumescent white cataract, and 10 cases were classified as intumescent white cataract. Intumescent cataracts were identified by the presence of asymmetric anterior chamber shallowing and by the in-clinic and intraoperative visual identification of clues such as water clefts, hydrated cortex, and bowing of the anterior capsule. Trypan blue was used in all CCC cases to aid in capsule visualization. In addition, a high-molecular-weight cohesive OVD (Healon 5, Johnson & Johnson Vision) was placed in the anterior chamber to maintain chamber pressure during capsulorhexis. CCC was then performed first by needle decompression, followed by using capsulorhexis forceps. One case of intumescent white cataract resulted in capsule radialization (Argentinian flag sign) during CCC despite the use of Healon 5 and needle decompression through a paracentesis.

PPCs in Intumescent and Nonintumescent White Cataracts

PPC was performed in a total of 20 cases. Eleven cases were classified as nonintumescent white cataract, and 9 cases were classified as intumescent white cataract. The PPC device was used according to the manufacturer's instructions. Briefly, the PPC device was removed from its packaging. The suction line was prefilled with a balanced salt solution and attached to the PPC console along with the power connection for the PPC handpiece. The PPC handpiece slider was then pushed forward to extend the capsulotomy tip into an elongated shape for insertion through the 2.4 to 2.75 mm primary incision. Once in the anterior chamber, the slider was retracted, and the capsulotomy tip allowed to assume its original circular shape. After positioning the PPC nitinol capsulotomy ring at the desired location above the lens, suction was initiated to securely appose the capsulotomy ring against the capsular surface. Energy was then delivered through the PPC console for capsulotomy creation. Suction was then reversed, and the PPC tip removed from the eye through the primary incision. Surgery continued with hydrodissection and phacoemulsification (see Video 1, available at http://links.lww.com/JRS/A765).

PPCs were performed with capsular prestaining with trypan blue only when there was a history of trauma. All PPCs were conducted in the presence of a dispersive OVD, similar to that used by the surgeon in routine cataract surgery. Needle decompression of the capsular bag was not performed before PPC. In all 20 white cataract cases, PPC successfully created 360-degree capsulotomies free of capsular tags or tears and that resulted in complete IOL overlap.

As the use of PPC in principle should have no direct bearing on lens cataract removal, no differences were observed in the cumulative dispersed energy used in CCC (5.5 ± 3.9) vs PPC cases (7.0 ± 3.3) (P = .22, t test, 2-tailed, unequal variance). No differences were observed in the ocular inflammatory response to cataract surgery involving CCC or PPC. At day 1 postoperatively, the clinical grading of anterior chamber cells showed a mean score of 1.9 ± 0.82 for CCC cases and 1.5 ± 0.84 for PPC cases (P = .29, t test, unpaired, 2-tailed, unequal variance). There was no difference in the mean AC cell grade at 1 week postoperatively between CCC (0.64 ± 0.22) and PPC (0.42 ± 0.33) (P = .09, t test, unpaired, 2-tailed, unequal variance), nor at 1 month between CCC (0.32 ± 0.39) and PPC (0.0.19 ± 0.12) (P = .12, t test, unpaired, 2-tailed, unequal variance). No differences were observed in IOP at day 1 (CCC 17 ± 3.6 mm Hg vs PPC 22 ± 7.24 mm Hg; P = .088, t test), at 1 week (CCC 18 ± 12.1 mm Hg vs PPC 17 ± 2.87 mm Hg; P = .749, t test), and at 1 month (CCC 13 ± 4.1 mm Hg vs PPC 17 ± 4.5 mm Hg; P = .085, t test). There were no cases of cystoid macular edema, capsular phimosis, and YAG capsulotomies in either the CCC or PPC cases assessed at 3 months postoperatively.

Visual Outcomes in CCC and PPC Cases

Visual outcome data (UDVA and CDVA) for both CCC and PPC cases are shown in Table 1. The data indicated that procedures using PPC showed a numeric advantage in both UDVA and CDVA at 1 week, 1 month, and

Table 1. Postsurgical UDVA and CDVA (mean scores) (logMAR units)

Time interval	Capsulotomy method	Capsulotomy method	Statistical analysis
UDVA	CCC	PPC	*t* test
Day 1	0.681 ± 0.542	0.629 ± 0.590	P = .91
Week 1	0.443 ± 0.579	0.273 ± 0.261	P = .36
1 mo	0.369 ± 0.373	0.215 ± 0.148	P = .29
3 mo	0.454 ± 0.570	0.144 ± 0.118	P = .31
CDVA	CCC	PPC	*t* test
Day 1	0.63 ± 0.55	0.57 ± 0.64	P = .80
Week 1	0.23 ± 0.26	0.12 ± 0.16	P = .26
1 mo	0.16 ± 0.12	0.07 ± 0.09	P = .12
3 mo	0.11 ± 0.19	0.01 ± 0.04	P = .17

CCC = continuous curvilinear capsulorhexis; PPC = precision pulse capsulotomy

3 months postoperatively compared with CCC cases. However, given the sample size, the reported advantages were not statistically significant. A mixed-effects analysis of variance model was performed in which outcome measures from week 1 through month 3 were analyzed. The covariance structure over the 3 measures was set to autoregressive. The main effect of the treatment type (PPC or CCC) did not show any statistically significant difference in UDVA or CDVA. An interaction between the treatment type and time (linear) was also explored. However, this did not show any significant difference in the time trends for the 2 procedures. In sum, despite the numerical advantages of the tabulated means in visual outcome UDVA and CDVA for PPC cases, the results do not rise to the level of statistical significance given the relatively small sample size.

PPC and CCC Capsulotomy Times

The time duration required for capsulotomy completion was significantly shorter in PPC cases compared with CCC cases (Table 2). CCC capsulotomies required a mean of 83 ± 18 seconds (range 55 to 118 seconds) to complete compared with a mean of 62 ± 14 seconds (range 42 to 86 seconds) for PPCs ($P < .05$, *t* test, 2-tailed, unequal variance).

Capsulotomy Roundness and Overlap

All PPCs were found to be substantially rounder than CCC capsulotomies (Table 2). The mean roundness index of CCC capsulotomies was 0.85 ± 0.03, whereas that of PPCs was 0.95 ± 0.03 ($P < .001$, *t* test, unpaired, 2-tailed, unequal variance) (the roundness index of a perfect circle is 1.0). There was complete capsulotomy overlap with the IOL in all 20 PPC cases based on the review of surgical videos. Surgical videos were available for 7 of 15 CCC cases. There was complete capsulotomy overlap with the IOL in these 7 cases.

Reduced Use of Trypan Blue in PPC Cases

PPC permitted a substantially different approach to the capsulotomy step in the surgical treatment of white cataracts. As CCC involves the creation of a capsular tear that the surgeon must control and move in a circular path by hand, surgeon visualization of the capsule is essential at each step along the circular capsulotomy. By contrast, PPC uses a ring element for capsule cutting that is securely applanated to the anterior capsule, and visualization of the capsule is not strictly necessary. A decreased use of trypan blue was observed in this study (Table 2). Trypan blue was used in 100% of CCC cases and only in 40% of PPC cases ($P < .001$, chi-square test). Trypan blue use in PPC cases included cases performed during the period when PPC was being adopted by the surgeon and those where trauma was reported or suspected (Figure 1).

Time Required for Trypan Blue Use in CCC Cases

The use of trypan blue added a significant amount of time to the overall surgical procedure. Trypan blue capsular staining determined as the interval from dye instillation into the eye to the rinsing out of the dye from the eye required a mean of 54 ± 8 seconds (n = 15). By contrast, PPC cases did not require capsular staining before capsulotomy and thus avoided the procedural time associated with the use of this surgical disposable (Table 2). Although the time required for trypan blue use in the current study was based on a limited number of cases, the time savings, if substantiated, would help to increase surgical efficiency for the patient and the practice.

PPC Relief of Intracapsular Pressure

As PPC requires only 4 milliseconds to create the entire capsulotomy opening, intracapsular pressure is relieved through a larger capsular opening compared with a much smaller opening when the capsule is first punctured while

Table 2. Comparison of CCC and PPC metrics and resource utilization

Metric	CCC	PPC	Statistical analysis
Capsulotomy time (s) (mean ± SD)	83 ± 18	62 ± 14	$P < .05$, *t* test
Capsulotomy roundness index (mean ± SD)	0.85 ± 0.03	0.95 ± 0.03	$P < .001$, *t* test
% cases with incomplete capsulotomies	1	0	NA
% cases with intracapsular implantation	100	100	NA
Argentinian flag sign	1 of 15 cases	0 of 20 cases	NA
% cases using trypan blue	100	40	$P < .001$, chi-square test
Additional time required for trypan blue use (s)	54 ± 8 (n = 15)	Not needed	NA
% cases using extra OVD	40	0	$P < .01$, chi-square test

CCC = continuous curvilinear capsulorhexis; OVD = ophthalmic viscosurgical device; PPC = precision pulse capsulotomy

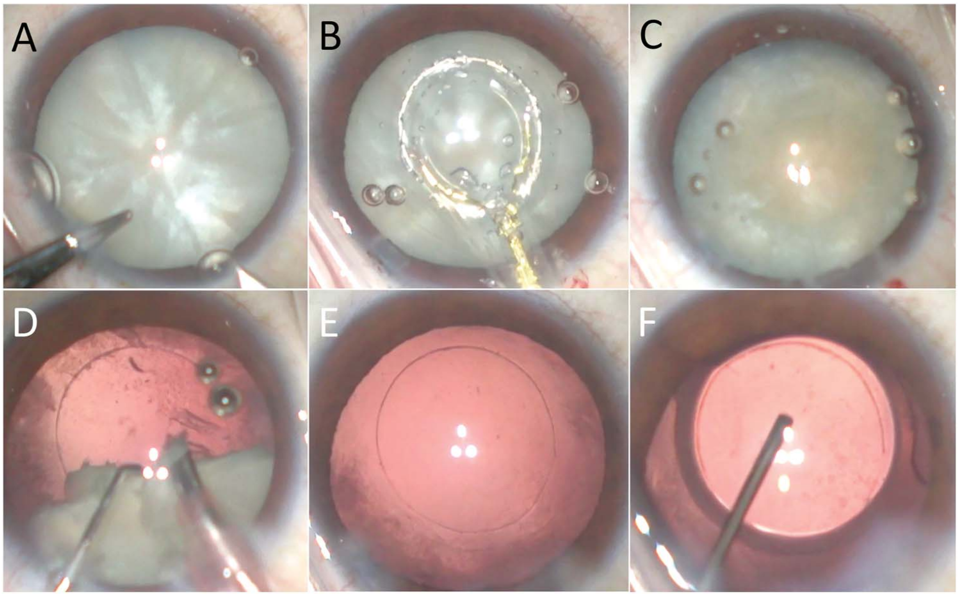

Figure 1. PPC in a case with an intumescent white cataract. *A*: Opaque appearance of the white cataract obscuring the red reflex. Trypan blue was not used in this case. *B*: The PPC device tip was inserted, and suction applied followed by energy discharge to create the entire 5.1 mm diameter capsulotomy in 4 milliseconds. *C*: After completion of the capsulotomy, the PPC device was removed from the anterior chamber exposing the lens cataract. *D*: Lens phacoemulsification was performed. *E*: The edges of the PPC were visible after removal of the cataractous lens material. *F*: Appearance of the PPC overlapping the lens implant. PPC = precision pulse capsulotomy

performing decompression during CCC. The near-instantaneous production of the entire capsulotomy is illustrated in Figure 2, showing a pair of consecutive video frames separated by approximately 30 milliseconds. Figure 2, A is the video frame immediately before capsulotomy, whereas Figure 2, B is the video frame immediately after creation of the PPC. The capsulotomy opening is indicated by the orange arrows, and the capsulotomy button is indicated by the yellow arrows.

PPC also likely limits stress on the capsulotomy edge and thus mitigates against tears from the abrupt exit of intracapsular fluid because of the presence of suction immediately after the capsulotomy. This suction serves to remove the fluid built up in the subcapsular space as soon as the capsulotomy opening is created. This was particularly well demonstrated in a case of a 27-year-old man with a history of head trauma and found to have a pressurized capsular bag with a completely liquified lens (Figure 3; see also Video 3, available at http://links.lww.com/JRS/A766). Capsulotomy was immediately followed by the evacuation of all liquified lens material into the PPC device by its suction action, leaving behind an empty bag and the recovery of the red reflex. The appearance of white milky material in the neck region of the PPC device can be observed during evacuation of the liquified lens material (Figure 3, C and D). No phacoemulsification was necessary, and surgery continued with IOL implantation. PPC use in a more typical intumescent white cataract is shown in Figure 3, E–H. Immediately after capsulotomy, liquified cortical material was observed flowing through the neck of the PPC device (Figure 3, H) (see Video 3, available at http://links.lww.com/JRS/A767).

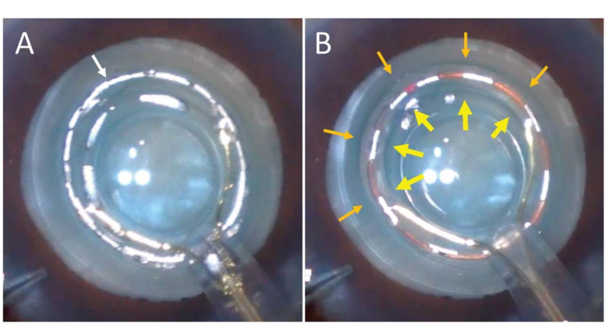

Figure 2. Two consecutive video frames separated by approximately 33 milliseconds immediately before and after activation of a PPC. *A*: The PPC nitinol capsulotomy ring element is reflective and is indicated by the *white arrow*. *B*: The presence of the capsulotomy opening is visible in the very next video frame after PPC. The capsulotomy edge is indicated by the *orange arrows*, and the perimeter edge of the capsulotomy button is indicated by the *yellow arrows*. Trypan blue was used to stain the capsule in this case, and its presence in the capsular tissue facilitated identification of the capsulotomy edges. PPC = precision pulse capsulotomy

Cohesive OVD Is Not Necessary for PPC

The near-instantaneous creation of the entire capsulotomy opening and the immediate removal of fluid under pressure may render the use of a cohesive OVD to mitigate against tears unnecessary. This was confirmed by the current study (Table 2). Additional cohesive OVD (Healon 5) was used before capsulotomy in 40% of CCC intumescent white cataract cases, whereas additional cohesive OVD was used in 0% of PPC intumescent white cataract cases ($P < .01$, chi-square test).

DISCUSSION

Capsulotomy creation is challenging in the setting of white cataracts. The surgical challenges posed include the lack of a red reflex leading to poor visibility during capsulotomy that necessitates the staining of the capsule with trypan blue. In

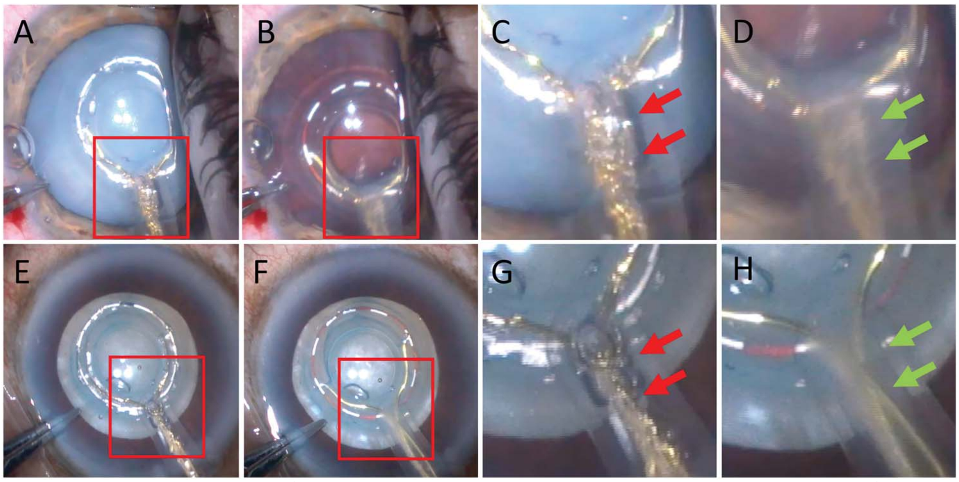

Figure 3. Removal of milky subcapsular fluid after creation of the capsulotomy opening by PPC. *A–D*: Case of a 27-year-old man with a history of head trauma and an intumescent cataract with a completely liquified lens. *A*: Image showing the PPC tip with suction engaged and in position before capsulotomy. The *red square* demarcates the neck region of the PPC device shown in higher magnification in panel *C*. *B*: Image showing the same region as in panel *A* immediately after capsulotomy. Note the clearing of the capsular bag and the return of a red reflex, as all the liquified material was evacuated by the PPC device. The *red square* demarcates the neck region of the PPC device shown in higher magnification in panel *D*. *C*: Image of the PPC device's neck region before capsulotomy. The *red arrows* point to the OVD pulled into the neck region by the suction that is used to appose the nitinol capsulotomy ring element against the capsule. *D*: Image of the neck region immediately after capsulotomy. The *green arrows* point to the subcapsular fluid that was pulled into the neck region under suction (see Video 1, available at http://links.lww.com/JRS/A765). *E*: A second case of white cataract performed using PPC. Image showing the PPC tip with suction engaged and in position before capsulotomy. The *red square* demarcates the neck region of the PPC device shown in higher magnification in panel *G*. *F*: Image showing the same region as in panel *E* immediately after capsulotomy. The *red square* demarcates the neck region of the PPC device shown in higher magnification in panel *H*. *G*: Image of the PPC device's neck region before capsulotomy. The *red arrows* point to the OVD pulled into the neck region by the applied suction. *H*: Image of the neck region immediately after capsulotomy. The *green arrows* point to the subcapsular fluid that is pulled into the neck region under suction (see Video 2, available at http://links.lww.com/JRS/A766, associated with *E–H*). OVD = ophthalmic viscosurgical device; PPC = precision pulse capsulotomy

addition, in the case of pressurized intumescent white cataracts, the increased intracapsular pressure increases the risk of uncontrolled capsular radialization as soon as the very first small opening is created in the capsule.[17,18] This has led to the use of a high-molecular-weight cohesive OVD before CCC to decrease the pressure gradient to mitigate the risk of an Argentinian flag sign. However, this is not always successful, and uncontrolled tears continue to be a potential risk in intumescent white cataracts that can significantly affect surgical outcome. In addition, after capsulotomy, this cohesive OVD should be replaced by a dispersive OVD for endothelial cell protection during subsequent lens phacoemulsification.

Femtosecond laser–assisted cataract surgery (FLACS) has been proposed as an improved capsulotomy method for white cataracts.[2–4] In addition, a new laser-based approach (CapsuLaser) has similarly been discussed in conference settings and potentially may also be used for white cataracts.[19] Of note, the CapsuLaser technology specifically requires thorough trypan blue staining of the capsule to assist in laser energy absorption. In the case of femtosecond laser technology, the substantial associated costs have resulted in limiting the availability of this technology. Furthermore, capsular tags and the Argentinian flag sign can still occur in FLACS for white cataracts.[5] These capsulotomy complications may be due to the release of cortical contents that interfere with laser path.[6] A similar interference of the laser path in postradial keratotomy patients has been reported to result in anterior capsule tears.[20]

The surgical challenges of poor capsular visibility and the presence of an elevated intralenticular pressure gradient in the case of intumescent white cataracts are in principle mitigated by PPC. PPC automatically creates a circular capsulotomy opening without the need for surgeon visualization of the capsule as in CCC. Furthermore, the near-instantaneous creation of the entire full capsulotomy all at once and the presence of suction to evacuate built-up subcapsular fluid provide a highly effective method to quickly release and neutralize any intralenticular pressure that may be present.

Our experience in the use of PPC for capsulotomy creation in white cataracts lends support for these potential benefits derived from PPC device operating principles. Trypan blue capsular staining for enhanced capsular visualization was found not to be necessary when PPC was used. The suction delivered by the device's silicone suction cup ensured even apposition of the nitinol capsulotomy cutting ring element against the anterior capsule. The use of a capsulotomy ring eliminated the need in the case of CCC for the surgeon to visually track the behavior and to direct the manually created capsule tear in a circular path. Our experience with PPC in intumescent white cataracts also showed that the use of a cohesive OVD to reduce the pressure gradient between the pressurized bag and the anterior chamber was not necessary. In all cases, PPCs in intumescent white cataracts were complete with no capsular tags or radial extensions. A major reason for the success of PPCs in pressurized cataracts is likely the near-instantaneous creation of the entire capsulotomy opening to release pressure through a relatively large opening. In addition, the presence of suction during and after the capsulotomy event also facilitated removal of built-up intracapsular fluid and further contributed to pressure relief. Finally, the presence of suction along the entire perimeter of the capsulotomy opening after the capsulotomy event and the superior strength of the PPC edge may also be of benefit to ensure stability of the capsular opening.[9]

The elimination of trypan blue capsular staining and a cohesive OVD helped streamline the treatment of white cataracts to shorten the overall procedural time and reduce resource utilization. Additional cost savings may also derive from the reduction in the overall procedural time of approximately 1 minute 15 seconds on average from not having to use trypan blue combined with a shorter capsulotomy time (the time needed to set up the PPC device is typically performed by the OR staff and not included in the procedural time savings achieved by the surgeon). The actual amount of savings from the reduction in time will be influenced by the overall efficiency of the facility, the payor reimbursement and potentially result in a larger cost savings in some situations.

It should be noted that there is a cost associated with the use of PPC technology for cataract surgery. However, the cost of acquisition may be partially balanced by the fact that cataract surgery is a relatively short procedure overall, and a savings of 1 minute 15 seconds per case can cumulatively add up into an opportunity to perform another case. In addition, the potential avoidance of capsular complications may be the most important benefit for patients and surgical efficiency. In the case of intumescent white cataracts, this may include the Argentinian flag sign that can alter outcome and require additional steps by the surgeon. In addition, posterior extension and posterior capsular rupture add significant costs in terms of operating room time, additional procedures, and visits that average over $1100 or more per case.[21] A systematic cost/benefit analysis of PPC technology would be of interest as a topic for future study and should take into account all associated technology costs weighed against any reduction in resource utilization and potential clinical benefits.

We believe that the data from this study demonstrate that the use of PPC technology for capsulotomy in white cataracts, including for intumescent cataracts, provides important benefits and merit consideration. As this study was an initial effort to study the use of PPC in white cataracts, there are limitations including its design as a retrospective study and the fact that the current report is of the surgical experience from a single surgeon and that the number of cases of white cataract is relatively small. However, the results presented in the current study may help focus specific hypotheses for testing in future prospective studies supported by more research resources. Future work likely should include a greater number of surgeons from multiple sites and a greater number of cases in the comparison arms to test the validity and general applicability of the current findings.

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WHAT WAS KNOWN

- Capsulorhexis in white cataracts is challenging.
- Trypan blue is used to improve capsule visualization.
- Cohesive ophthalmic viscosurgical device (OVD) is used to mitigate against capsular tears including the Argentinian flag sign.

WHAT THIS PAPER ADDS

- Precision pulse capsulotomy (PPC) can be used to reliably create capsulotomies without tags or tears in intumescent and nonintumescent white cataracts.
- PPCs were quicker, more consistently sized, and rounder than continuous curvilinear capsulorhexis.
- PPC reduced the utilization of trypan blue and OVD and lessened the overall procedural time.

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