Manual Small Incision Cataract Surgery

Bonnie An Henderson
Editor

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Manual Small-Incision Cataract Surgery

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Why MSICS Technique Is Performed

Cataract is the leading cause of avoidable blindness worldwide, accounting for nearly half (47.8 %) of all cases of blindness [1]. According to the World Health Organization (WHO), an estimated 20 million people worldwide are blind from bilateral cataracts [2]. While this poses one of the greatest public health challenges for developing countries, it poses a growing economic challenge for the well-developed country as well.

Tabin et al. concluded that cataract accounts for almost 75 % of blindness in the developing world [3]. It is estimated that over 90 % of the world's visually impaired live in developing countries [4]. In these communities in particular, blindness is associated with considerable disability and excess mortality, with dire economic and social consequences [5]. These statistics reveal a profound societal economic impact through the loss of productivity of both the blind and those who care for them. Because of the significant reduction in life expectancy and quality of life for the blind, sight-restoring cataract surgery is undoubtedly one of society's most cost-effective medical interventions. The increase in economic productivity during the first postoperative year alone is estimated to exceed the cost of the surgery by a factor of 15 [6].

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In well-developed countries, increased life expectancy and the growing baby boomer population is contributing to higher demand for cataract surgery. The vision requirement needed to drive legally, and patients' desires for better vision to enhance quality of life, exponentially increases this demand. While in 2004, 20.5 million Americans older than age 40 were estimated to have cataract in either eye, that number is estimated to rise to 30.1 million by 2020 [7]. In the United States, more ophthalmic surgeons are needed to address this demand. Shift in ophthalmic surgical education in the 1990s from manual cataract surgery to phacoemulsification, the broad acceptance of phacoemulsification by practicing ophthalmologists, and attrition of older ophthalmologists trained in the manual techniques of cataract surgery have meant a growing reliance on phacoemulsification as the main modality for cataract surgery in the developed world [8]. Many training programs in the United States no longer train their residents in techniques other than phacoemulsification [9]. Since inception, phacoemulsification technology has evolved from a far simpler device console to today's intelligent microprocessor-controlled consoles with sophisticated fluidics and myriad of handpieces and tips. Research and development costs have been factored into the capital cost of phacoemulsification consoles and consumables needed for each procedure.

The cataract surgical rate (CSR) is an important public health metric which represents the number of cataract operations annually performed per one million population. There are significant variations in the CSR among different countries. As expected, the highest rates are seen in those countries with the highest gross domestic product (GDP). The CSR in economically well-developed countries is usually between 4000 and 6000 cataract operations per million population per year. The recent Rochester Epidemiology Project data from the United States reported a CSR of 11,000 in Minnesota as of 2011, a rate which has increased since 2005, without showing signs of leveling off [8]. India has dramatically increased its CSR in the last 20 years from less than 1500 to around 4000 currently. In the middle-income nations of Latin America and parts of Asia, the CSR ranges between 500 and 2000 per million per year. In most of Africa, China, and the poorer countries of Asia, the CSR is closer to 500 or less [10]. It is certainly surprising that China, which has experienced a tenfold rise in its GDP since 1978, has such a low CSR. This places China on par with some of the poorest African nations [6].

Naturally, it is those countries with the lowest CSR that have major problems with increasing cataract blindness. There is clearly a pressing need in the developing world to reduce the backlog of cataract blindness by increasing the CSR over current low rates. In order to prevent a country's backlog of cataract blindness from increasing, the CSR must at least equal the rate of new cases of advanced cataract each year. There are many reasons for low cataract surgical rates in developing countries. Besides obvious factors such as lack of affordable care and access to cataract surgeons, less obvious barriers to delivering needed care include ignorance, fear of surgery, cultural factors, lack of transportation, and poor visual outcomes associated with inadequately trained surgeons and poor surgical practices [10, 11].

Phacoemulsification is the accepted standard for cataract surgery in the developed world. Although it is often available in the developing world, particularly to those cataract patients who can privately afford it, there are many disadvantages to this method for the poorest societies. Compared to manual extracapsular cataract surgery (ECCE), phaco requires a significant capital purchase and higher costs per case. Annual maintenance is not only an issue of cost but also of readily available technical support. In addition, there is a longer learning curve for new cataract surgeons to master, which is particularly challenging given the poor educational infrastructure available to most ophthalmologists in the developing world. Finally, the advanced mature cataracts that are so prevalent among poor populations are more challenging to remove with phaco, and the complication rate is higher with these cataracts in the hands of all but the most skilled and experienced phaco surgeons using the most advanced phaco systems. Yet even if phacoemulsification technology were universally available in developing countries, the cost to use this technology might be prohibitive for many health-care settings.

Because of these challenges associated with phaco in the developing world, alternative cataract surgical techniques such as sutureless manual small incision cataract surgery (MSICS) are gaining popularity in these countries. MSICS is able to achieve excellent outcomes with lower cost and average surgical time than phaco. Besides speed and affordability, for less experienced surgeons, MSICS is easier to learn and safer for advanced mature cataracts. Factoring the dearth of vitreoretinal surgeons in many developing world communities, the rarity of dropped nuclei with MSICS is an important but frequently overlooked factor.

Origins of MSICS Technique

Classical Blumenthal Technique of MSICS

As phaco became more popular in the 1980s, extracapsular cataract extraction (ECCE) techniques utilizing smaller incisions were also explored and advocated. In 1987, Blumenthal first described the use of an anterior chamber maintainer (ACM) in ECCE along with a reduction in incision size [12]. The classic "Mini-Nuc" MSICS procedure as described by Blumenthal employs the ACM to allow virtually all steps to be performed under positive pressure. After placement of the ACM fixation, a side port is made and a capsulotomy is performed. The scleral tunnel incision is made and the hydrosteps are carried out. The nucleus is guided out of the eye by a glide, and this is facilitated by the positive pressure generated by the ACM. Aspiration of the cortex is carried out through a side port using an aspirating cannula, while irrigation is supplied by the ACM. The ACM is only removed after the IOL is inserted and the incision is confirmed to be watertight.

Modifications to MSICS Technique

Another major modification in the technique of MSICS was later introduced by Ruit et al. [13]. A 6.5–7-mm temporal scleral tunnel was created with a straight incision, starting 2 mm posterior to the limbus. A side port was created to facilitate further intraocular manipulation. A "V"-shaped capsulotomy and hydrodissection were performed. Viscoelastic was injected above and behind the nucleus, which was then prolapsed into the anterior chamber. An irrigating Simcoe cannula with a serrated surface was inserted below the nucleus, prior to extracting it through the scleral tunnel. The remaining cortex was manually removed with the same Simcoe irrigation-aspiration cannula. After implanting a PMMA lens into the capsular bag, the unsutured scleral pocket incision was confirmed to be watertight.

Other major modifications to the MSICS technique described in the literature relate either to the incision or nucleus delivery.

Variations in Incision

Richard Kratz was the first surgeon to move the cataract incision posteriorly from the limbus to the sclera in order to enhance wound healing and reduce astigmatism. It was Girard and Mailman [14] who coined the term of scleral tunnel incision. Singer [15] described the "frown incision" which was a modified scleral pocket incision, curved opposite to the natural limbal curve. The purpose of the frown configuration was to reduce wound-induced astigmatism. Lam et al. [16] developed the sutureless large-incision manual cataract extraction (SLIMCE) technique as a modified manual ECCE technique specifically designed to allow less experienced surgeons in developing countries to reliably extract the nucleus through a self-sealing temporal scleral pocket incision. The salient features of this modified technique include (1) a large scleral pocket incision (8-mm linear length) to permit safe and easy nucleus expression, (2) a long sclerocorneal tunnel (4 mm) for achieving a self-sealing sutureless wound, (3) a posterior incision position (2 mm posterior to the limbus) and a frown-shaped wound configuration for astigmatic neutrality, and (4) the use of an anterior chamber (AC) maintainer to assist nucleus delivery. Gokhale et al. [17] compared the induced astigmatism with various positions of scleral incision (superior, superotemporal, and temporal incision) in MSICS and found that surgically induced astigmatism was lower with the temporal and superotemporal incisions compared to incisions located superiorly.

Variations in Nucleus Delivery

Hydroexpression and viscoexpression – Corydon and Thim [18] introduced the concept of hydro- or viscoexpression of the nucleus with the help of a specially designed bent cannula to deliver the nucleus through a continuous circular capsulorhexis. Several studies have confirmed the efficacy of these procedures [19, 20].

Sandwich technique – Bayramlar et al. [21] performed MSICS in 37 eyes using their sandwich technique. After capsulorhexis, hydrodissection, and hydrodelineation, the nucleus was prolapsed into the anterior chamber and extracted by sandwiching it between the irrigating vectis and iris spatula.

Modified fish hook technique – Hennig et al. [22] reported data from 500 eyes in which MSICS was performed using the fish hook technique for nucleus delivery. This technique utilizes a sclerocorneal tunnel, capsulotomy, hydrodissection, and nucleus extraction with a needle tip bent into a sharply curved hook. The mean duration of surgery was 4 min.

Use of anterior chamber maintainer (ACM) – Blumenthal and Moisseiev [11] described the use of an anterior chamber maintainer during the surgery. Its use was found to increase intraoperative safety, which was later confirmed in other studies as well [23, 24].

Irrigating cannula – Nishi [25] described the use of an irrigating cannula for nucleus delivery. It consists of a 20-gauge needle attached with a flat insertion plate at 90° to its axis with a flow outlet. The apex of the plate, with the flow outlet, is inserted beneath the nucleus during continuous irrigation, and the nucleus is expelled by the irrigating solution.

Manual phaco fracture – Bartov et al. [26] described a technique for planned manual extracapsular cataract extraction (ECCE) incorporating a modification of mini-nuc ECCE in which the scleral tunnel is made wide enough to allow a nucleus of any size to become lodged within the tunnel. A 5.0-mm, inverted-V "Chevron" frown incision is made in which the exposed part of the nucleus lodged in the scleral pocket can be manually sliced and fragmented until it is small enough to be removed through the incision. Vector analysis of preoperative and 3-month postoperative keratometric astigmatism in 30 patients showed that the surgically induced vector was 0.54 diopter (D) ± 0.58 (SD).

Nucleus trisection – Kansas and Sax [27] described a technique in which the nucleus is manually split into three pieces using Kansas trisector and vectis, so that the resulting smaller fragments can be viscoexpressed through a small incision. Hepsen et al. [28] performed MSICS by manual phacotrisection technique in 59 eyes of 54 patients. After capsulorhexis and hydrodissection were performed, the endonucleus was prolapsed into the anterior chamber and trisected using an anteriorly positioned triangular trisector and posteriorly placed solid vectis.

Nuclear management by snare technique – Keener [29] in 1983 was the first to snare the nucleus into two halves and bring the fragments out through a sclerocorneal flap valve incision. A wire loop stainless steel snare is a single instrument with two cannulas with the wire loop in the tip of the first cannula. While pulling the second cannula, the wire loop constricts. When the wire loop is lassoed around the nucleus and constricted, it divides the hardest of nuclei into two.

Sinskey hook method – Rao and Lam [30] described an MSICS technique using two Sinskey hooks to extract the nucleus from the capsular bag. The two Sinskey hooks are introduced through separate paracentesis entry sites. The left-handed hook is slipped under the capsulorhexis where it engages, rotates, and elevates the superior pole of the nucleus toward the incision. The second hook held in the right hand is placed beneath the elevated superior pole of the nucleus to prevent it from falling back into the bag as the first hook is retracted.

Advantages/Disadvantages of MSICS

To evaluate MSICS against phacoemulsification, the following areas need to be examined: surgically induced astigmatism, intraoperative and postoperative complications, appropriateness for advanced mature cataracts, surgical times, and costs.

Surgically Induced Astigmatism

Table 1 reports data from several studies comparing surgically induced astigmatism with phacoemulsification and MSICS at 6 weeks and 6 months postoperatively. At 6 months follow-up, Ruit et al. [31] reported mean astigmatism of 0.7 D for the phacoemulsification group and 0.88 D for the MSICS group. This difference was not statistically significant. At 6 weeks postoperatively, Gogate et al. [32] reported mean astigmatism of 1.1 D for phacoemulsification and 1.2 D for MSICS which was not statistically significant. Both of these studies used a foldable IOL in the phacoemulsification arm. Both Venkatesh et al. [28] and George [33] reported that phacoemulsification caused significantly lesser surgically induced astigmatism compared to MSICS at 6 weeks postoperatively. This would explain the poorer uncorrected visual acuity levels at 6 weeks for the MSICS group. Another randomized trial [34] comparing surgically induced astigmatism associated with phacoemulsification and MSICS reported no significant difference at either the 6 weeks or 6 months follow-up exam. Muralikrishnan et al. [33] reported that, compared to the surgical induced astigmatism of approximately 4 diopters for large-incision ECCE, MSICS and phacoemulsification were clearly superior with approximately 1 diopter of induced astigmatism.

Other MSICS studies report differences in surgically induced astigmatism based on incision size made and the type of tunnel construction (Table 2). A prospective Japanese trial comparing 3.2-mm with 5.5-mm MSICS incisions found 0.3 D less surgically induced astigmatism when the smaller incision was used [35]. Additional MSICS studies report less surgically induced astigmatism with temporal and superotemporal scleral tunnel incisions compared with those located superiorly [16, 36].

Table 1 Surgically induced astigmatism of phacoemulsification and MSICS (in diopters)

	At 6 weeks		At 6 months	
Study	Phaco	MSICS	Phaco	MSICS
Venkatesh [32]	0.80	1.20	–	–
Gogate [31]	1.10	1.20	–	–
George [28]	0.77	1.17	–	–
Ruit [30]	–	–	0.70	0.88
Muralikrishnan [33]	1.10	1.12	1.11	1.33

Table 2 Surgically induced astigmatism of MSICS according to the type of tunnel constructed

Study	Superior (diopters)	Superotemporal (diopters)	Temporal (diopters)
Venkatesh [32]	1.08	–	0.72
Kimura [34]	1.41	1.02	–
Gokhale [16]	1.28	0.20	0.37
Reddy [35]	1.92	–	1.57

Common hypotheses for this observation are that temporal incisions are less likely to be affected by blinking and gravity.

Overall, early postoperative surgically induced astigmatism was either the same or slightly worse with MSICS in these various studies, but incision location appears to be an important variable. For MSICS, smaller incision size and temporal location gives astigmatic results closest to phaco. The only prospective randomized comparison with long-term (6 months) data showed no difference in surgically induced astigmatism between phaco and MSICS performed temporally [30].

Intraoperative and Postoperative Complications

Both retrospective and prospective studies have compared complication rates for phaco and MSICS. The three prospective studies comparing phaco and MSICS reported the incidence of posterior capsule rupture (PCR) with each of the two techniques (Table 3). In their study of white cataracts, Venkatesh et al. [32] reported that PCR occurred in 2.2 % of cases performed with phacoemulsification compared to 1.4 % of cases performed with MSICS; Ruit et al. [30] had a 1.85 % PCR rate with phacoemulsification compared to zero in the MSICS group. In a retrospective analysis of safety and efficacy of MSICS for brown and black cataracts, Venkatesh et al. encountered PCR in only 2 % of their cases. However, Gogate et al. [31] reported a slightly higher rate of PCR for MSICS (6 %) compared to phacoemulsification (3.5 %). It should be noted that all of the prospective trials had small study populations.

The largest and best comparative study to date was a retrospective study by Haripriya et al. [37], which analyzed 79,777 consecutive surgeries performed during a 1-year period at the Madurai Aravind Eye Hospital. Of these, 20,438 (26 %) were phaco, 53,603 (67 %) were MSICS, and 5736 (7 %) were large-incision ECCE. The overall rate of endophthalmitis was 0.04 % with no statistical difference between phaco and MSICS (Table 4). If performed by staff surgeons, both procedures had complication rates less than 1 %, suggesting comparable safety in the hands of experienced surgeons. However, for trainee surgeons (residents, fellows, and visiting surgeon fellows), the complication rate was significantly higher with phaco (4.8 %) than with MSICS (1.46 %) ($P < 0.001$). For example, the trainee rate of posterior capsule rupture with vitreous loss was 3.8 % with phaco and 0.67 % with MSICS ($P < 0.001$).

Table 3 Percentage of intraoperative and postoperative complications related to phacoemulsification and MSICS

Complications	Study	Phacoemulsification			MSICS		
Posterior capsule rupture	Venkatesh [32]	2.2			1.4		
	Gogate [31]	3.5			6.0*		
	Haripriya (staff) [37]	0.65			0.5		
	Haripriya (trainees) [37]	4.6			0.84		
	Ruit [30]	1.85			0		
PCO at 6 months	Ruit [30]	***None***	***1+***	***2+***	***None***	***1+***	***2+***
		85.4	14.6	0	56.5	26.1	17.4
Endothelial cell count	George [28]	4.21			5.41		
Anterior chamber contamination	Parmar [36]	2.7			4		
Endophthalmitis	Haripriya [37]	0.05			0.03		

Table 4 Intraoperative complication rate comparison between different surgeon groups for each of three surgical techniques [37]

Surgeon category	Total surgical volume	Intraoperative complication rate			
		Phaco	MSICS	ECCE	Overall
Staff	52,274	174 (0.9 %)	225 (0.71 %)	13 (1.03 %)	412 (0.79 %)
Fellow	11,324	15 (2.06 %)[a]	85 (0.94 %)[a]	35 (2.30 %)[a]	135 (1.19 %)[a]
Resident	14,818	10 (8.2 %)[a]	216 (1.75 %)[a]	79 (3.39 %)[a]	305 (2.06 %)[a]
Visiting trainee	1361	28 (11.2 %)[a]	18 (3.68 %)[a]	22 (3.54 %)[a]	68 (5.0 %)[a]
Overall	79,777	227 (1.11 %)	544 (1.01 %)	149 (2.60 %)	920 (1.15 %)

From Haripriya [37]

Phaco phacoemulsification, *MSICS* manual small incision cataract surgery, *ECCE* extracapsular cataract extraction

[a]Means p <0.05 when compared to the staff complication rate for the respective procedure

Posterior capsule opacification (PCO) occurred more often in the MSICS group compared to the phacoemulsification group in the Ruit study [30]. In that study, at the 6-month follow-up exam, 26.1 % of the MSICS patients compared to 14.6 % of the phaco patients had grade 1 PCO. The incidence of grade 2 PCO was 17.4 % in the MSICS group and zero in the phacoemulsification group. In this study, foldable IOLs with a square edge were employed in the phaco patients, compared to a rounded edge PMMA IOL in the MSICS patients, and only the phaco patients had a capsulorhexis.

Overall, complication and endophthalmitis rates appear to be similar between both procedures when performed by experienced surgeons. However, for inexperienced surgeons, MSICS appears to be the safer procedure.

Appropriateness for Advanced Cataracts

Advanced and complicated cataracts are far more prevalent in poor populations. The literature reports good visual outcomes and complication rates when MSICS is employed for complicated cases, such as ultra-brunescent cataract [38], white cataracts [32, 39], and cataracts causing phacolytic and phacomorphic glaucoma [40, 41].

Finally, for a surgeon already experienced with manual large-incision ECCE, the learning curve for MSICS is shorter compared to that for learning phacoemulsification, which is more challenging to perform in advanced cataracts. Brunescent and mature cataracts increase the risk of posterior capsular rupture, dropped nuclei, and corneal decompensation. Therefore, an important consideration is that in many developing world settings, access to vitreoretinal or corneal transplantation surgery may be limited or completely lacking.

Surgical Times

Another consideration in the developing world is the desirability of performing very high-volume surgery. In terms of mean procedural times, MSICS takes significantly less time than phacoemulsification (Table 5), even in the hands of very experienced surgeons. In their comparative trials, Ruit et al. [30] and Gogate et al. [31] reported identical mean surgical times (including turnover) of 15.5 min for phacoemulsification and 8.5–9 min for MSICS. Others have reported reducing mean surgical times to less than 4.5 min with MSICS [42, 43]. In the developing world, where care and procedures must be scalable to the highest volumes, improved surgical efficiency increases the productivity of the most critically scarce resource – the cataract surgeon.

Table 5 Mean duration (minutes) of phacoemulsification and MSICS

Study	Phacoemulsification	MSICS
Ruit [30]	15.5	9
Gogate [31]	15.5	8.5
Trivedy [46]	–	4.25
Venkatesh [32]	12.2	8.8
Venkatesh [31]	–	3.75
Balent [39]	–	4

Costs

In the developing world, the cost per case of providing phacoemulsification ranges from $25.55–$70, compared to $15–$17 for MSICS (Table 6). The wide variation in the cost of phacoemulsification relates to the varying case volumes, over which the fixed costs of expensive instrumentation are spread out. For example, Muralikrishnan et al. [44] reported a cost per case of $25.55 for phaco in a high-volume center in India. The IOL cost also significantly influences the overall cost per case. For instance, Ruit et al. [30] reported a cost of $70 for phacoemulsification of which $52 was the cost of the most expensive foldable acrylic IOL. In comparison, the cost of a PMMA lens used in MSICS was only $5. If a cheaper IOL was used instead of a foldable acrylic IOL, then the cost of phacoemulsification as estimated by Ruit et al. [30] should be in the $25 range as reported by Muralikrishnan et al. [44] and Gogate et al [45]. Compared to phaco, MSCIS clearly emerges as the more cost-effective option. Phaco entails a larger initial capital expense, higher per case consumable costs (phacoemulsification tips, sleeves, and tubing), and higher ongoing maintenance costs [44]. Another disadvantage of phacoemulsification for some rural developing world settings is the requirement for a dependable source of electricity. In contrast, the only significant capital equipment expense for MSICS is the operating microscope, and this can be powered by a battery or small diesel generator [44].

Of course, which procedure is more affordable and cost-effective depends on other factors besides just the consumable supplies and amortized capital equipment costs. These include facility costs, nursing and staff salaries, and pre- and postoperative care, medications, and visits. Health-care delivery systems that most efficiently perform higher volume surgery while safely minimizing cost are providing the most cost-effective care in the developing world. In this context, the higher procedural volumes attainable with MSICS provide further advantages in terms of cost-effectiveness.

Outcomes

Comparison to Phacoemulsification

Three randomized prospective studies conducted in developing countries have compared phacoemulsification with MSICS. In these, MSICS was comparable to phaco in achieving excellent visual outcomes (Table 7) [30, 31, 32]. Venkatesh et al. [32]

Table 6 Provider's cost (US$) of phacoemulsification and MSICS

Study	Phaco	MSICS
Muralikrishnan [45]	25.55	17.03
Gogate	42.10	15.34
Ruit [30]	70	15

Table 7 Percentage of postoperative visual outcomes of phacoemulsification and MSICS

	UDVA						CDVA					
	Venkatesh [32] (at 6 weeks)		Gogate [31] (at 6 weeks)		Ruit [30] (at 6 months)		Venkatesh [32] (at 6 weeks)		Gogate [31] (at 6 weeks)		Ruit [30] (at 6 months)	
	Phaco	MSICS	Phaco	MSICS	Phaco	MSICS	Phaco	MSICS	Phaco	MSICS	Phaco	MSICS
6/6–6/9	45.1	36.4	36.8	31.6	53.7	31.5	92.0	83.8	77.8	85.6	94.4	88.9
6/6–6/18	42.5	45.3	44.3	38.5	31.5	57.4	7.1	14.5	20.5	12.8	3.7	9.2
6/24–6/60	11.5	16.6	18.4	28.9	14.8	11.1	0.9	1.7	1.1	1.6	1.9	1.9
<6/60	0.9	1.7	0.5	0			0	0	0.5	0		

UDVA uncorrected distance visual acuity, *CDVA* corrected distance visual acuity randomized 270 consecutive patients with white cataracts to phacoemulsification and MSICS and found that uncorrected visual acuity of 6/18 or better was achieved in 87.6 % of eyes in the phacoemulsification group and 82 % of eyes in the MSICS group by 6 weeks postoperatively. The corresponding best corrected visual acuity of 6/18 or better was achieved in 99 % from the phacoemulsification group and 98.2 % from the MSICS group by 6 weeks postoperatively.

Gogate et al. [31] compared phacoemulsification with MSICS in a prospective randomized trial of 400 eyes and reported that uncorrected visual acuity of 6/18 or better was achieved by 81.08 % of the phacoemulsification eyes, vs. 71.1 % of the MSICS eyes at 6 weeks postoperatively. The best corrected visual acuity was 6/18 or better in 98.4 % of the phacoemulsification group and in 98.4 % of the MSICS group at 6 weeks postoperatively. These studies suggest that both techniques achieved similar results in terms of best corrected visual acuity at 6 weeks.

Ruit et al. [30] reported longer-term outcomes in a randomized prospective trial of 108 eyes in Nepal. The patients were randomized to MSICS or phaco, with each type of surgery performed by an acknowledged expert in that technique. They reported comparable rates of 98 % achieving best corrected visual acuity of 6/18 or better at 6 months postoperatively. Uncorrected visual acuity was comparable at 6 months.

A number of other studies [21, 38, 40, 43, 46] document good postoperative visual outcomes with MSICS (Table 8).

Summary

Although phacoemulsification is the preferred cataract surgical method in developed countries, MSICS is gaining strong popularity in many developing world settings where the backlog of cataract blindness persists due to the lack of health-care resources, funding, and eye surgeons. MSICS reduces the consumable costs per case as well as the capital and maintenance costs for phaco equipment. As a faster procedure, it permits higher daily case volumes compared to phaco. Although experienced surgeons achieve comparable visual outcomes and complication rates with both procedures, MSICS is safer in the hands of novice and less experienced

Table 8 Percentage of postoperative visual outcomes of MSICS

	UDVA			CDVA		
Study	6/6 – 6/18	6/24 – 6/60	<6/60	6/6 – 6/18	6/24 – 6/60	<6/60
Venkatesh [38]	43.9	51	5.3	94.4	4.0	1.6
Hennig [21]	70.5	28	1.5	96.2	3.6	0.2
Trivedy [40]	81.8	15.7	5.2	NA	NA	NA
Gogate [48]	47.9	47.7	4.3	89.8	8.4	1.7
Venkatesh [43]	78.4	21.5	0	97.1	2.9	0

UDVA uncorrected distance visual acuity, *CDVA* corrected distance visual acuity surgeons. These differences are even greater when considering the mature advanced cataracts that are so prevalent in poor populations. Because of the imperative to train large numbers of new cataract surgeons in the developing world, having a procedure that is easier and safer to learn, particularly with advanced and complicated cataracts, is vital. This is especially important because vitreoretinal surgeons are not available in many of these settings to manage retained nuclei. For all of these reasons, we believe that MSICS is the procedure of choice for less experienced surgeons in the developing world.

After mastering MSICS, proficient cataract surgeons have eventually been able to adopt and offer phacoemulsification in many developing countries. Being adept with both techniques, they often still select MSICS for the most advanced and complicated cases whenever the risks with phaco are felt to be greater. Such versatility is enviable to younger generations of Western surgeons who lack sufficient training and experience with large- or small-incision ECCE.

Finally, with the highly marketed adoption of femtosecond laser technology for cataract surgery in many countries, the issue of cost-effectiveness has become even more important [47]. As populations worldwide are aging, the need for and rates of cataract surgery will increase in virtually every society. It is ironic then that the best surgical innovation thus far for the leading cause of world blindness is a low-tech method that provides the most cost-effective and scalable approach in the developing world.

References

1. Resnikoff S, Pascolini D, Etya'ale D, et al. Global data on visual impairment in the year 2002. Bull World Health Organ. 2004;82:844–51.
2. Baltussen R, Sylla M, Mariotti SP. Cost-effectiveness analysis of cataract surgery: a global and regional analysis. Bull World Health Organ. 2004;82:338–45.
3. Tabin G, Michael Chen M, Espandar L. Cataract surgery for the developing world. Curr Opin Ophthalmol. 2008;19:55–9.
4. Thylefors B. A simplified methodology for the assessment of blindness and its main causes. World Health Stat Q. 1987;40:129–41.
5. Frick KD, Foster A. The magnitude and cost of global blindness: an increasing problem that can be alleviated. Am J Ophthalmol. 2003;135:471–6.
6. Lam DS, Li EY, Chang DF, Zhang MZ, Zhan HK, Pang CP. Project vision: a new and sustainable model for eliminating cataract blindness in China. Clin Experiment Ophthalmol. 2009;37:427–30.
7. Congdon N, Vingerling JR, Klein BE, West S, Friedman DS, Kempen J, O'Colmain B, Taylor HR. Eye Diseases Prevalence Research Group. Prevalence of cataract and pseudophakia/aphakia among adults in the United States. Arch Ophthalmol. 2004;122:487–94.
8. Gollogly HE, Hodge DO, St Sauver JL, Erie JC. Increasing incidence of cataract surgery: population-based study. J Cataract Refract Surg. 2013;39:1383–9.
9. Bhagat N, Nissirios N, Potdevin L, Chung J, Lama P, Zarbin MA, Fechtner R, Guo S, Chu D, Langer P. Complications in resident-performed phacoemulsification cataract surgery at New Jersey Medical School. Br J Ophthalmol. 2007;91(10):1315–7.
10. Foster A. VISION 2020: the cataract challenge. Community Eye Health. 2000;13:17–9.

11. Zhang XJ, Jhanji V, Leung CK, Li EY, Liu Y, Zheng C, Musch DC, Chang DF, Liang YB, Lam DSC. Barriers for poor cataract surgery uptake among patients with operable cataract in a program of outreach screening and low cost surgery in rural China. Ophthalmic Epidemiol. 2014;21(3):153–60.
12. Blumenthal M, Moisseiev J. Anterior chamber maintainer for extracapsular cataract extraction and intraocular lens implantation. J Cataract Refract Surg. 1987;13:204–6.
13. Ruit S, Paudyal G, Gurung R, Tabin G, Moran D, Brian G. An innovation in developing world cataract surgery: sutureless extracapsular cataract extraction with intraocular lens implantation. Clin Experiment Ophthalmol. 2000;28:274–9.
14. Girard LJ, Rodriguez J, Mailman ML. Reducing surgically induced astigmatism by using a scleral tunnel. Am J Ophthalmol. 1984;97(4):450–6.
15. Singer JA. Frown incision for minimizing induced astigmatism after small incision cataract surgery with rigid optic intraocular lens implantation. J Cataract Refract Surg. 1991;17:677–88.
16. Lam DS, Rao SK, Fan AH, Congdon NG, Wong V, Liu Y, Lam PT. Endothelial cell loss and surgically induced astigmatism after sutureless large-incision manual cataract extraction (SLIMCE). Arch Ophthalmol. 2009;127:1284–9.
17. Gokhale NS, Sawhney S. Reduction in astigmatism in manual small incision cataract surgery through change of incision site. Indian J Ophthalmol. 2005;53:201–3.
18. Corydon L, Thim K. Continuous circular capsulorhexis and nucleus delivery in planned extracapsular cataract extraction. J Cataract Refract Surg. 1991;17:628–32.
19. Thim K, Krag S, Corydon L. Hydroexpression and viscoexpression of the nucleus through a continuous circular capsulorrhexis. J Cataract Refract Surg. 1993;19:209–12.
20. Bellucci R, Morselli S, Pucci V, Bonomi L. Nucleus viscoexpression compared with other techniques of nucleus removal in extracapsular cataract extraction with capsulorhexis. Ophthalmic Surg. 1994;25:432–7.
21. Bayramlar H, Cekiç O, Totan Y. Manual tunnel incision extracapsular cataract extraction using the sandwich technique. J Cataract Refract Surg. 1999;25:312–5.
22. Hennig A, Kumar J, Yorston D, Foster A. Sutureless cataract surgery with nucleus extraction: outcome of a prospective study in Nepal. Br J Ophthalmol. 2003;87:266–70.
23. Hennig A, Kumar J, Yorston D, Foster A. Use of the anterior chamber maintainer in anterior segment surgery. J Cataract Refract Surg. 1996;22:172–7.
24. Wright M, Chawla H, Adams A. Results of small incision extracapsular cataract surgery using the anterior chamber maintainer without viscoelastic. Br J Ophthalmol. 1999;83:71–5.
25. Nishi O. A new type of irrigating cannula for lens nucleus delivery by extracapsular extraction. Ophthalmic Surg. 1986;17:47–9.
26. Bartov E, Isakov I, Rock T. Nucleus fragmentation in a scleral pocket for small incision extracapsular cataract extraction. J Cataract Refract Surg. 1998;24:160–5.
27. Kansas PG, Sax R. Small incision cataract extraction and implantation surgery using a manual phacofragmentation technique. J Cataract Refract Surg. 1988;14:328–30.
28. Venkatesh R, Tan CSH, Sengupta S, Ravindran RD, Krishnan KT, Chang DF. Phacoemulsification versus manual small-incision cataract surgery for white cataract. J Cataract Refract Surg. 2010;36:1849–54.
29. Keener GT. The nucleus division technique for small incision cataract extraction. In: Rozakis GW, editor. Cataract surgery: alternative small incision techniques. 1st ed. New Delhi: Jaypee Brothers; 1995. p. 163–91.
30. Rao SK, Lam DS. A simple technique for nucleus extraction from the capsular bag in manual small incision cataract surgery. Indian J Ophthalmol. 2005;53:214–5.
31. Ruit S, Tabin G, Chang DF, Bajracharya L, Kline DC, Richheimer W, Shrestha M, Paudyal G. A prospective randomized clinical trial of phacoemulsification vs manual sutureless small-incision extracapsular cataract surgery in Nepal. Am J Ophthalmol. 2007;143:32–8.
32. Gogate PM, Kulkarni SR, Krishnaiah S, Deshpande RD, Shilpa A, Joshi SA, Palimkar A, Deshpande MD. Safety and efficacy of phacoemulsification compared with manual small-incision

cataract surgery by a randomized controlled clinical trial: six-week results. Ophthalmology. 2005;112:869–74.

33. George R, Rupauliha P, Sripriya AV, Rajesh PS, Vahan PV, Praveen S. Comparison of endothelial cell loss and surgically induced astigmatism following conventional extracapsular cataract surgery, manual small-incision surgery and phacoemulsification. Ophthalmic Epidemiol. 2005;12:293–7.
34. Muralikrishnan R, Venkatesh R, Manohar BB, Venkatesh PN. A comparison of the effectiveness and cost effectiveness of three different methods of cataract extraction in relation to the magnitude of post-operative astigmatism. Asia Pacific J Vol. 2003;15:33–40.
35. Kimura H, Kuroda S, Mizoguchi N, Terauchi H, Matsumura M, Nagata M. Extracapsular cataract extraction with a sutureless incision for dense cataracts. J Cataract Refract Surg. 1999;25:1275–9.
36. Reddy B, Raj A, Singh VP. Site of incision and corneal astigmatism in conventional SICS versus phacoemulsification. Ann Ophthalmol (Skokie). 2007;39:209–16.
37. Haripriya A, Chang DF, Reena M, Shekhar M. Complication rates of phacoemulsification and manual small-incision cataract surgery at Aravind Eye Hospital. J Cataract Refract Surg. 2012;38:1360–9.
38. Venkatesh R, Tan CSH, Singh GP, Veena K, Krishnan KT, Ravindran RD. Safety and efficacy of manual small incision cataract surgery for brunescent and black cataracts. Eye. 2009;23:1155–7.
39. Venkatesh R, Das M, Prashanth S, Muralikrishnan R. Manual small incision cataract surgery in eyes with white cataracts. Indian J Ophthalmol. 2005;54:181–4.
40. Venkatesh R, Tan CSH, Kumar TT, Ravindran RD. Safety and efficacy of manual small incision cataract surgery for phacolytic glaucoma. Br J Ophthalmol. 2007;91:279–81.
41. Ramakrishanan R, Maheshwari D, Kadar MA, Singh R, Pawar N, Bharathi M. Visual prognosis, intraocular pressure control and complications in phacomorphic glaucoma following manual small incision cataract surgery. Indian J Ophthalmol. 2010;58:303–6.
42. Venkatesh R, Muralikrishnan R, Balent LC, Prakash SK, Prajna NV. Outcomes of high volume cataract surgeries in a developing country. Br J Ophthalmol. 2005;89:1079–83.
43. Balent LC, Narendran K, Patel S. High volume suture less intraocular lens surgery in a rural eye camp in India. Ophthalmic Surg Lasers. 2001;32:446–55.
44. Muralikrishnan R, Venkatesh R, Venkatesh PN, Frick KD. Economic cost of cataract surgery procedures in an established eye care centre in southern India. Ophthalmic Epidemiol. 2004;11:369–80.
45. Gogate P, Deshpande M, Nirmalan PK. Why do phacoemulsification? Manual small-incision cataract surgery is almost as effective, but less expensive. Ophthalmology. 2007;114:965–8.
46. Trivedy J. Outcomes of high volume cataract surgeries at a Lions Sight first Eye Hospital in Kenya. Nepal J Ophthalmol. 2011;3:31–8.
47. Abell RG, Vote BJ. Cost-effectiveness of femtosecond laser-assisted cataract surgery versus phacoemulsification cataract surgery. Ophthalmology. 2014;121:10–6.
48. Gogate PM, Deshpande M, Wormald RP, Deshpande R, Kulkarni SR. Extracapsular cataract surgery compared with manual small incision cataract surgery in community eye care setting in western India: a randomised controlled trial. Br J Ophthalmol. 2003;87:667–72.

Instruments and Supplies

Divya Manohar

This chapter will describe the various surgical instruments used in small-incision cataract surgery (SICS).

1. Eyelid speculum:

   - The lid speculum is used to separate eyelids gently without causing distress to the patient/interference to the surgery. The speculum lifts the lid margin off the globe, thereby reducing pressure on the globe, and prevents excessive lid handling, thereby preventing operative field contamination. It also aids in tucking the drape over the lid margin covering the lashes. The lid speculum can be divided into the rigid and the wire speculum.
   - An ideal speculum is one which will allow adequate working space for the surgeon. There are many types of speculums. We commonly use the Barraquer wire speculum and Lieberman eye speculum with locking screws.
   - The Lieberman speculum has screws at one end to adjust the height of the palpebral fissure and is robust and sturdy. The advantage of speculums with locking screws is that the interpalpebral fissure height can be adjusted and it gives adequate working space (Fig. 1).
   - The Barraquer wire vspeculum is commonly used in SICS as there is no bar to restrict the instruments used. It is cheaper and easily available in most places. The only disadvantage of the wire speculum is that the palpebral fissure height cannot be altered (Fig. 2).

2. Calipers (Fig. 3):

   - The caliper is made up of stainless steel with a length of 8.5 cm with measurements in 0.5 mm increments, is calibrated in millimeters, and has a maximum measurement of 20 mm with scale readings on both sides.

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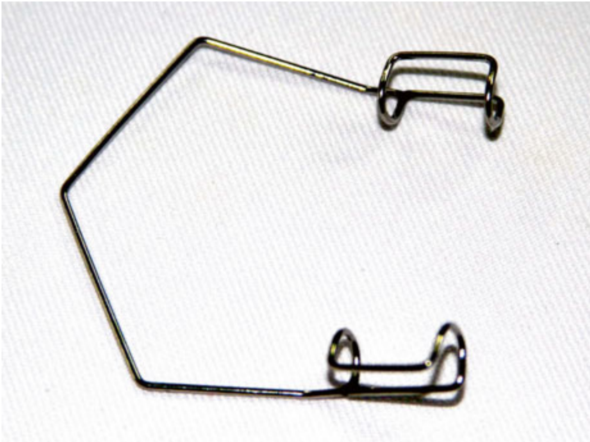
Fig. 1 Lieberman speculum

Fig. 2 Barraquer speculum



- The calipers are used in SICS to measure the distance of the incision groove from the limbus.
- Used for measurements during surgery:
  - Cataract incision
  - Squint surgery
  - Trabeculectomy flap
  - Intravitreal injections
  - Retinal surgery ports

3. Artery clamp:

- The artery clamp is used to hold drapes and to hold or fix sutures.
- The most commonly used artery clamp is the straight artery clamp with fine serrations at its tip (Fig. 4).
- The artery clamp in SICS is used to hold the superior rectus suture tightly to the drape, thereby keeping the field of view of the incisional site immobile, and also to give adequate resistance.
- The artery clamp is also further useful in holding the drape together with the drain bag.

Fig. 3 Calipers

Fig. 4 Straight Artery forceps

4. Silcock's needle holder:
   - The needle holder is used in SICS to thread the needle with a suture through the superior rectus and placing a bridle suture.
   - The needle holder has a lock in place to hold the needle, and the thumb is placed adjacent to this lock for easy disengagement of the needle after passing the bridle suture (Fig. 5).
5. Superior rectus forceps (Fig. 6):
   - This is a double angulated forceps to facilitate better view, keeping the body of instrument and fingers away from the field.
   - The forceps is generally used to hold the superior rectus muscle and pass the bridle suture under the muscle. The angulated tip measures 7.7 mm to grasp the superior rectus from the limbus.
   - The forceps is held with the tip pointing face down toward the conjunctiva, and the superior rectus is fixed through the intact conjunctiva and held with the help of the toothed forceps. Before the bridle suture is passed, moving the muscle from side to side tests the hold of the muscle and makes sure that the globe moves accordingly so that you do not puncture the globe or do not pass over the muscle and bridle only the conjunctiva and Tenon's capsule.

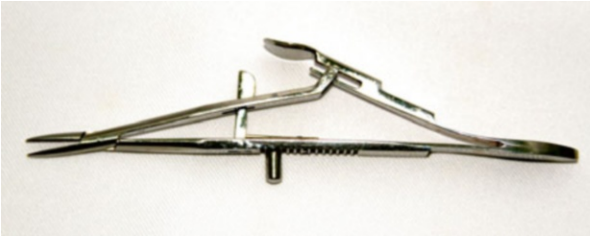


Fig. 5 Silcock's needle holder

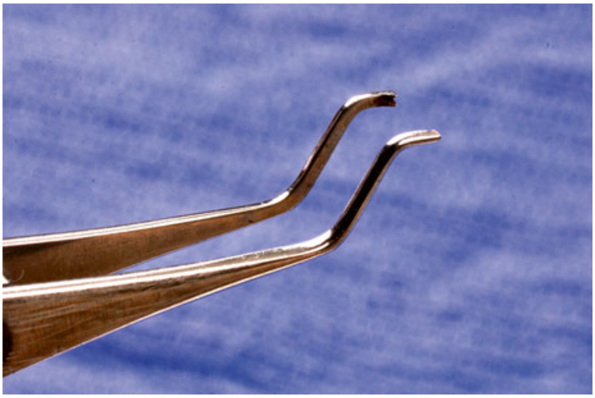


Fig. 6 Superior rectus forceps

6. Barraquer's blade breaker (Fig. 7):
   - The blade breaker allows the surgeons to fashion a fresh, sharp knife for each case. It has a spring lock.
   - Blade holders have straight jaws that are used to break the tip of a blade by closing the jaws together and breaking the tip manually. The jaw tip is locked using a clasp, and this now can be used for incision.
   - The thinner and longer the desired fragment, the closer the blade to the cutting edge. The opposing jaws are convex and concave for better grip.
   - The broken tip should be examined to determine the quality of the blade point.
   - As pointed by Troutman, the ideal razor blade should have high carbon content.
   - Used for making incisions in cataract/sac surgeries and chalazion curettage, trimming suture knots, and removing suture.
7. Crescent knife (Fig. 8):
   - The crescent knife is used for lamellar dissection and tunnel construction.
   - This is an angulated steel blade firmly attached to a knife handle or to a plastic handle that provides firm grip and clear field of view while making a scleral incision. It has a rounded tip, which is blunt, and has sharp edges on the sides, which provide smooth tunnel formation [4]. Using this angled crescent knife, the second part of the tri-faceted tunnel is constructed.

Fig. 7 Barraquer's Blade breaker

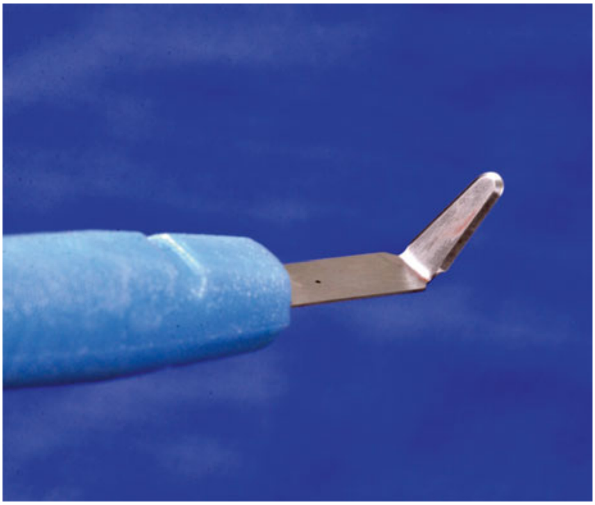


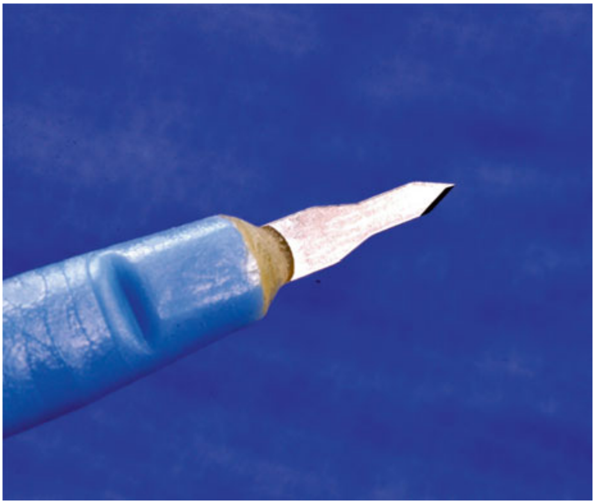
Fig. 8 Crescent Knife

- There are various types of crescent tips available based on their bevel characteristics:
  - Bevel up
  - Bevel down
  - Straight
  - Angled bevel up tip only

8. Side port:(Fig. 9):

- The side port is made using a Super blade 150.
- Used to make side port entry at about 1.5–2 mm from limbus or at limbus.
- This is a straight triangular-shaped knife with one edge of the base sharp and the tip is pointed. This can be placed in a blade holder or comes with a disposable plastic handle. This tip is angulated and provides better control while constructing a side port entry.

Fig. 9 Side port



- Helps to form anterior chamber and facilitate second instrument introduction.

9. Keratome (Fig. 10):

   - The keratome used to enter the anterior chamber after the crescent has been used to form the tunnel.
   - This is a straight-tipped knife with the blade that can be placed in a blade holder or is fixed to a plastic handle. This is used to make the entry into the anterior chamber and is designed to produce a smaller internal incision and a larger external incision. The incision groove is extended on both sides of the entry point with the help of the sharp edges of the sides of the knife. Using this knife provides the third angulation in the tri-faceted tunnel construction.
   - Keratome size:
     - 3.2 mm – used for AC entry
     - 5.2 mm – used for tunnel extension in SICS and phaco with rigid IOL

10. Forceps:

    - Forceps are required to hold accurately and securely with a minimum of trauma [3]. Different forceps fine enough have been reported, but to make them delicate enough, they have been proportionately reduced in length, which has resulted in uncomfortable handling. The thumb, index, and 3rd fingers can hold it comfortably, while the opposite end of the instrument rests against the dorsum of the hand between the thumb and index finger. The branches are sturdy to prevent overlapping and tapered toward the tips. There are different types of forceps used, and only those that are used regularly are described here.

Fig. 10 Keratome

Fig. 11 Toothed forceps

A. Toothed forceps (Fig. 11):

- These are interdigitating toothed straight forceps with a long handle and are useful to grasp the conjunctiva while doing surgery in deep-seated eye/giving bridal suture.

B. Corneal forceps (Fig. 12a, b):

- These are interdigitating toothed straight forceps with a long handle and are used to grasp the cornea/conjunctiva during cataract, glaucoma, and corneal surgeries

C. Utrata forceps (Fig. 13):

- This is an angulated tip forceps used for capsulorhexis to avoid extension and anterior capsule removal.

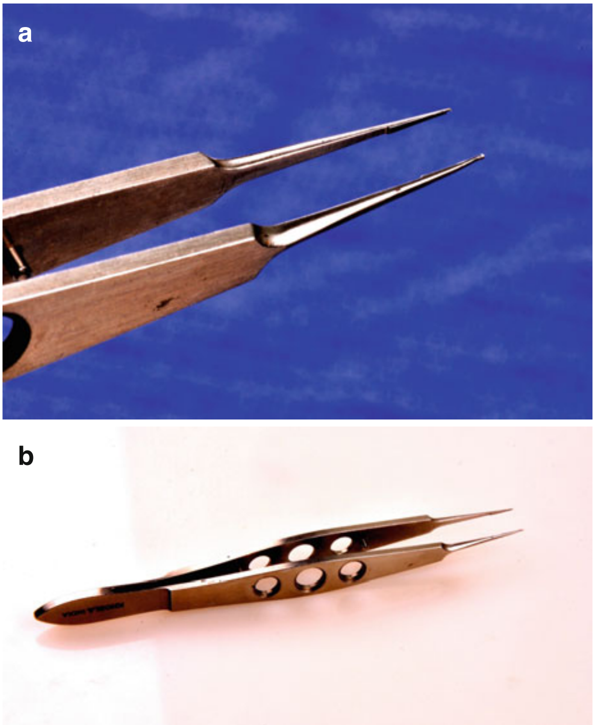


Fig. 12 Corneal forceps

Fig. 13 Utrata Forceps

D. Harms tying forceps (Fig. 14):

- They are non-toothed forceps; they can be serrated or non-serrated.
- Used for tying/removing sutures and holding friable or delicate tissues where button holing should be avoided.

Fig. 14 Harm's tying forceps

Fig. 15 Mcpherson's forceps

E. McPherson's forceps (Fig. 15):

- Angled non-toothed forceps with angulations about 6–10 mm from the body and is used in anterior capsulectomy and IOL insertion

F. Shepard IOL forceps (Fig. 16):

- They have a gentle long curved tip which helps in IOL implantation by holding optic without scratching it or blocking the view.

G. Curved needle holder (Fig. 17a, b):

- Better for working at locations other than working directly ahead. It should be held like a pen, and the needle should be grasped at its center for maximum control during initial pass of the needle.

11. Scissors:

Scissors used in SICS are small and easy to use and are made with stainless steel and are more durable and easy to maintain. There are various types of scissors used by different surgeons, and a few of the commonly used are described below.

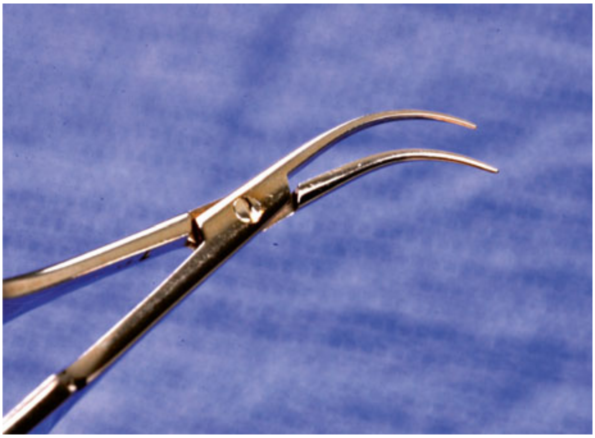


Fig. 16 Shepard IOL forceps

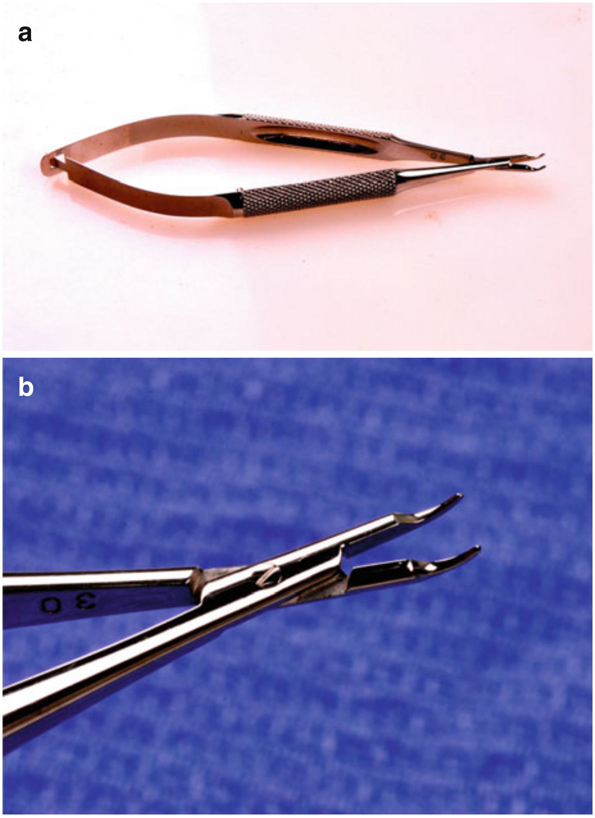


Fig. 17 Curved needle holder

A. Eyelash-cutting scissors (Fig. 18):

- They are straight scissors with a blunt tip used to cut eyelashes before surgery and also to cut the plastic drapes. Eyelashes are not trimmed in many high-volume surgical centers. Plastic drapes cover the lashes.

B. Westcott conjunctival scissors (Fig. 19):

- They have slightly blunted points to avoid globe injury and are used easily with either hand and at any angle. Spring action ensures minimum pressure required only to close the tip and guards against excessive opening of the blade.

C. Castroviejo corneoscleral scissors (Fig. 20):

- They have unequal blades with a long blade inserted into the anterior chamber, which cuts against the convex curve of the upper blade producing shelving cut. Cutting should be done at the distal half of the scissors, and they are also used for suture end cutting/trimming/removal. Universal scissors is also equally good.

Fig. 18 Eyelash cutting scissors

Fig. 19 Westcott Conjunctival scissors

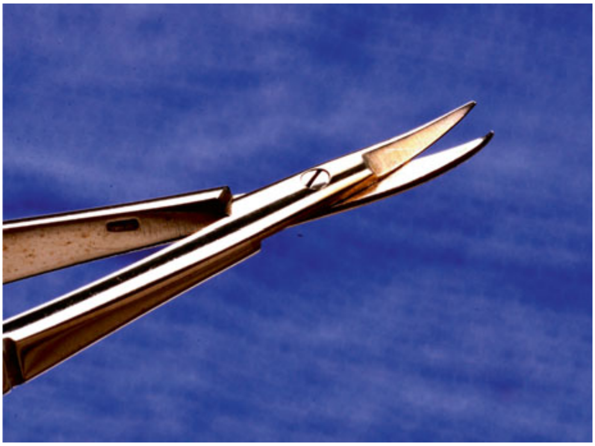


Fig. 20 Castroviejo corneoscleral scissors

Fig. 21 Vannas scissors

D. Vannas scissors (Fig. 21):

- They are angulated fine scissors with narrow blades and are well suited for intraocular dissection of vitreous strands during anterior vitrectomy, anterior capsule, sphincterectomy, and iridotomy. It can be introduced and operated through a very small incision.

12. Cystotome (Figs. 22, 23 24, and 25):

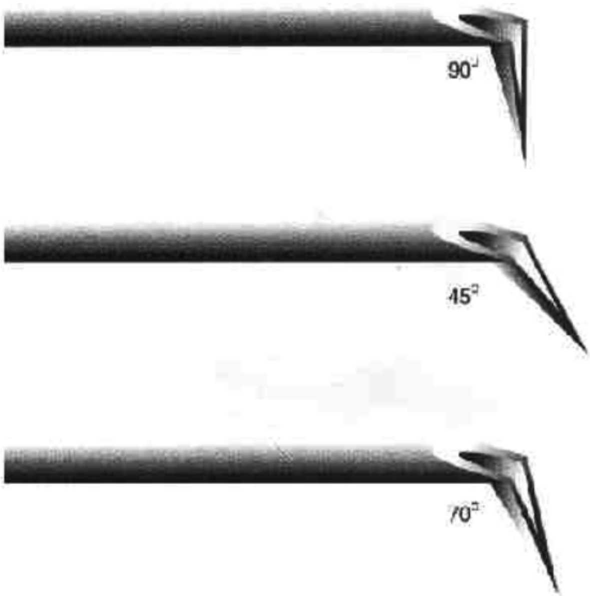


Fig. 22 Cystotome

Fig. 23 Cystotome

- Disposable 26G needle is used to create a capsulorhexis or a capsulotomy in the anterior lens capsule.
- The needle is made into a cystotome by creating two bends in the needle shaft. The first bend at the tip should be 90° bevel down, making sure the bent tip is not more than 1.0 mm. The second bend is near the hub of the needle, exactly opposite to the direction of the first bend and slightly less than 90°.
- The final cystotome is examined under a microscope before being used to make sure the angulation is right.

13. Sinskey hook (Fig. 26):

- This is a stainless steel straight probe with an angled end with a bent tip at the end to hold the nucleus and to prolapse it into the anterior chamber. The hook is engaged also into the dialing hole of the optic of the IOL or the optic-haptic junction to guide it into the bag and to dial it into place.

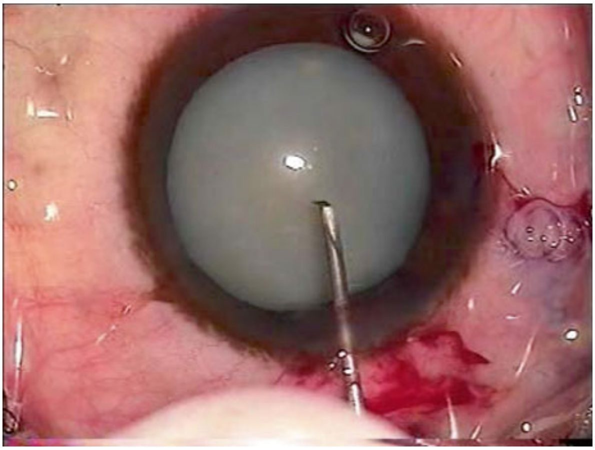


Fig. 24 Cystotome

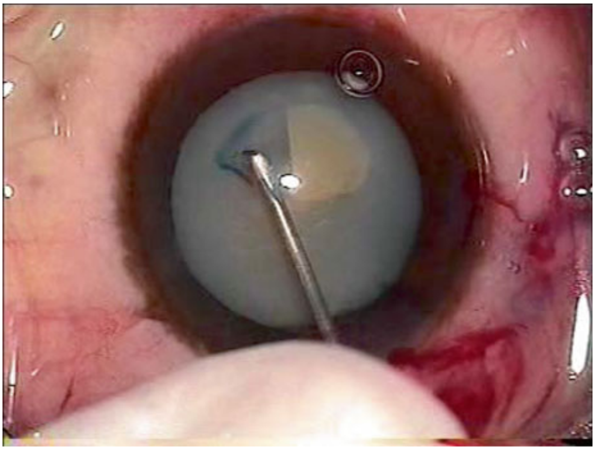


Fig. 25 Cystotome

14. Double-barrelled Simcoe cannula (Figs. 27, 28, and 29):
    - This is a 23-gauge cannula with two barrels, one for irrigation and one for aspiration. The cannula for irrigation and aspiration is parallel – not coaxial.
    - While aspiration can be manually controlled, the rate of irrigation is dictated by the height of the infusion bottle, which is usually 25 inches above the eye level.
    - The aspiration tip is directed upward for greater safety of posterior capsule during its use.
    - The aspiration tube is connected to a disposable syringe with which the rate of aspiration is controlled.
    - The Simcoe cannula is used for cortex aspiration and anterior chamber wash of viscoelastics or blood and also for posterior capsule polishing.

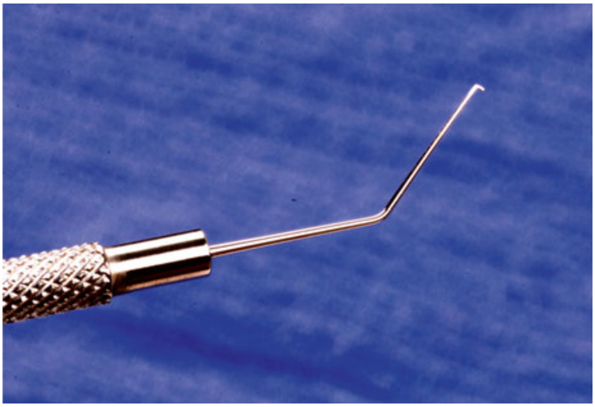


Fig. 26 Sinskey Hook

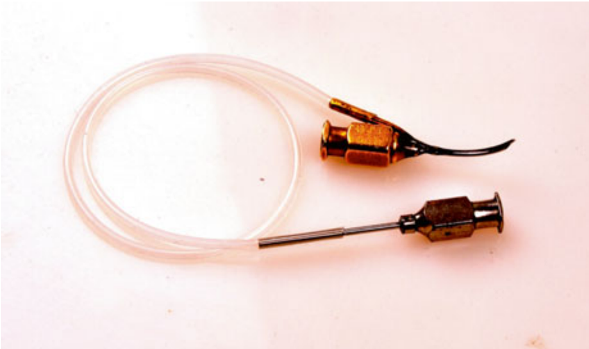


Fig. 27 Double Barrelled Simcoe cannula

Fig. 28 Double Barrelled Simcoe cannula

15. Irrigating vectis (Fig. 30):

- The nucleus is extracted using the irrigating vectis.
- The irrigating vectis is available in various sizes and shapes [1]. The vectis is of 23 gauge with a 35 mm overall length with three outer ports at 10, 12, and 2 o'clock positions in a 3–5-mm-wide and 9-mm-long loop. The anterior surface is slightly concave. This vectis is attached to a syringe, usually a 5 cc syringe containing BSS [2].

Fig. 29 Double Barrelled Simcoe cannula

Fig. 30 Irrigating Vectis

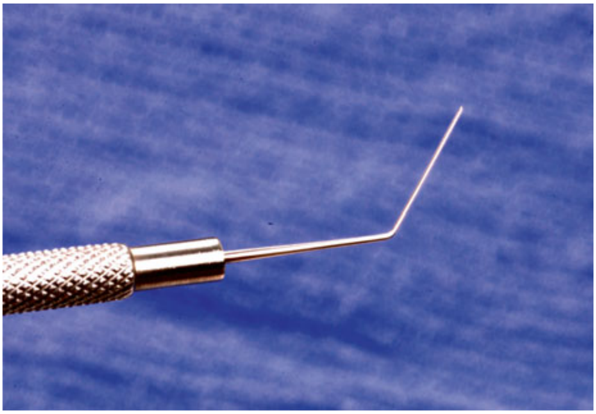


Fig. 31 Cyclodialysis Spatula

16. Cyclodialysis spatula (Fig. 31):

    - Used for cyclodialysis in aphakic glaucoma in the past and now used during cataract surgery for bimanual nucleus prolapse and to check vitreous distur-

Fig. 32 Hydrodissection cannula

bance in case of posterior capsular rupture, repositioning of bellowing, or sailing iris.

17. Hydrodissection cannulas (Fig. 32):

    - Hydrodissection and hydrodelineation are carried out with a 1–2 cc syringe (disposable or glass). The smaller syringe gives more control over the amount and rate of fluid injected, and glass syringes usually have a smoother movement as compared to disposable ones. The cannula may be 26–30 G in size and suitably angled and must have a smooth rounded tip. Always check the patency of the cannula and smooth functioning of the syringe before starting the hydroprocedures.

References

1. Akura J. Manual sutureless cataract surgery using a claw vectis. J Cataract Refract Surg. 2000;26(4):491–6.
2. Aravind S. Nucleus management with irrigating vectis. Indian J Ophthalmol. 2009;57(1):19–21.
3. Castroviejo R. Suturing forceps for corneal and cataract surgery. Trans Am Ophthalmol Soc. 1965;63:255–7.
4. Storz product catalogue.
5. Natchair.G. Manual Small Incision Cataract Surgery. 2nd ed. Madurai: Aravind Eye Hospital & Postgraduate Institute of Ophthalmology; 2000.

Anesthesia for Small-Incision Cataract Surgery

Jaime Tejedor

Introduction

Anesthesia for manual small-incision cataract surgery (SICS) incorporates the techniques used in extracapsular cataract extraction and in phacoemulsification but with significant peculiarities. When it is performed using a scleral tunnel, retrobulbar and peribulbar anesthesia may be preferred, but with smaller stepped, clear corneal incisions, sub-Tenon's anesthesia, topical anesthesia, intracameral anesthesia, and cryoanalgesia are allowed, because little manipulation is required. Anesthetic modality for this procedure implies choosing the most appropriate anesthetic agent in combination with a compatible surgical technique, thus ensuring patient comfort during surgery and in the postoperative period. The main goal of this chapter is that the reader is able to identify an optimum local anesthesia strategy for SICS.

Retrobulbar anesthesia was described by Herman Knapp in 1884, and was followed by van Lint orbicularis anesthesia in 1914 [1]. Using hyaluronidase, Atkinson reported that large volumes of anesthetic could be injected with less orbital pressure in 1948. Peribulbar injection of local anesthesia was published in 1985. Topical tetracaine anesthesia was first introduced for cataract surgery in 1992 by Fichman. General anesthesia is rarely employed for manual small-incision cataract surgery. In selected cases, no anesthesia, as described by Agarwal (1998), or cryoanalgesia (1999), could be used in manual SICS.

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Type of Anesthesia

General Anesthesia

General anesthesia may be necessary in mentally impaired, who cannot communicate, unstable, or completely uncooperative patients. Due to obvious advantages as rapid recovery and compatibility with ambulatory surgery, local anesthesia is virtually the rule in manual SICS. Topical anesthesia eliminates some of the risks involved in other types of local anesthesia, but only in selected cases is chosen for manual SICS.

Anesthetic Delivery Techniques in Local Anesthesia

The popular modalities of local anesthesia are retrobulbar, peribulbar, sub-Tenon's (regional modalities, with injection delivery of the anesthetic agent), and topical anesthesia (see Table 1 for anesthetics used and Table 2 for typical combinations of them in different modalities). The latter includes adjunct intracameral anesthesia and the option of Xylocaine gel and viscoanesthesia. The variant of cryoanalgesia is also considered.

Table 1 Characteristics of anesthetics used in small-incision cataract surgery

		Onset	Duration	Potency	Toxicity
Ester-type hydrolyzed by plasma cholinesterase (liver) Allergic reaction more likely (formation of PABA)	Procaine	S	S	L	L
	Tetracaine	S	I	I	I
	Cocaine	S	L	H	H
	Benoxinate (oxybuprocaine)	S	I	I	H (cardiotoxic)
	Chloroprocaine	F	I	I	L
Amide type	Lidocaine	F	S/I	I	L/I
	Mepivacaine	F	S/I	I	I
	Bupivacaine	S/I	L	H	H
	Ropivacaine	S/I	L	I	I
	Etidocaine	F	L	H	H
New drugs	Articaine	S/I	L	I	L
	Levobupivacaine	S/I	L	H	H/I
	Proxymetacaine	F/I	I	I	L

Onset: *S* slow; *I* intermediate; *F* fast
Duration: *S* short; *I* intermediate; *L* long
Potency and toxicity: *L* low; *I* intermediate; *H* high

Table 2 Typical combination of anesthetics for different modalities

Anesthetic modality	Agent
Topical	Tetracaine (hydrochloride) 0.1 % + oxybuprocaine hydrochloride 0.4 %
Intracameral	Preservative-free lidocaine 1 % or a mixture of preservative-free lidocaine 1 % and preservative-free bupivacaine 0.5 %
Regional (Retrobulbar, peribulbar, sub-Tenon's block)	Lidocaine 2 % – short-duration procedures Lidocaine 2 % + bupivacaine 0.5–0.75 % [or ropivacaine 1 %] – 1 h duration Mixture (50 %–50 %) of mepivacaine 2 % and bupivacaine 0.5–0.75 % – 1 h or longer duration

Sedatives may be used in local anesthesia but can result in a confused uncooperative patient in the middle of an operation. If sedation is not used, small amounts of clear fluids can be permitted 2 h before surgery. Monitoring should include ECG and pulse oximetry. Intravenous access may become necessary and therefore should be considered in the plan. The most commonly used sedatives are midazolam (benzodiazepine with a half-life of 2 h), propofol (short-acting phenol with rapid recovery, it causes respiratory depression and fall in blood pressure), fentanyl (potent short-acting – 30 min – narcotic analgesic), and remifentanil (ultrashort-acting analgesic metabolized by esterases, with half-life of 3–10 min, causes fall in heart rate and blood pressure).

Regional Anesthesia

Retrobulbar Anesthesia

This procedure achieves good ocular akinesia and anesthesia by delivery of 3.5–5 ml of anesthetic into the retrobulbar space (see Fig. 1). A shorter round-tipped needle than classical (31–38 mm) is introduced with precise placement between the inferior and lateral rectus muscles (point between medial two thirds-lateral one third of the inferior orbital rim) while the patient is in primary or slight upgaze. After the resistance of the orbital septum is encountered, the posteriorly directed needle is directed toward the apex of the orbit, until it meets the resistance of the intermuscular septum. When the latter is passed, the retrobulbar space is reached. While retrobulbar anesthesia is used by 9 % of surveyed surgeons of the ASCRS in phacoemulsification [2], this percentage is surely larger in manual SICS.

Pearl

Avoid placing the needle "far from the globe" to prevent perforation. It usually leads to peribulbar placement of the anesthetic. After initial resistance of the orbital septum, a small rotational or vertical movement of the globe is observed when resistance of the intermuscular septum is found.

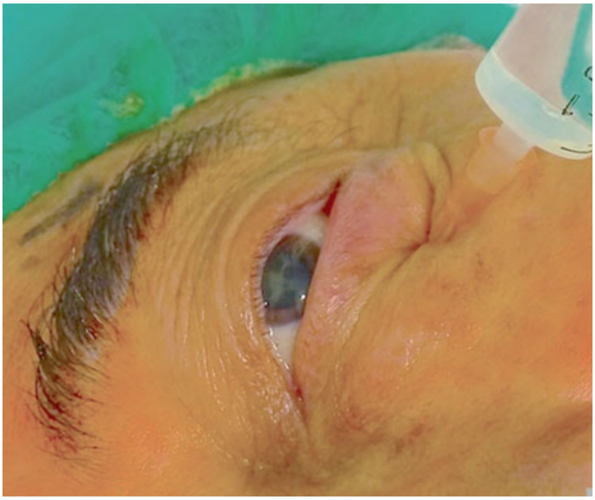

Fig. 1 Insertion of needle (35 mm length) for retrobulbar block at the junction of the middle and lateral third of the inferior eyelid above the inferior orbital rim. The needle is directed toward the orbital apex (medial and lateral orbital walls make an angle of 45°)

Complications

Potential complications of retrobulbar block include retrobulbar hemorrhage, perforation of the globe, retinal vascular obstruction, and subarachnoid injection with possible cardiovascular consequences.

Retrobulbar hemorrhage occurs in less than 5 % of retrobulbar injections [1]. There are various possible sources of bleeding. The vortex veins leave the globe 4 mm posterior to the equator, so shearing forces during needle insertion could well affect them and the inferior ophthalmic and central retinal vein. In cases of sudden onset of proptosis, chemosis, hemorrhage, and immobility of the globe, arterial bleeding is presumed. Candidates are the posterior ciliary arteries supplying the choroid and ophthalmic artery branches (including the central retinal artery) or the ophthalmic artery near the optic foramen. Use of needles longer than 31 mm is not recommended (25G, 25-mm long is the most frequently employed) [3].

In most cases, retrobulbar hemorrhage resolves without complication, and surgery should be postponed for 3–4 weeks, with topical or general anesthesia depending on cooperation and availability. If vision is compromised as a result of closure of the central retinal artery due to increased intraorbital or intraocular pressure, a lateral canthotomy is indicated. Damage to smaller vessels could also occur. Anterior chamber paracentesis and orbital decompression are other therapeutic options. Computed tomography is usually undertaken before orbital decompression to help localize the blood and rule out the possibility of bleeding within the optic nerve sheath, which might also require decompression.

Perforation of the globe is a sight-threatening complication, and highly myopic eyes are particularly susceptible to this occurrence. The scleral perforation should be repaired as soon as possible, using cryopexy, laser treatment, scleral buckling, or pars plana vitrectomy. Inadvertent injection of lidocaine into the vitreous cavity may be tolerated, but could cause elevation of the intraocular pressure and rapid opacification of the cornea.

Retinal vascular obstruction has also been reported after retrobulbar anesthesia. Central retinal artery obstruction frequently reverses spontaneously and reperfuses within several hours. Possible mechanisms are spasm of the artery, trauma to the vessel from the needle, and external compression by an injected solution or blood. Anterior chamber paracentesis may help by lowering intraocular pressure, but its efficacy is questionable. When there is combined obstruction of central retinal artery and central retinal vein, a cherry red spot is seen with intraretinal hemorrhages and dilated retinal veins, due to direct trauma of the retinal vessels or compression from fluid or blood injected into the optic nerve sheath. The prognosis in these cases is dull, and hemorrhage or hematoma of the optic nerve sheath may be detected by computed tomography, leading to decompression of the nerve sheath. Neovascularization of the iris may develop, which could be avoided by the use of intravitreal anti-VEGF injection and/or panretinal photocoagulation. Apparently, retrobulbar injection with the eye in primary position could help prevent this complication, whereas when the eye is looking up and in, the optic nerve and retinal vessels are placed more easily in the pathway of the needle.

Inadvertent injection into the subarachnoid space or diffusion from the surrounding orbit could have respiratory or cardiovascular consequences. Optic atrophy and blindness are very infrequent complications of retrobulbar block.

Peribulbar Anesthesia

The peribulbar technique achieves good ocular akinesia and anesthesia using several injections external to the muscle cone (usually 2), but anesthetic effect is frequently of poorer quality than in the retrobulbar technique. The efficacy of peribulbar blockade using short (15.0 mm), medium (25.0 mm), and long (37.5 mm) needles depends on the proximity of the deposition of the local anesthetic solution to the globe or the orbital apex. Orbital hemorrhage and globe perforation are less frequent than in retrobulbar anesthesia. Peribulbar anesthesia could be classified as circumocular (sub-Tenon episcleral), periocular (anterior, superficial), periconal (posterior, deep), and apical (ultra deep). A potential effect of this modality of anesthesia is reduction in pulsatile ocular blood flow and IOP, which in certain operations could be beneficial [4].

Sub-Tenon Anesthesia

The Tenon capsule is a fascial layer of connective tissue surrounding the globe and extraocular muscles and attached anteriorly to the limbus of the eye, extending posteriorly to fuse with the dura that surrounds the optic nerve.

In this technique, after instillation of topical anesthetic, the conjunctiva and Tenon's capsule are incised with Westcott scissors and dissected in the inferior nasal quadrant, and a blunt cannula is introduced into the sub-Tenon space to administer 3–4 ml of anesthetic agent, to produce anterior segment and conjunctival anesthesia. Globe akinesia follows after a few minutes of rapid induction of anesthesia. This technique requires skill to dissect into the sub-Tenon space and to correctly place the anesthetic agent using a blunt irrigating cannula. The anesthetic is placed in the intraconical space in an attempt to affect the ciliary ganglion. Conjunctival bleeding and especially chemosis are the main complications that should be avoided.

The incidence of conjunctival swelling in the sub-Tenon block is around 39.4 % [5, 6]. It could be attributable to anterior leakage of the anesthetic. Chemosis is exaggerated if the solution is administered into the anterior compartment of sub-Tenon space or the subconjunctival space. The reported incidence of subconjunctival hemorrhage is 32–56 %, which might be reduced with cauterization of the conjunctival incision to reduce hemorrhage. Retrobulbar hemorrhage could occur when we perform the dissection, introduce the cannula through the tunnel, or use a continuous infusion with catheter.

Retrobulbar and peribulbar procedures produce equally good akinesia, in theory, and sub-Tenon procedures produce slightly less akinesia, but there is insufficient evidence for this conclusion.

Pearl

A frequent mistake is subconjunctival injection of the anesthetic, because dissection into the sub-Tenon's space reaching the sclera is not correctly made, leading to conjunctival chemosis.

Topical Anesthesia

Cataract patients are often managed with topical anesthesia to facilitate recovery and rehabilitation after surgery. It can be supplemented with intracameral anesthesia or oral/IV sedation [7]. A particular advantage of topical anesthesia is that visual recovery is almost immediate or at least faster than after retrobulbar or peribulbar anesthetic technique.

Topical anesthetic agents (Tables 1 and 2) block trigeminal nerve endings in the cornea and the conjunctiva only, leaving the intraocular structures in the anterior segment unanesthetized. Manipulation of the iris and stretching of the ciliary and zonular tissues during surgery can irritate the ciliary nerves, resulting in discomfort, and should be avoided when this anesthesia is used. Consequently, the addition of intracameral anesthesia is frequently used to enhance the effect of topical anesthetics.

Topical anesthesia consists in the use of eye drops or gels. Allergies to local anesthetic agents determine the suitability of anesthetics for choice in a particular case. Patient discomfort and epithelial toxicity are also important factors when topical anesthesia is used. Toxicity to the corneal epithelium might lead to corneal clouding and more difficult surgery due to poor visibility, as well as corneal erosion and prolonged wound healing. Tetracaine (an ester-type anesthetic agent) is the most irritating of the commonly used anesthetic eye drops and should be avoided in patients allergic to this particular family of agents [8]. Proparacaine does not metabolize to p-aminobenzoate, although an ester type, and therefore may be used safely in patients allergic to other ester-type anesthetic drugs.

Viscous lidocaine gel may be used as an alternative or adjunct for topical application of anesthetics. The gel is often mixed with dilating medications and antibiotic and nonsteroidal anti-inflammatory agents, for example, lidocaine gel 2 % mixed with tropicamide, cyclopentolate 1 %, and phenylephrine 10 % or 2.5 % (with or without moxifloxacin and ketorolac applied to the operative eye twice before surgery to achieve good mydriasis and anesthesia) [8]. Topical anesthesia with 2 % lidocaine gel keeps the cornea moistened and increases the contact time with the ocular surface, with sustained diffusion and prolonged anesthetic effect. In my experience, it has some epithelial toxicity that could impair visibility during the cataract surgery procedure, but it is also true of topical anesthesia drops when employed several times before starting surgery.

A non-pharmacological topical anesthesia technique, named cryoanalgesia, consists in using cool fluids but no anesthetic drops [9]. Only selected patients can cooperate for a manual cataract surgery technique with this approach. Before surgery, the patient will feel a cold sensation in his eye. It is necessary to cool all fluids to be used during surgery to approximately 4 °C (excluding povidone, which remains at normal temperature). An eye mask of cold gel is placed over the eye for 10 min before surgery. A cold methylcellulose drop is instilled into the eye also before placing the ophthalmic drape and before starting surgery. The cornea is cooled with continuous irrigation of cold BSS®. Cold viscoelastic material (e.g., Viscoat®) is injected into the anterior chamber, and the cornea is continuously cooled with BSS® throughout the procedure.

Intracameral Anesthesia

Intracameral anesthesia is sometimes used as an adjunct to topical anesthesia in phacoemulsification and is potentially useful also in manual SICS [8]. Whether it provides sensory blockage of the iris and ciliary body to relieve discomfort experienced during IOL placement remains to be clarified. A study compared intracameral lidocaine with placebo and no difference was observed in terms of anesthetic effect (pain scale) for phacoemulsification [10]. Intracameral lidocaine alone dilates the pupil well or at least contributes to pupillary dilation [11], presumably because of the direct action of lidocaine on the iris, which causes muscle relaxation. Preservative-free lidocaine 1 % with epinephrine (0.3 cc of 1: 1000) enhances pupillary dilation compared with lidocaine 1 % alone and could sometimes eliminate the need for preoperative dilating drops [12].

Advantages of intracameral anesthesia include: injuries to ocular tissue or life-threatening systemic side effects are minimal, the vision is restored more rapidly after the operation, the undesirable cosmetic side effects are avoided, and the technique is economical in comparison with other procedures. A report by the American Academy of Ophthalmology discusses the efficacy and possible retinal and corneal endothelial toxicity of intracameral anesthesia [13]. The efficacy of intracameral anesthesia is supported by some of the papers clearly, but others fail to support this conclusion. However, as topical anesthesia alone is effective, it concludes that intracameral anesthesia should be reserved to deal with pain arising during the procedure.

Preservative-free lidocaine 1 % is well tolerated by the corneal endothelium, whereas higher concentrations are toxic [8]. Although short-term studies indicate safety of intracameral lidocaine, the long-term effects are not known. Retinal toxicity can occur because of posterior diffusion of local anesthetic to the retina, and a temporary loss of light perception has been reported after intracameral anesthesia. In vitro studies suggest that lidocaine and bupivacaine may be toxic for the retina; therefore, a minimal concentration of local anesthesia should be used [8]. The toxic effects of the commonly available anesthetic agents on corneal endothelium as part of intracameral anesthesia administration are not fully understood. Preservative-free lidocaine 1 % in doses of 0.1–0.5 ml is not associated with significant corneal endothelial toxicity, but higher concentrations may be toxic. Intracameral bupivacaine toxicity is not well known, but it may be more toxic to corneal endothelium than lidocaine 1 %. Thus, preservative-free lidocaine 1 % has been suggested as the local anesthetic of choice for intracameral anesthesia [8].

However, preservative benzalkonium chloride (at a concentration of 0.025–0.05 %) in commercially available anesthetics may cause irreversible damage to corneal tissues [14] according to a study in rabbits. Injecting unpreserved lidocaine hydrochloric acid 4 % into the anterior chamber for several days [14] produces significant corneal thickening and opacification in rabbit models. Exposure time to the agent and the preservative in the agent are important in determining the effect of lidocaine. A brief exposure to unpreserved lidocaine is unlikely to produce injury to the corneal endothelium.

Although several incidents of rare visual sensations (ranging from a rapid sensation to perception of real objects) have been reported during surgery using topical anesthesia, this fear may be considerably reduced with adequate patient counseling.

Viscoanesthesia is a type of topical anesthesia using viscoelastic cohesive material which contains an anesthetic component. It usually includes an intracameral component of 1.5 % sodium hyaluronate and 1 % lidocaine hydrochloride (used for the capsulorhexis and IOL implantation), after a topical component of 0.3 % and 2 % concentration of the same elements, respectively. Apparently, it is effective and provides a longer anesthetic effect than merely aqueous topical, but its efficacy has not been specifically studied and reported in manual techniques. There is no evidence of increased endothelial damage or loss, or retinal toxicity using commercially available viscoanesthesia products [15, 16]. The author does not use this modality of anesthesia in his current practice, since in his experience it does not add much benefit to the use of topical anesthetic with or without lidocaine.

Patient-Reported Pain in Anesthetic Techniques

Friedman et al. [17] confirmed that the design and outcomes of most of the studies related to randomized trials in regional anesthesia are largely heterogeneous, using a systematic literature search with PubMed and Cochrane Collaboration's database for the synthesis of the findings of various trials. Therefore, in these cases, the scientific justification for the meta-analysis is not always met. The outcome of a recent meta-analysis report [18], comparing pain scores of topical anesthesia against regional anesthesia, is consistent with the findings by Friedman et al.

Among the injection types, the perceived pain is least with the sub-Tenon approach, followed by retrobulbar, peribulbar, and topical anesthesia. The clinical impression of the author is that retrobulbar anesthesia perceived pain least or not greater than that of sub-Tenon procedure. Overall, the application of anesthesia by injection is relatively more painful than that by topical means. Using a vertical scale arbitrary scale 0–10, where zero score represents no pain, 1–2 mild pain, 3–5 moderate pain, and a score of more than five severe pain, patient perceived pain during intraoperative surgery is greater with topical anesthesia than that with injection blocks, using the data reported by Friedman et al. [17], with a qualitative outcome based on the global plot of perceived pain constructed by Malik et al. [19]. Pain scale results experienced during surgery for different types of topical anesthetic agents such as lidocaine gel 2 %, bupivacaine 5 % drops, and benoxinate 0.4 % drops were reported to be 1.6, 4.1, and 7.1, respectively [20]. A study reported pain scores of 2 % lidocaine gel similar to those obtained with intracameral anesthesia [21]. Retrobulbar and peribulbar anesthesia produce equally good akinesia, in theory. Addition of hyaluronidase appears to increase the effectiveness of these blocks to induce akinesia. However, use of hyaluronidase in procedures other than retrobulbar is controversial and is not even employed routinely in retrobulbar block. Akinesia appears to be slightly less effective in sub-Tenon's procedures, but there is no sufficient evidence to support this conclusion.

Trend in Use of Anesthetic Modalities

The trend in the use of various local anesthetic techniques in the USA from 1995–2003, according to a practice-pattern survey of the American Society of Cataract and Refractive Surgery (ASCRS) members [2], was toward a significant decline in the use of retrobulbar anesthesia procedures and an increase in topical procedures, from 1998–2003. The percentage of topical anesthesia significantly varied depending on the surgical volume: 38 % for institutions with one to five procedures a month and 76 % in institutions with more than 75 procedures a month. A renewed interest in sub-Tenon techniques was also detected. In the author's opinion, sub-Tenon's anesthesia is not frequently used by cataract surgeons in small-incision manual techniques, nor in phacoemulsification, in contrast to findings of published surveys. In a personal unpublished small survey, none of ten cataract surgeons interviewed used sub-Tenon's anesthesia at all, for any kind of cataract procedure, including small-incision manual techniques and phacoemulsification. On the other hand, a 2002 European survey [22] comparing anesthesia techniques and practices indicated that peribulbar block was the most frequently used technique and that topical anesthesia was used by a minority of surgeons only. These results are surprising, and probably not true in 2014, but in the specific case of manual small-incision techniques, the frequency of topical anesthesia is lower than in phacoemulsification.

In the USA and the UK, there was a decline in the use of retrobulbar and peribulbar techniques since 1996, whereas topical and sub-Tenon's anesthesia gained increasing frequency of use.

Safety of Procedures

A UK-based survey concluded that potentially life-threatening complications exist with all techniques, except topical/intracameral local anesthesia [23]. This suggests that an anesthetist must be present [24] for intraocular surgery, to deal with adverse events. The UK-based survey [23] also showed that potentially sight-threatening complications were mostly associated with retrobulbar and peribulbar techniques.

Orbital hemorrhage can be reduced by avoiding injection into the apex (vascular area), using fine, short needles (25G, 25 mm needles). Fanning [3] did not recommend the use of needles longer than 31 mm. The use of retrobulbar and peribulbar anesthesia, particularly the latter, is decreasing primarily because of the increased risk and severity of complications such as globe perforation and retrobulbar hemorrhage, especially as other modalities have been found to be as effective. Delivery of the anesthetic agent with a blunt needle, such as that used in sub-Tenon delivery, reduces this risk substantially. In my experience, peribulbar anesthesia is clearly less effective than retrobulbar anesthesia. However, retrobulbar injection is a very effective modality of anesthesia, second in frequency after topical +/− intracameral lidocaine for many surgeons. It is very rare to cause a retrobulbar hemorrhage when the instructions described above for introduction and positioning of the needle are taken into account, the needle is gently introduced in the retrobulbar space, and the anesthetic liquid is slowly injected.

Globe perforation is a rare complication. It is more frequent in myopic eyes (which are thinner and longer), especially in retrobulbar and peribulbar blocks. The reported incidence of globe perforation ranges from 0 in 2,000 to 1 in 16,224 for peribulbar procedures [25], 3 in 4,000 for retrobulbar, and 1 in 12,000 for a mixture of peribulbar and retrobulbar procedures [26]. Globe penetrations are frequently not detected during administration of the anesthetic agent but may be noticed later with the development of hypotony, poor red reflex, and vitreous hemorrhage during surgery.

During delivery of the anesthetic agent, patients could be asked to move their eyes from side to side to ensure that no contact with the globe has occurred.

The rate of globe perforation can be reduced by correct knowledge of orbital anatomy, patient cooperation, and the use of blunt needles. Blunt needles make perforation unlikely, but in the event of a perforation, more trauma is involved [27].

Systemic risk [24] such as brainstem reach of anesthesia can occur with local anesthesia. Patients must be monitored carefully during and after administration of the anesthesia and also during surgery. Symptoms such as drowsiness and loss of or confused verbal contact may suggest affected brainstem, which can lead to respiratory and cardiac arrest [24]. The onset usually occurs within 8–10 min or almost immediately after anesthetic delivery. Resuscitation equipment and personnel trained to use it must be available. The oculocardiac reflex—episodes of bradycardia provoked by eye manipulation—is blocked when the ciliary ganglion is anesthetized. Therefore, it is rare with local anesthesia procedures in which blockade of the ciliary ganglion ablates the afferent oculocardiac reflex [27], but it could happen in topical anesthesia. Rapid distension of the tissues by volume or hemorrhage can occasionally provoke it, so it is recommended that retrobulbar or peribulbar injection is made gently.

Death may very rarely occur as a result of spread of the anesthetic agent along the optic nerve sheath or intra-arterial injection of the anesthetic solution with retrograde reaching the brainstem [27]. Apparently, it is more likely to occur with retrobulbar anesthesia (0.1–0.3 %) and less with peribulbar and short needles, as they avoid the cone of the extraocular muscles. If short needles are used in primary gaze to avoid rotation of the needle toward the nerve [28], the risk is reduced. In the UK, during the period 2002–2003, seven of eight reported neurological complications (consistent with affected brainstem) were due to retrobulbar and peribulbar anesthesia [23].

In a New Zealand study of the management of cataract in a predominantly elderly female population exhibiting significant systemic illness and coexisting advanced cataract, adverse intraoperative events were reported in only 5 % [29].

Allergic or vasovagal reactions are relatively common complications associated with local anesthesia which could lead to systemic complications [23]. Allergy to proparacaine eye drops has been reported [30], and cross-sensitization with other related agents, like tetracaine, is a relatively rare finding.

Amide local anesthetic agents are considered rare allergens; only about 1 % of reported reactions are believed to be caused by an immune-mediated process [31]. Hyaluronidase, which is less frequently used today as an additive agent for the block, may rarely cause allergic reactions [32].

Persistent diplopia (overall incidence 0.25 %) is another undesirable effect of the retrobulbar technique due to damage to the inferior rectus muscle, another muscle, or nerve damage (e.g., the inferior division of the third nerve) [33, 34]. Peribulbar anesthesia may also cause these complications, extending its effect even to the horizontal recti muscles, superior rectus, or rarely superior oblique. Muscle palsy (diplopia and ptosis) can be prevented by not using high concentrations of local anesthesia, which can become both neurotoxic and myotoxic; injection when resistance is found during needle insertion should also be avoided. Facial nerve blocks can lead to dysphagia or respiratory obstruction [35] from spread of the anesthesia to the glossopharyngeal nerve, thus decreasing its use in normal practice, unless severe blepharospasm is encountered. Adjuvant IV anesthetic agents for the reduction of pain could be associated with an increase in medical events [36].

The incidence of perioperative myocardial ischemia, although rare in elderly patients having cataract surgery and lower under local than general anesthesia, should be borne in mind when indications of surgery are established [37]. High or prolonged doses of local anesthesia are toxic to the corneal epithelium which prolongs wound healing and may cause corneal erosion. Repeated administration of topical local anesthetic agents, frequently sting, is responsible of temporary clouding of the cornea and impairs visibility considerably during surgery.

References

1. Garg A, Gutiérrez-Carmona FJ. Anesthesia. In: Gutiérrez-Carmona FJ, editor. Phaco without the phaco. ECCE and manual small-incision techniques for cataract surgery. New Delhi: Jaypee Brothers Medical Publishers; 2005.
2. Leaming DV. Practice styles and preferences of ASCRS members – 2003 survey. J Cataract Refract Surg. 2004;30(4):892–900.
3. Fanning GL. Orbital regional anesthesia. Ophthalmol Clin North Am. 2006;19(2):221–32.
4. Chang BY, Hee WC, Ling R, Broadway DC, Beigi B. Local anaesthetic techniques and pulsatile ocular blood flow. Br J Ophthalmol. 2000;84(11):1260–3.
5. Canavan KS, Dark A, Garrioch MA. Sub-Tenon's administration of local anaesthetic: a review of the technique. Br J Anaesth. 2003;90(6):787–93.
6. Roman SJ, Chong Sit DA, Boureau CM, Auclin FX, Ullern MM. Sub-Tenon's anaesthesia: an efficient and safe technique. Br J Ophthalmol. 1997;81(8):673–6.
7. Rocha G, Turner C. Safety of cataract surgery under topical anesthesia with oral sedation without anesthetic monitoring. Can J Ophthalmol. 2007;42(2):288–94.
8. Cass GD. Choices of local anesthetics for ocular surgery. Ophthalmol Clin North Am. 2006;19(2):203–7.
9. Gutiérrez-Carmona FJ. Phacoemulsification with cryoanalgesia: a new approach for cataract surgery. In: Phacoemulsification, laser cataract surgery and foldable IOLs. 2nd ed. New Delhi: Jaypee Brothers Medical Publishers; 2000. p. 226–9.
10. Boulton JE, Lopatatzidis A, Luck J, Baer RM. A randomized controlled trial of intracameral lidocaine during phacoemulsification under topical anesthesia. Ophthalmology. 2000;107(1):68–71.
11. Lee JJ, Moster MR, Henderer JD, Membreno JH. Pupil dilation with intracameral 1% lidocaine during glaucoma filtering surgery. Am J Ophthalmol. 2003;136(1):201–3.
12. Cionni RJ, Barros MG, Kaufman AH, Osher RH. Cataract surgery without preoperative eyedrops. J Cataract Refract Surg. 2003;29(12):2281–3.
13. Karp CL, Cox TA, Wagoner MD, Ariyasu RG, Jacobs DS. Intracameral anesthesia: a report by the American Academy of Ophthalmology. Ophthalmology. 2001;108(9):1704–10.
14. Judge AJ, Najafi K, Lee DA, Miller KM. Corneal endothelial toxicity of topical anesthesia. Ophthalmology. 1997;104(9):1373–9.
15. Trivedi RH, Werner L, Apple DJ, Izak AM, Pandey SK, Macky TA. Viscoanesthesia. Part I: toxicity to corneal endothelial cells in a rabbit model. J Cataract Refract Surg. 2003;29(3):550–5.
16. Macky TA, Werner L, Apple DJ, Izak AM, Pandey SK, Trivedi RH. Viscoanesthesia. Part II: toxicity to intraocular structures after phacoemulsification in a rabbit model. J Cataract Refract Surg. 2003;29(3):556–62.

17. Friedman DS, Bass EB, Lubomski LH, Fleisher LA, Kempen JH, et al. Synthesis of the literature on the effectiveness of regional anesthesia for cataract surgery. Ophthalmology. 2001;108(3):519–29.
18. Zhao LQ, Zhu H, Zhao PQ, Wu QR, Hu YQ. Topical anesthesia versus regional anesthesia for cataract surgery: a meta-analysis of randomized controlled trials. Ophthalmology. 2012;119(4):659–67.
19. Malik A, Fletcher EC, Chong V, Dasan J. Local anesthesia for cataract surgery. J Cataract Refract Surg. 2010;36(1):133–52.
20. Soliman MM, Macky TA, Samir MK. Comparative clinical trial of topical anesthetic agents in cataract surgery: lidocaine 2% gel, bupivacaine 0.5% drops, and benoxinate 0.4% drops. J Cataract Refract Surg. 2004;30(8):1716–20.
21. Koch PS. Efficacy of lidocaine 2% jelly as a topical agent in cataract surgery. J Cataract Refract Surg. 1999;25(5):632–4.
22. Eichel R, Goldberg I. Anaesthesia techniques for cataract surgery: a survey of delegates to the congress of the International Council of Ophthalmology, 2002. Clin Experiment Ophthalmol. 2005;33(5):469–72.
23. Eke T, Thompson JR. Serious complications of local anaesthesia for cataract surgery: a 1 year national survey in the United Kingdom. Br J Ophthalmol. 2007;91(4):470–5.
24. Royal College of Anaesthetists. Chapter 10. Ophthalmic anesthesia services. In: Guidelines on the provision of anesthesia services. London: Royal College of Anaesthetists; 2009.
25. Davis 2nd DB, Mandel MR. Efficacy and complication rate of 16,224 consecutive peribulbar blocks. A prospective multicenter study. J Cataract Refract Surg. 1994;20(3):327–37.
26. Hamilton RC, Gimbel HV, Strunin L. Regional anaesthesia for 12,000 cataract extraction and intraocular lens implantation procedures. Can J Anaesth. 1988;35(6):615–23.
27. Hamilton RC. Complications of ophthalmic regional anesthesia. Ophthalmol Clin North Am. 1998;11:99–114.
28. Malik A. Efficacy and performance of various local anesthesia modalities for cataract surgery. J Clinic Exp Ophthalmol. 2013;S1:007. doi:10.4172/2155-9570.S1-007.
29. Riley AF, Malik TY, Grupcheva CN, Fisk MJ, Craig JP, et al. The Auckland cataract study: co-morbidity, surgical techniques, and clinical outcomes in a public hospital service. Br J Ophthalmol. 2002;86(2):185–90.
30. Dannaker CJ, Maibach HI, Austin E. Allergic contact dermatitis to proparacaine with subsequent cross-sensitization to tetracaine from ophthalmic preparations. Am J Contact Dermat. 2001;12(3):177–9.
31. Jackson T, McLure HA. Pharmacology of local anesthetics. Ophthalmol Clin North Am. 2006;19(2):155–61.
32. Quhill F, Bowling B, Packard RB. Hyaluronidase allergy after peribulbar anesthesia with orbital inflammation. J Cataract Refract Surg. 2004;30(4):916–7.
33. Munoz M. Inferior rectus muscle overaction after cataract extraction (letter). Am J Ophthalmol. 1994;118(5):664–6.
34. Hunter DG, Lam GC, Guyton DL. Inferior oblique muscle injury from local anesthesia for cataract surgery. Ophthalmology. 1995;102(3):501–9.
35. Rubin AP. Complications of local anesthesia for ophthalmic surgery. Br J Anaesth. 1995;75(1):93–6.
36. Katz J, Feldman MA, Bass EB, Lubomski LH, Tielsch JM, et al. Adverse intraoperative medical events and their association with anesthesia management strategies in cataract surgery; the Study of Medical Testing for Cataract Surgery Study Team. Ophthalmology. 2001;108(10):1721–6.
37. Glantz L, Drenger B, Gozal Y. Perioperative myocardial ischemia in cataract surgery patients: general versus local anesthesia. Anesth Analg. 2000;91(6):1415–9.

Prep/Drape

Minu M. Mathen

For manual small-incision cataract surgery (MSICS), preparation and draping are similar to sutured large-incision manual extracapsular cataract extraction or instrumental phacoemulsification.

MSICS can be performed under peri/retrobulbar, sub-tenon or topical anesthesia. During the learning curve, it is always better to perform the case under peribulbar anesthesia so that adequate akinesia and analgesia are achieved. Once comfortable with the technique, one can move on to sub-tenon and then to topical anesthesia.

In case of injection anesthesia, it is very important to give adequate ocular massage to avoid raised vitreous pressure during the procedure. In MSICS, although the incision is a valved self-sealing corneoscleral tunnel, during some steps the large incision remains open during manipulations. During these steps, it is very crucial that the chamber does not shallow.

If surgery is being performed under topical anesthesia, touching the conjunctiva has to be done very gently to avoid pain. If the patient has pain while doing peritomy, it is better to give a subconjunctival injection of lidocaine locally.

The eyelashes need not be trimmed. Painting the skin of the lids and around the eye is performed with 10 % Betadine. 5 % Betadine drops is instilled into the conjunctival cul-de-sac. Then if the case is to be performed under peri/retro/sub-tenon's block, the block is performed. Again, a Betadine painting around the eye and Betadine drops into the conjunctival sac are repeated.

Now the drape is applied. Here, care has to be taken to get all the eyelashes under the plastic drape so that they do not come into the surgical field. While applying the eye speculum, one can further ensure that the lashes are tucked back under the lids covered by the drape. A wire speculum or a universal eye speculum

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(any speculum of a particular surgeon's preference will do) is applied to achieve adequate exposure of the surgical field including the limbal area. The conjunctiva and cornea are flushed with BSS. It is always good to use a drape with a fluid collection bag although not as much fluid is used in MSICS as in phacoemulsification.

As the first step of MSICS, a bridle suture is applied. We call it a bridle suture because it gives the surgeon control over moving the otherwise anesthetized and immobilized eyeball. It also lets one turn the globe in particular directions while performing specific steps, which we will describe later. If the surgery is being planned to be performed under topical anesthesia, applying a bridle suture can sometimes be painful. So most often, a local infiltration with lidocaine around the area (muscle insertion) where the bridle suture is planned is preferred.

Technique of Applying a Bridle Suture

1. For adequate exposure of the superior rectus muscle, the globe can be held by a toothed forceps at the limbus diagonally opposite to the muscle (Figs. 1a and 2a).
2. The muscle insertion is identified according to its distance from limbus (either superior 7.7 mm or temporal 6.9 mm), and the muscle is grasped just beyond the insertion with the superior rectus holding forceps. This forceps has a double curve at the end. When the proximal bent is placed at the limbus, the distal bent at the tip will be at 7.7 mm from the limbus to catch the muscle with its single large tooth at the tip (Figs. 1b, 2b).
3. The curved needle (with cutting edge) threaded with cotton or 6–0 silk suture is passed under the area held by the forceps to include the muscle also in the bite (Figs. 1c and 2c).
4. The thread can then be held taut and fixed to the drape using an artery forceps (Figs. 1d and 2d).

Tips

(a) In cases where the incision is placed at 12–0 clock, the superior rectus bridle suture is applied.
(b) When the suture is pulled back, the globe tends to turn down because the superior orbital margin acts as a fulcrum to allow this movement.
(c) If the incision is placed temporally, the lateral rectus bridle suture is applied.
(d) The lateral rectus suture, when pulled back, moves the globe more laterally as there is no brow effect here.
(e) To move the eye with a lateral rectus suture, the suture has to be pulled in the same direction to which one wants to turn the globe.

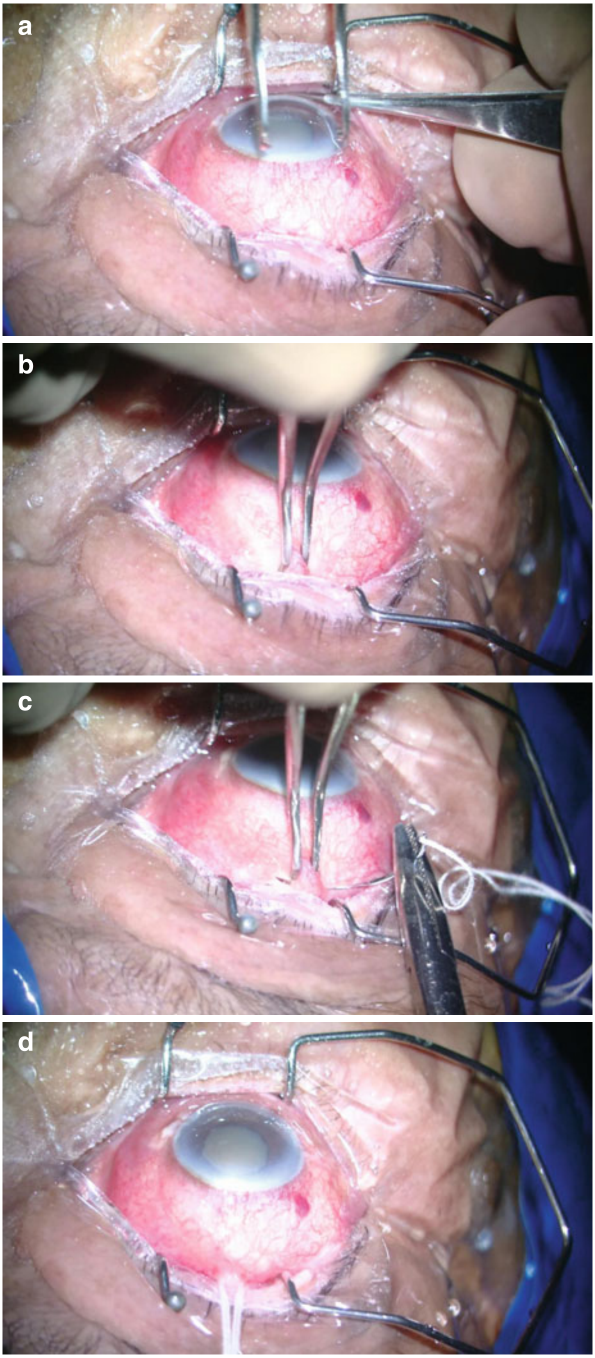

Fig. 1 Superior rectus bridle suture (**a**). Superior conjunctiva exposed. (**b**). Superior rectus muscle grasped. (**c**) Suture passed under the muscle (**d**). Globe steadied by pulling and clamping the suture

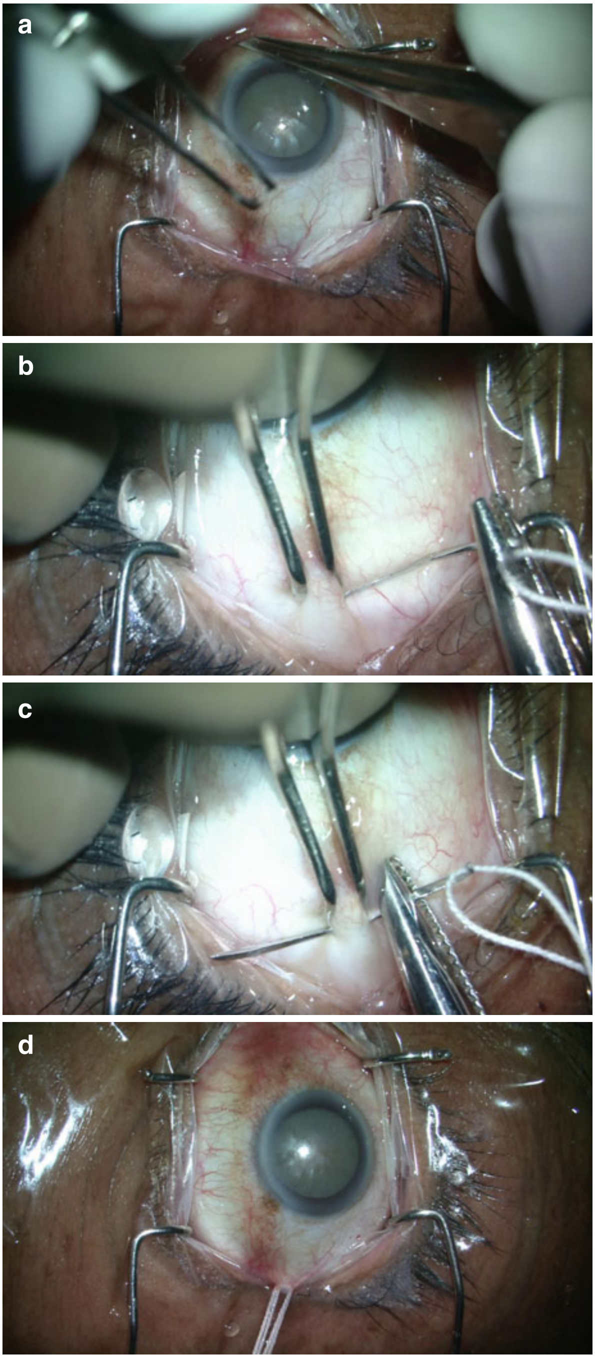

Fig. 2 Lateral rectus bridle suture (**a**). Temporal conjunctiva exposed. (**b**). Lateral rectus muscle grasped. (**c**.) Suture passed under the muscle. (**d**). Globe steadied by pulling and clamping the suture

Uses of a Bridle Suture

1. To hold the globe steady while performing peritomy and while creating the corneoscleral tunnel.
2. After the anterior chamber is entered for the first time (either through the paracentesis or through the corneoscleral tunnel), the artery forceps holding the suture should be released to reduce the pressure on the globe caused by a taut bridle suture.
3. During nucleus delivery:

   (a) To turn the globe nasally (in temporal sections), the lateral rectus suture is pulled nasally.
   (b) To turn the globe inferiorly (in superior incisions) the superior rectus suture is pulled back.

4. During IOL implantation: Here also to provide adequate exposure of the corneoscleral tunnel, the bridle suture is manipulated.
5. Deep set, small eyes can be made to lift up and become more prominent, so that surgical steps can be more easily performed, by applying a suture each on the superior and inferior rectus muscles.

Complications

1. The dreaded complication of a bridle suture is globe perforation. To avoid perforation:

   (a) The needle is passed exactly under the area where the muscle is grasped.
   (b) The forceps holding the muscle is slightly lifted while the needle is passed under it.

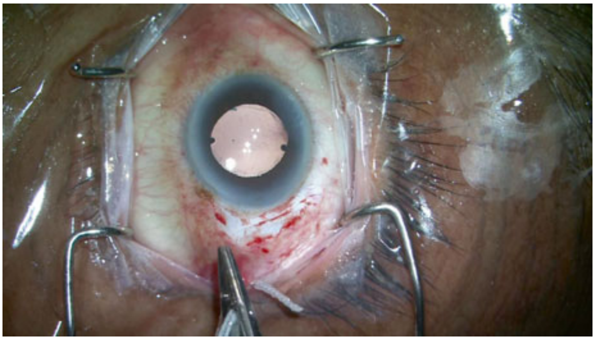

Fig. 3 As the penultimate step (before closing the peritomy), the bridle suture is removed. The suture can be cut close to the conjunctiva and removed

(c) The tip of the needle is directed upward after the initial pass under the muscle. The tip of the needle is almost always under direct visualization.
(d) Take only a small bite (not a broad one).

IF THERE IS A PERFORATION, the globe will feel soft during the corneo-scleral tunnel creation. If perforation is suspected, stop the procedure and try to view the possible area of perforation by indirect ophthalmoscopy. If cataract is not that dense and the damage is assessable, proceed to treat (either laser or cryo). If the cataract is too dense, perform a B scan and proceed according to the findings.

2. Bleeding
   To avoid bleeding and subconjunctival large hematomas, try to avoid larger conjunctival vessels while taking the bite.
3. The bite can pass superficially over the muscle. If the muscle is missed in the bite, then globe will not turn in the required direction as it should, when pulled. If so, the bite has to be repeated to include the muscle in the bite.
4. Injury to the rectus muscle like laceration or avulsion.
5. Postoperative ptosis.

Incision

Aravind Haripriya, Tanpreet Pal Singh, and Durga Prasad Nayak

Introduction

The ultimate result of a cataract surgery is dependent on the optimal performance of each step of the procedure. The success of each step in turn depends on the steps preceding it. Wound construction in MSICS can be considered as a rate-limiting step of cataract surgery. An error in this step can spiral into the subsequent steps and also weigh adversely in the immediate post-op period.

The present chapter will try to emphasize on the proper technique of wound construction and the problems that are encountered during the learning phase. For the sake of description, the chapter has been divided as follows:

1. Conjunctival peritomy
2. Cautery
3. Scleral incision
4. Sclero corneal tunneling and keratotomy
5. Complications of tunnel construction

Before elaborating on each step in detail, the basic background knowledge of the surgical limbus is essential to understand tunnel construction in MSICS. The corneoscleral limbus is not an anatomic structure as such but is a transition area between the cornea and the sclera, the episclera, and the conjunctiva. Under the operating microscope, the limbus is a grey semitransparent area, which separates transparent cornea from the opaque sclera.

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The transparent anterior surface of the cornea terminates with the insertion of the conjunctiva and the tenon's capsule. Between the insertions of the conjunctiva and the tenon lies the blue zone of the limbus. Behind the blue zone lies the opaque white zone of the limbus. The white zone is almost uniformly 1 mm all along the corneal circumference. The blue zone however is varied due to the differential attachment of the conjunctiva and tenons. The blue zone is about 0.8–1.2 mm in the superior aspect and about 0.4–0.8 in the temporal and nasal aspect.

These two zones of limbus are bounded by three limbal lines (Fig. 1). They are:

- Anterior limbal line – corresponds to termination of the Bowman's membrane
- Mid limbal line – corresponds to the termination of the Descemet's membrane(Schwalbe's line)
- Posterior limbal line – corresponds to the scleral spur

With this basic background of the surgical limbus, we will now elaborate on the steps of the MSICS.

Conjunctival Peritomy

The opening of the conjunctival flap in MSICS is done with forceps (Colibri/Pierce Hoskin) in the non-dominant hand and conjunctival scissors in the dominant hand of the surgeon. The flap is based toward the fornix. Initiation of the conjunctival flap is done at 10 clock hour. The conjunctiva has to be grasped just short of the limbus with forceps and a firm vertical traction[1] exerted to create a conjunctival fold (Fig. 2).

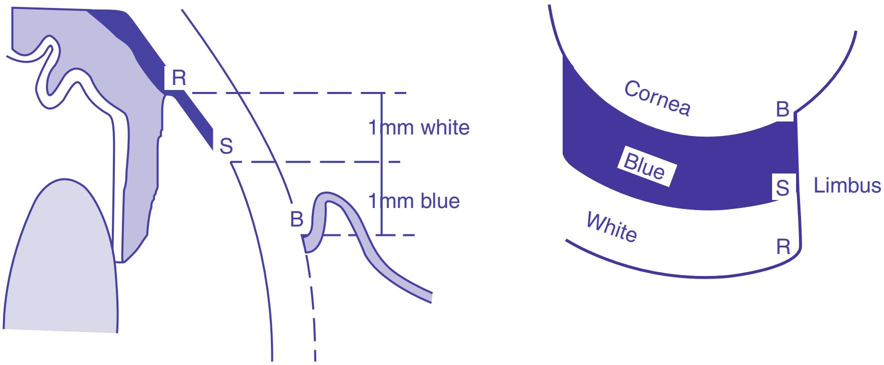


Fig. 1 A surgical anatomy of the limbus

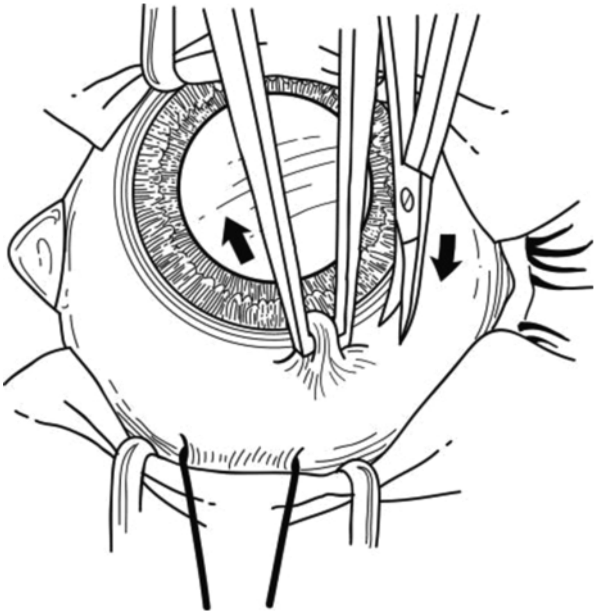
[1] Gives enough conjunctival surface to incise

The conjunctiva and tenons will be a safe distance away from the scleral surface.

Tangential inflicted cuts without proper vertical conjunctival traction can result inadvertent scleral injury.

The cut from the conjunctival scissors should be vertical with the limbs of the scissors perpendicular to the scleral surface. Since the tip of the scissors is blunt, it would not injure the sclera (Figs. 2 and 3).

Fig. 2 Illustrating vertical traction causing conjunctival fold away from the sclera



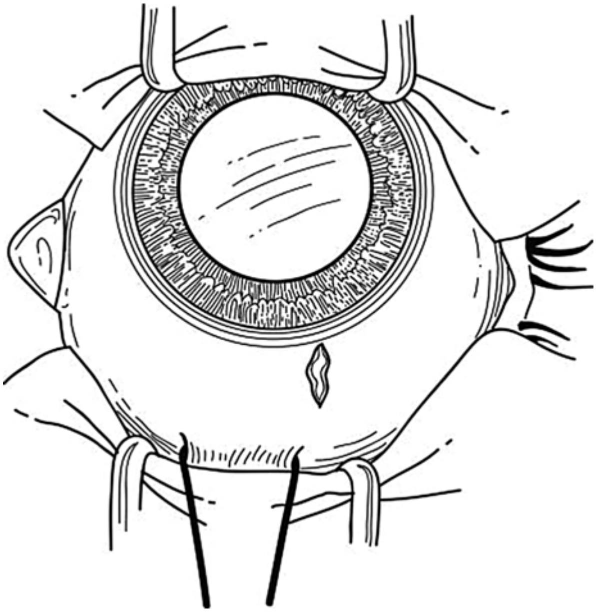
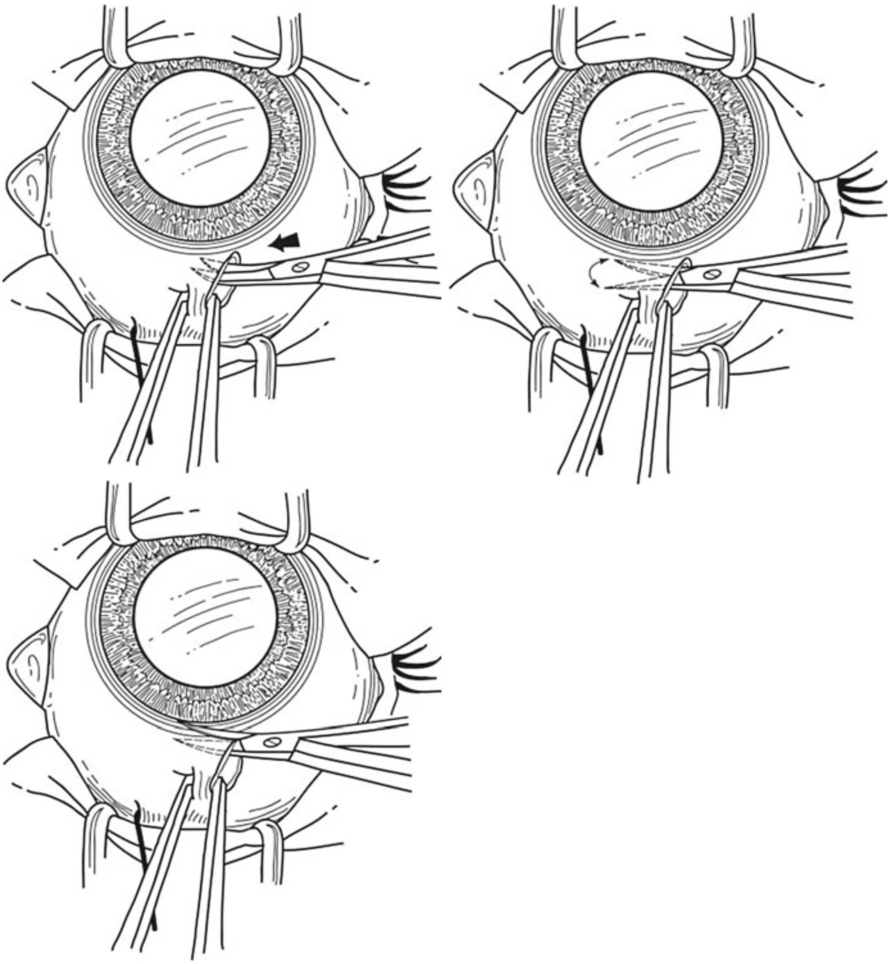


Fig. 3 Conjunctival/tenon opening with exposure of underlying sclera

Once the initial cut has been inflicted, the dissection of the conjunctiva and tenons can be done separately. Alternatively, sub-tenon plane of dissection can be directly sought. Blunt dissection of the conjunctiva is carried by initially inserting the blades (closed) beneath the tenon capsule. The tip has to be directed toward the limbus and blades opened to separate the tenons from the underlying sclera (Fig. 4).

Undue posterior dissection has to be avoided. The conjunctiva is then cut at the limbus flush with the cornea. During this step, the forceps should exert proper conjunctival/tenons traction to lift it away from the cornea and the blades of the scissors should be tangential to the cornea surface (Figs. 5 and 6).



Figs. 4, 5 and 6 Diagrams illustrating the position and direction of conjunctival scissors

An ideal conjunctival peritomy would thus expose the blue limbal zone without any overhanging conjunctival epithelium. A proper blunt dissection would have ensured that there is bare sclera at the bed without any islets of tenons[2] (Fig. 7).

Cautery

The purposes of using cautery before initiating a scleral incision:

- Allow proper visualization of the instrument during tunnel creation which otherwise gets obscured by blood.
- Prevent/minimize bleed into the anterior chamber intra- and postoperatively and sub-conjunctival hemorrhage postoperatively.

However, caution should be exercised since unjustified use of cautery results in more harm than the benefit. Wet-field bipolar cautery allows lateral distribution of heat over the scleral surface compared to unipolar/thermal ball point cautery and

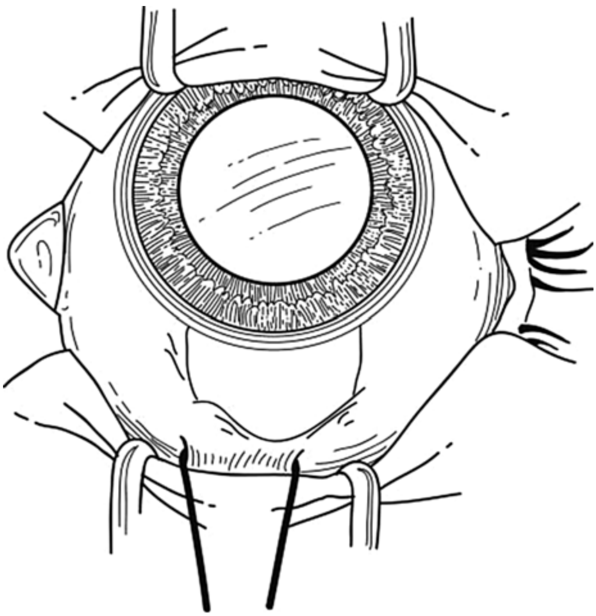


Fig. 7 Completed peritomy showing blue limbal zone

[2] Presence of tenons may cause irregular incision of variable depth along its extent. It also prevents smooth movement of the tunnel blade, which predisposes to septae within the tunnel.

Obscurance caused by overhanging limbal epithelium and remnant tenons may also lead to incorrect depth assessment while tunneling.

hence it is preferred than the latter. There are few points to consider when applying cautery:

- Point cautery should be applied to scleral bleeders only. Avoid forceful rubbing of the cautery tip to the scleral surface.
- Cautery of limbal "blue zone bleeders" has to be avoided.
- Cauterizing without proper tenons fascia removal may cause inefficient cauterization. Moreover cauterized tenons will be difficult to separate from the sclera.
- Once sclera incision and tunneling is done, cautery should not be applied. It may cause fish mouthing and subsequent wound leak.

Disadvantages of sclera cautery:

- Scleral thinning and scleral necrosis can occur following excessive cautery.
- Poor wound healing.

(These effects of cautery are also compounded by the relative avascularity of the sclera and postoperative steroid usage.)

In the late postoperative period, excessive cautery may result in higher induced astigmatism.

Scleral Incision

"What constitutes the essential elements of a self-sealing cataract incision?" There are three components of an ideal self sealing tunnel in MSICS:

- External sclera incision – constructed by the blade/surgical knife
- Sclerocorneal tunnel – constructed by tunnel blade/crescent knife
- Internal corneal incision – created by keratome

In practical terms one can think about the globe as a double-walled structure, at least in the vicinity of the wound. For the purposes of a cataract incision, one wall is the roof of the tunnel and one is the floor of the tunnel. It is these two layers acting in a predictable manner when pressure is applied from within during reformation of the anterior chamber that results in closure of the wound. During the initiation of the incision, the blade has to be kept as perpendicular as possible to the scleral surface. An angled or slanted incision will cause more separation of the lips of incision and consequent wound sagging or gaping (Figs. 8, 9, 10, and 11).

The characteristics of the external scleral incision include:

1. Size
2. Shape
3. Location
4. Depth

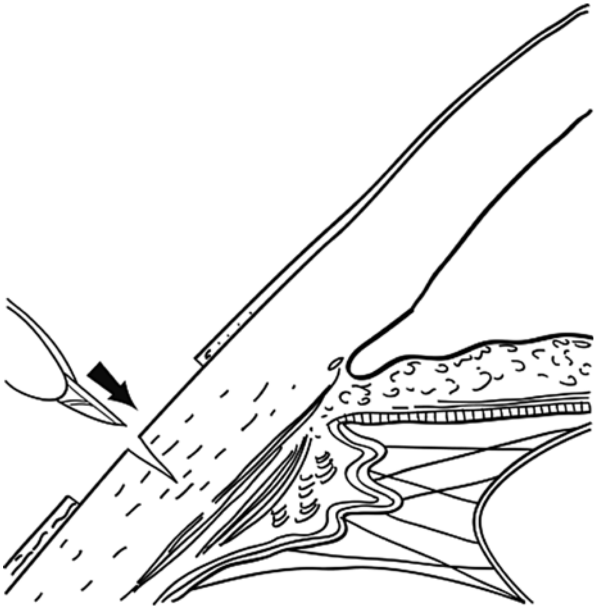


Fig. 8 Diagram illustrating perpendicular position of the blade while making incision

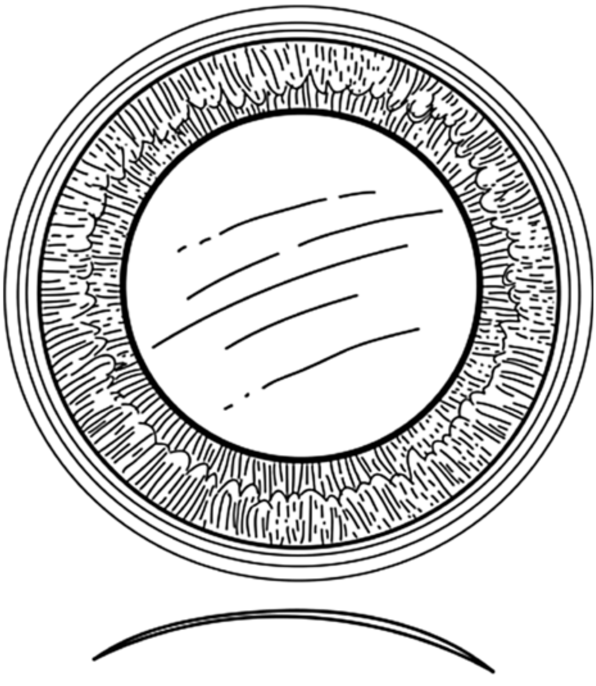


Fig. 9 Non-sagging and closely apposed incision

Fig. 10 Blade held at an angle to the sclera

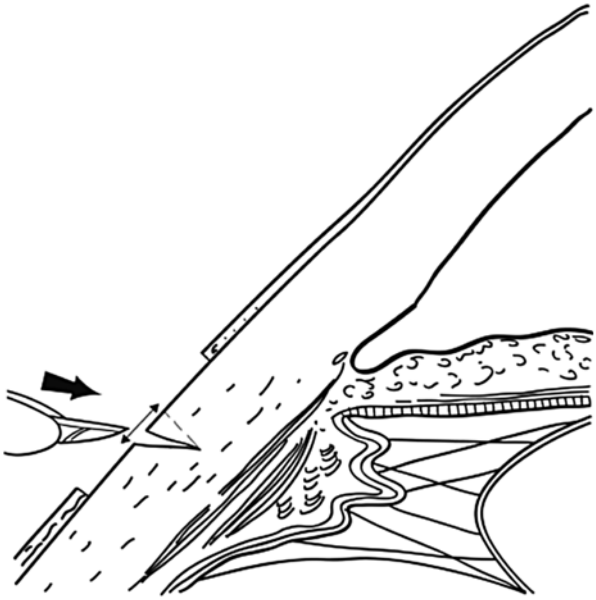
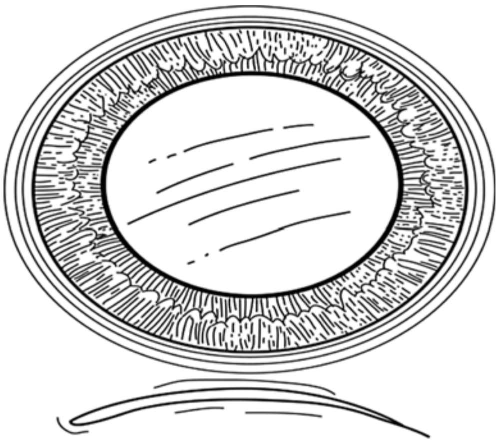


Fig. 11 An angled wound resulting in wound gape following surgical maneuvering



Size

The size of the incision on the sclera is titrated according to the density of the nucleus to be extracted.

Considering the average equatorial diameter of an adult lens (8.8–9.2) as 9 mm and sclera extensibility of 0.5–1 mm, nucleus of any size can be promptly delivered through the external incision. Harder cataracts have lesser epinucleus and are less yielding. Hence the size has to be appropriate lest there will corneal endothelial damage and/or nuclear fracture while delivery.

Shape *(Figs. 12, 13, 14, 15, and 16)*

The concept of arc length and chord length has to be explained to understand the effect of various shaped incisions.

Arc length is measured along the line of incision. Chord length is measured from point of initiation to the point of ending of the incision (end to end).

Various incision configuration which are used are as follows:

Smile incision: When the incision is made parallel to limbus, the inferior edge of the incision may fall back, which flattens the cornea in this meridian. If the incision is made at 12 o'clock, this incision flattens the vertical meridian of the cornea, causing against the rule astigmatism.

Straight incision: When straight incision is fashioned, there are no chances of the inferior edge falling back. Whatever astigmatism is produced by the straight incision is because of the instability of the central portion of the wound, which is much less than the smile incision.

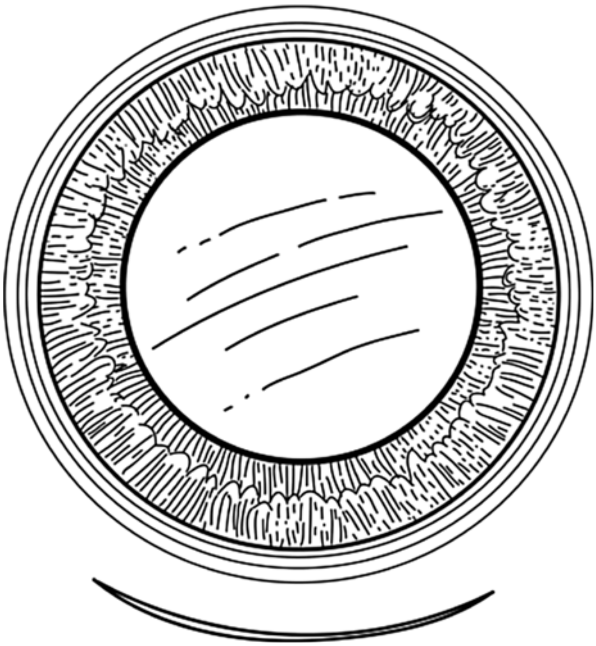
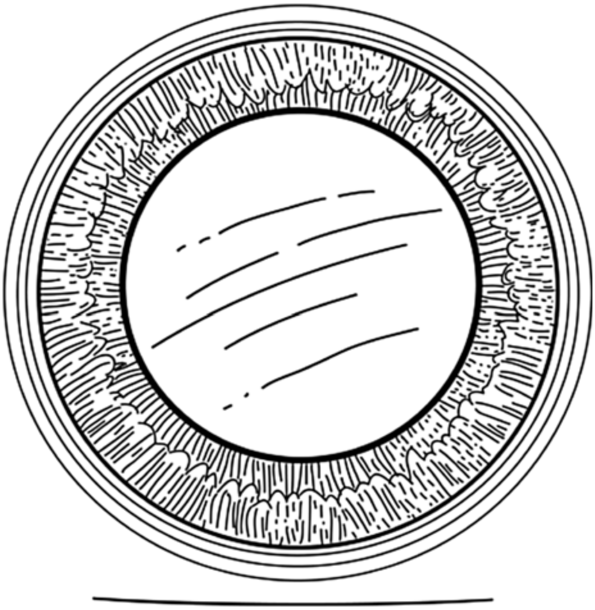


Fig. 12 Smile incision

Fig. 13 Straight incision



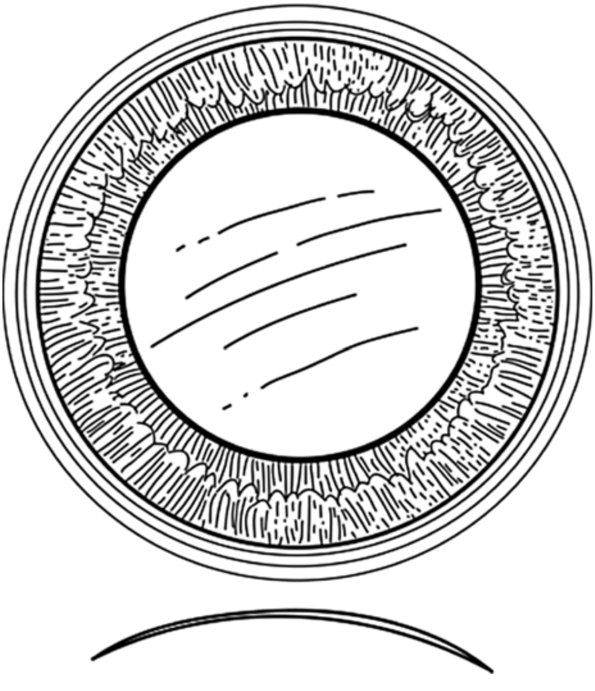


Fig. 14 Frown incision

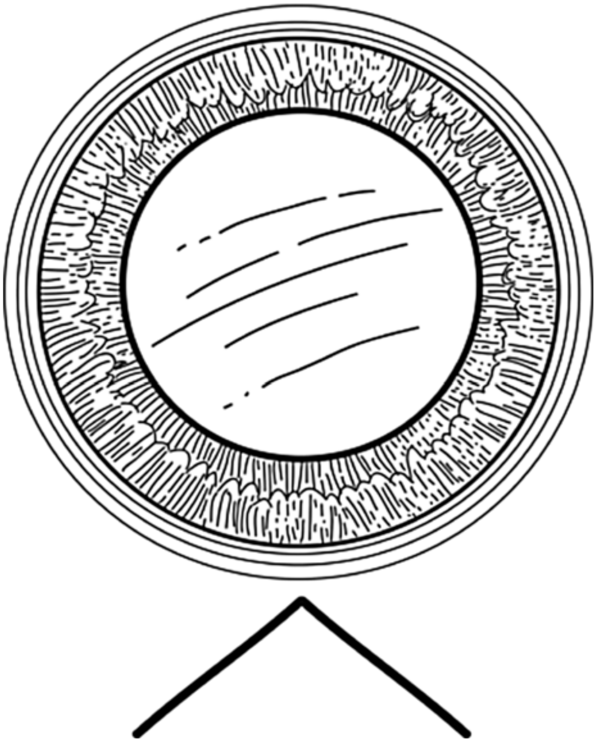


Fig. 15 Chevron incision

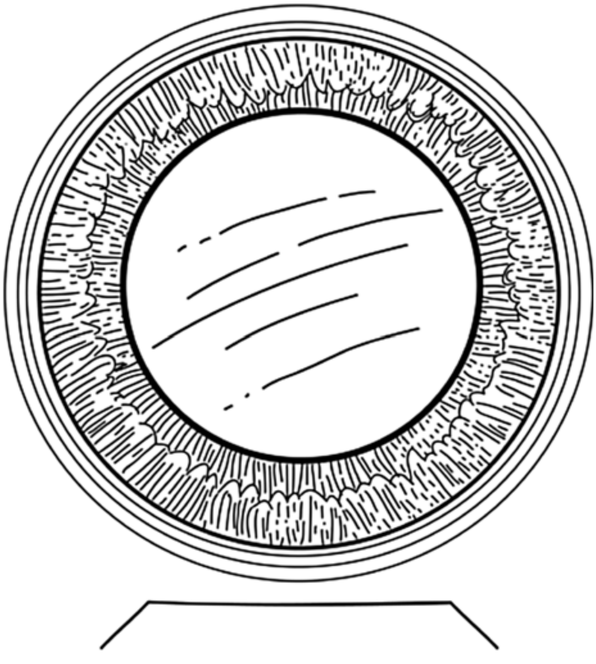


Fig. 16 Inverted batwing incision

However, although both these incisions open the wound better during nucleus delivery, they induce more astigmatism.

Frown/chevron/inverted bat wing:

The common feature shared by these incisions is that their chord length is less than the arc length. Lesser astigmatism is produced because the edges of this incision are further away from the cornea. Therefore, this incision induces the least amount of astigmatism.

Astigmatically Neutral Funnel
The concept of astigmatic funnel arose from two mathematical relationships: first, that corneal astigmatism is directly proportional to the cube of the length of the incision and, second, that it is inversely related to the distance from the limbus.

Location
Usually the convex part of the frown incision is along the posterior limbal line. This corresponds to about 1.5 mm from conjunctival insertion.

Incision Depth
Ideal incision depth should be half to three fourth of the scleral thickness. Also, it should be uniformly deep along its length.

<50 % ⟶ Thin roof/buttonhole during tunneling
50–75 % ⟶ Optimal
>75 % ⟶ Deeper plane/thin floor/premature entry
100 % ⟶ Scleral disinsertion/ciliary prolapse

Sclerocorneal Tunnel Construction

Steps
1. Initiation – Finding the right plane
2. Propagation – Maintaining the achieved right plane and widening the tunnel to desired dimension
3. Keratotomy – Entry into the AC to create a third plane for the valve effect
4. Extension – Extending the inner corneal lip to the desired dimension

Initiation

Once an incision is made, the incision is swept with the tip of the crescent blade (bevel up). This is done so that the incision along its entire length is smooth, non-ragged, and of uniform depth. In the subsequent sweeps, the heel of the blade is slowly lowered such that it rests on the scleral surface. If the heal of the blade is very low from the beginning, there is a possibility of superficial plane/buttonholing

(Fig. 17a, b). If the heel of the blade is very high, then there is a possibility of deeper plane/premature entry during propagation (Fig. 17c, d). The heel of the blade should be just above the scleral surface to get the right plane (Fig. 17e, f).

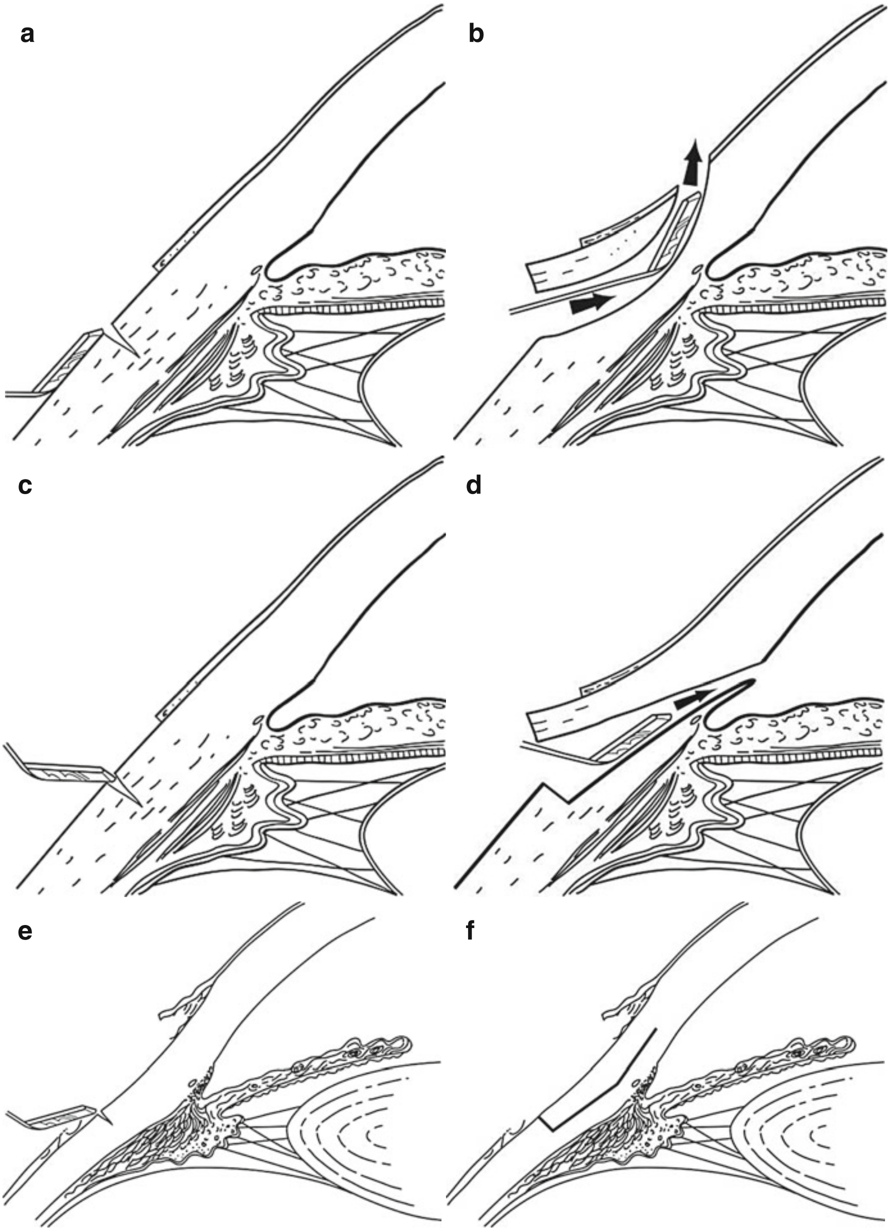


Fig. 17 (**a**, **b**) Heel of the blade very low, causing subsequent buttonholing. (**c**, **d**) Heel of the blade very high, causing subsequent deep plane and premature entry. (**e**, **f**) Heel of the blade is just above the sclera surface to get the correct plane

Propagation

The propagation of the tunnel blade is initially forward with a swiveling movement. Here the depth of the tunnel is judged by the visibility of the blade trans-sclerally. If it is hardly visible, then the plane is too deep. If it is clearly seen, then the tunnel is progressing superficially. The blade should be "moderately seen" which is indicative of a correct plane. Forward movement of the blade is always done by swiveling/pivoting.

These forward movements are directed from the sclera to the limbus to the cornea. During these movements, one should remember the change in the curvature from the relatively less steep sclera to a steeper cornea. Once the limbus is reached, the tip of the blade should be directed higher to match the corneal curvature. Once corneal curvature is matched, then forward swivel of the blade will give us the right plane. The forward propagation causes lamellar separation of the layers. Cutting is done while the blade is withdrawn backward and laterally (swiping).

When the blade is moved laterally, the contour of the globe has to be taken into account (Fig. 18a). The bevel is used to dissect the sclera and lateralize the extent of the tunnel. Lateral swiping movements should always be done in a way that the tilt of the blade is along and equal to the contour of the globe. Inadequate blade tilt while swiping will cause buttonholing while excess of tilt will lead to a deeper plane or an inadvertent premature entry (Fig. 18b).

The dimensions of the created sclera corneal tunnel should correspond to the size of the nucleus to be delivered out. Ideally the length of the tunnel is about 3–3.5 mm and width of the tunnel at its anterior (corneal) extent is 7–8 mm and 6–7 mm at its posterior (scleral) extent.

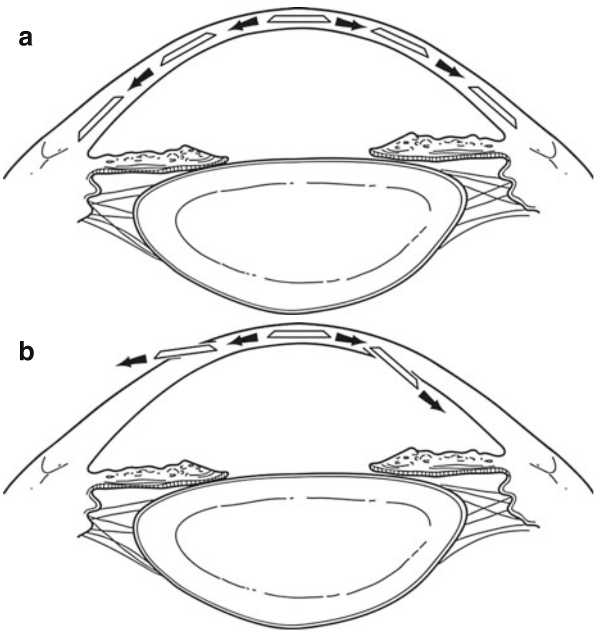


Fig. 18 (**a**) Diagram illustrating maintenance of the tunnel blade along the contour of the globe. (**b**) Tilt of the blade greater than the contour of the globe causing premature entry and tilt of the blade lesser than the contour of the globe causing buttonhole

Keratotomy

Entry into anterior chamber is made with a bevel down keratome by using the dimple-down technique. This third plane gives the tunnel a secure and valved effect. In the dimple-down technique, care is taken to enter the keratome so that the tip reaches the anterior extent of the sclerocorneal tunnel. This is done by pivoting the blade (Fig. 19a, b) rather than directly entering the tunnel. In the learning phase, directing the sharp tip into the tunnel can cause inadvertent premature entry into the floor of the sclerocorneal tunnel. Once the tip reaches the anterior extent of the tunnel, the heel of the keratome is lifted up to make the entry into AC as perpendicular as possible. This ensures the creation of a third plane. The globe has to firm before entry lest it may lead to lamellar entry or Descemet's detachment. This is achieved by filling the AC with viscoelastic substance through the side port. The entry also has to be controlled so that the tip does not injure the iris/anterior capsule.

Extension

Once entry into the AC is achieved, the keratome is kept parallel to the plane of the iris and tunnel extended with forward cutting movement on either sides (in contrast to backward cutting movement with crescent blade). The extension of the

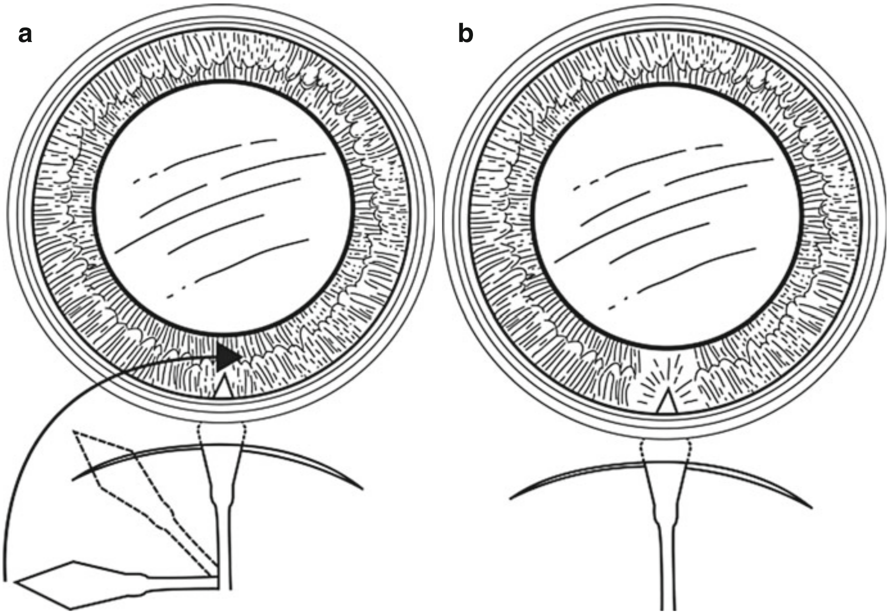


Fig. 19 (**a**) Pivoting of the keratome to reach the anterior extent of the tunnel. (**b**) Dimpling down the tip of the keratome to achieve the third plane

internal lip is done from limbus to limbus. The inner lip thus created should be concentric to the tunnel (Fig. 20a). Alternatively, the inner lip can be made straighter. The idea is to have adequate corneal floor to maintain the integrity of the sutureless tunnel.

Ideal Tunnel (Fig. 20b)

- Location :1.5–2 mm from anterior border of limbus
- Depth : between 1/2 and 3/4 thickness of the sclera
- 1.5 mm internal corneal lip

The wound construction in small incision cataract surgery in the form of a sclerocorneal tunnel should aim to achieve a self-sealed, astigmatically neutral wound. A guarded 0.3 mm diamond or steel knife is the best for making the external groove. Alternatively a knife with 11 number blade can be used. A poorly constructed wound will produce problems and make the surgery more difficult.

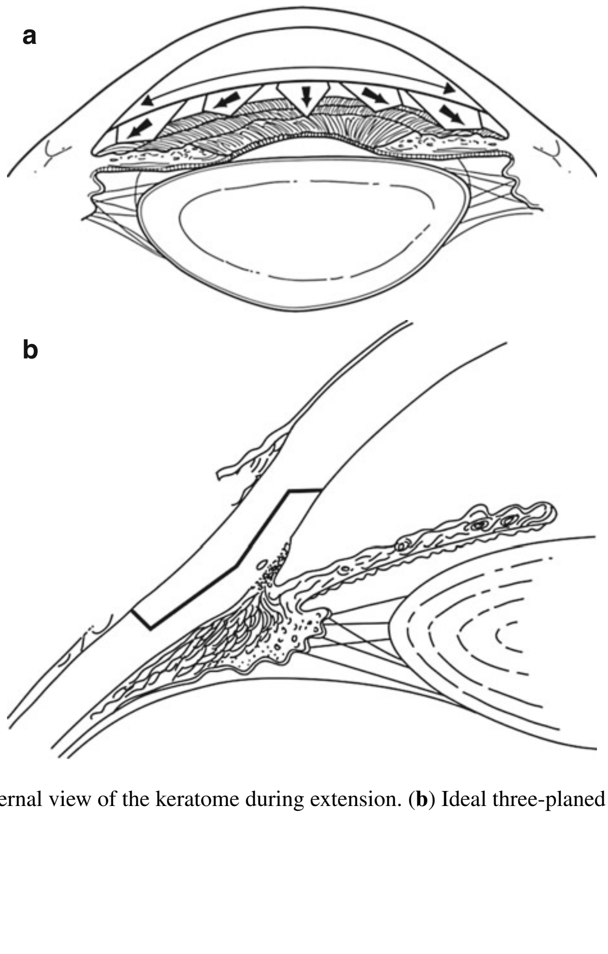


Fig. 20 (**a**) Internal view of the keratome during extension. (**b**) Ideal three-planed tunnel

Complications of Tunnel Construction

Complications related to wound construction can be broadly classified based on the step of procedure involved:

1. External scleral incision
2. Sclerocorneal tunnel
3. Internal corneal incision

Complications Related to External Scleral Incision
The complications that may be encountered are related to:

(a) Wound placement
(b) Incision width
(c) Depth of incision

Wound Placement

The incision should be ideally placed at a distance of 2 mm from the anterior border of the limbus. Although an anteriorly placed incision, closer to the limbus has an advantage of faster surgery with easy maneuverability, it may also cause undesired effects. Anterior incisions usually have poor sealing effect, which is seen as pouting of the external incision at the end of surgery. These incisions are prone for wound leak, which increase the risk of endophthalmitis. Since corneal astigmatism is inversely proportional to the distance of external incision from the limbus, an anterior incision increases surgically induced astigmatism.

Tip: In case of an anteriorly placed incision, the sclerocorneal tunneling should be well extended up to 1.5–2 mm into clear cornea so that optimum incision architecture with wound stability is maintained. In such cases it is preferable to suture the tunnel at the end of surgery.

A posteriorly placed incision increases the risk of premature entry with tunnel bleeding and postoperative hyphema. The sclerocorneal tunnel created is comparatively wider. For novice surgeons, a posterior incision makes instrument manipulation and nucleus delivery difficult.

Incision Width

The width of a scleral tunnel is defined as the distance between the ends of the incision measured along the contour of incision. One needs to plan the incision size based on the size and density of nucleus. A short incision makes nucleus delivery difficult leading to endothelial damage and superior iridodialysis. Usually an external groove of 6.5–7 mm length is made. When the wound is inadequate for the nucleus, the incision is enlarged with a keratome.

In rare instances especially with hard cataracts, in spite of tunnel extension, the necessity to convert to a conventional ECCE arises when the surgeon is not comfortable with the proper technique of nucleus extraction. Conversion involves extending the two ends of the tunnel up to the limbus and then extension along the limbus to the desired length using a corneal scissors. At the end of the procedure, the wound is closed with interrupted sutures. Long incisions induce more astigmatism in direct proportion to the cube of the length of the incision. Also they may have poor approximation inducing wound leak. It is better to suture the tunnel to ensure better wound stability.

Depth of Incision

Depth of the external incision should be controlled and uniform. External incision is the gateway for adequate and efficient scleropocket tunnel dissection. A smooth, well-defined, sharply cut, uniform scleral groove is therefore desirable. The optimal depth for the sclera flap incision is 0.3 mm, i.e., half to one third of the scleral depth. While placing the external incision, one may encounter the following problems:

1. Superficial incision: Usually occurs with novice surgeons who do not have an estimation of the exact depth of a sclerocorneal tunnel. Most surgeons do not have access to guarded diamond or steel knives; hence freehand incisions with routine blades are made. Another better option is to use the bevel of the crescent to make the initial incision followed by regular undermining so that the sclera fibers are properly dissected. This is the most crucial step because further tunneling shall depend on it. Make sure that the eyeball is firm. If it is hypotonic, create a side port and inject viscoelastic before proceeding for the initial incision.
2. Deep incision: A very deep scleral incision may enter the suprachoroidal space, causing problems of scleral disinsertion and premature entry. Scleral disinsertion causes complete separation of the inferior sclera from the superior one. A surgeon may notice exposure of underlying uveal tissue with sudden hypotony and shallowing of anterior chamber. This situation leads to downward shift of the wound. One should never try to proceed with the same incision since the subsequent surgical steps will be cumbersome. The incision needs to be sutured using deep radial bites to secure the edges of incision on either side of scleral groove. A fresh tunnel can be constructed on the temporal side. The wound should be well secured since the chance of postoperative wound leak is high in such cases. Certain conditions like pathological myopia, healed scleritis, trauma, or connective tissue disorders usually have thin sclera. Surgeon should be cautious in such situations.
3. Uneven placement or irregular incision: If the tenon's capsule is not properly dissected from the underlying sclera, the initial depth of incision becomes irregular.

Complications Related to Sclerocorneal Tunnel

The sclerocorneal tunnel is created by gentle forward wriggling and sideward swiping movement of bevel-up crescent blade. It should be uniform in thickness and extend up to 1.5 mm into the clear cornea.

The following complications may occur during tunnel construction:

1. Buttonhole: This usually follows a superficial incision and incorrect superficial blade direction during forward dissection. Blunt crescent blades are also responsible for causing buttonholes. A surgeon may notice a clearly visible blade causing tissue drag with crushing effect rather than cutting. Reexamining the external incision with re-undermining the edges of incision and reentering at a deeper plane from another site will rectify the situation. If the lateral walls of tunnel are torn, then it should be secured with a suture. Blunt crescents also lead to buttonholing because of added resistance during tunnel formation.
2. Premature entry: This is the most common wound-related complication faced by all surgeons in initial stages. Premature entry into anterior chamber lacks the self-sealing corneal valve, which is required for wound integrity. The crescent directly enters the anterior chamber with shallowing of the anterior chamber.

   Premature entry can be due to number of reasons:

   (a) The initial groove may have been too deep, thus leading to deeper plane of dissection.
   (b) Sharp crescent blades resulting in uncontrolled entry.
   (c) Failure to move the crescent in accordance with the curvature of corneal dome.

   If the initial groove is too deep with dissection in deep plane, one can try to move to a more superficial plane. Tip should be pointed toward the ceiling rather than the floor while advancing.

   If premature entry has already occurred, further dissection should be stopped, viscoelastic injected through paracentesis to firm the eyeball and a new tunnel dissected at a superficial plane away from site of premature entry. Premature entry wounds are prone for wound leak, conjunctival bleb, and hyphema in the postoperative period. So all such cases should be sutured at the end of surgery even if the anterior chamber is well formed or the eyeball is firm. Premature entry causes injury to the iris base and may result in iridodialysis, iris chaffing, and subsequent hemorrhage. The dialysis may be further extended during nucleus delivery. Viscoelastic should be injected to push the iris posteriorly, section should be checked for adequate extension, and nucleus should be delivered out carefully without causing further damage. In case of large premature entry with iris prolapse, the section should be closed with radial sutures and surgery can be performed through a new tunnel at different site.
3. Torn edges: This occurs because the surgeon moves the crescent parallel to the floor rather than along the curvature of the eyeball. The problem occurs more frequently when the initial groove is superficial. Holding the lips of external incision for fixing the eye ball also may damage/tear the tunnel.

4. Long tunnel: A posterior scleral incision or an anterior corneal entry may lead to a long tunnel which may be seen in the form of striae during instrumentation within the anterior chamber. The scleral part of tunnel should be around 2 mm and should be extended 1.5 mm into the cornea.

Complications Related to Internal Corneal Incision

An ideal self-sealing incision requires an internal corneal lip of around 1.5 mm. Less than 0.5 mm results in poor wound integrity, hyphema, and filtering blebs. However, corneal lip longer than 1.5 mm creates too much corneal distortion during surgery, poor visualization of sub-incisional cortex, and high astigmatism.

The following complications may occur during AC entry with keratome:

1. Descemet's membrane detachment

   The cut in the Descemet's membrane should be linear in a straight line, which is attained with forward cutting movement of the keratome. Penetration must occur at an angle of 45° with respect to the internal surface of the Descemet's membrane.

   Causes of Descemet's membrane detachment:

   (a) Blunt keratomes, which cause a pull rather than cut in the Descemet
   (b) If the keratome entry in the anterior chamber is beyond the previously created corneal tunnel, thereby needing more force to create the internal valve
   (c) Shallow anterior chamber

       A Descemet's membrane detachment near the section should be recognized early by the surgeon and the aim will be to prevent further extension. Careful instrumentation and manipulation should be done especially during viscoelastic injection and cortex aspiration since the fluid through simcoe cannula can cause lamellar hydrodissection of the cornea. One must be careful not to mistake a Descemet's membrane flap for a tag of anterior capsule.

       A small Descemet's membrane detachment apposes on its own once the eye is hypertensive at the end of surgery after anterior chamber is formed with saline. A full-chamber air bubble introduced through side port in such situations is adequate for Descemet's membrane apposition. However in cases of large Descemet's membrane detachment involving more than one third of the cornea, a full-thickness corneal suture may be useful.

2. Premature entry

   Premature entry into the anterior chamber is one of the common complications made especially by beginning surgeons. This entry may be near the root of the iris which will then prolapse out during further maneuvers. The bevel of keratome is always entered sideways into the scleral tunnel and is then straightened to reach the anterior edge of corneal tunnel. This prevents premature entry. Also forward movement of keratome is recommended while cutting. This ensures the uniform cut in Descemet's membrane and an internal incision parallel to the limbus. Cutting moments while bringing out the keratome may lead to small inner lip with poor sealing effect.

3. Irregular incision: At times the keratome may be introduced in a different plane than the original dissected tunnel, or multiple passages may be created while extending the tunnel on either side, leading to formation of new tracks. So the surgeon should always try to get in right in first attempt and reentry should be avoided. The keratome is advanced horizontally parallel to the iris which leads to linear cut in Descemet's membrane about 0.5–1 mm ahead of the vascular arcade.

Acknowledgments Dr.Sathish Devarajan who has contributed all the diagrams in this chapter.

The Capsular Opening

Jeff H. Pettey, Craig Chaya, and Kimberly Lavin

Introduction

The high rate of complications associated with intracapsular cataract extraction (ICCE) surgery was the impetus for a safer surgical technique. The optimal technique would reduce the size of the incision, minimize corneal trauma, preserve the posterior capsule, and allow for posterior chamber IOL implantation. Thus, in the late 1960s, extracapsular cataract extraction (ECCE) quickly supplanted intracapsular cataract surgery as the dominant cataract surgery technique [1, 2]. In a similar fashion, different anterior capsular opening styles emerged to take advantage of the benefits of ECCE techniques. Each capsular opening technique developed either out of necessity (e.g., limited access to capsular stains, OVDs, etc.) or with refinements in surgical technique.

While successful cataract surgery is the product of sequentially completed steps, the capsular opening is arguably one of the most critical steps of the entire surgery. For this reason, it is also one of the most anxiety-provoking steps of the whole surgery especially for inexperienced surgeons. Respect for the capsular opening is warranted for several reasons. First, the delicate nature of the capsular tissue is less

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forgiving to either errant surgeon maneuvers or unsuspecting patient movement. Secondly, visualization of the anterior capsule in select cases (e.g., white cataract) may be challenging if good microscopes or capsular stains are not available. Finally, a practical understanding of vector forces is vital to creating an appropriately sized capsular opening. This comes mostly with real patient experience but can be mimicked with modern-day computer virtual simulation or artificial capsular models.

In this chapter, we will describe the four main styles of the anterior capsular opening and their related advantages and disadvantages. Though our impression is that each surgeon will choose a preferred technique, we recommend that more than one technique be mastered. This would allow for a surgeon to modify the capsular opening technique based on available equipment/supplies and various patient characteristics.

Basic Principles of the Capsulotomy

Some general principles should guide the creation of the capsulotomy regardless of the technique used. The opening should be large enough to accommodate the lens or lens fragments without causing complications. It should be sufficiently stable to prevent anterior capsular tears from continuing to the posterior capsule. Finally, it should ideally allow 360° of capsule, optic overlap.

For each capsulotomy technique, there is a range of sizes that can be successfully utilized to accomplish the goal of safe removal of the nucleus. Depending on the density and size of the nucleus, an opening of variable size may be used to safely deliver the lens from the capsular bag. It is often difficult to predict the exact size needed to safely and atraumatically deliver the lens. Openings that are too large may not provide adequate overlap with the anterior surface of the optic. Openings that are too small risk iatrogenic zonular dehiscence and/or propagation of anterior capsular tears to the posterior capsule.

Ideally, the capsulotomy opening provides 360° of coverage over the optic, which decreases the likelihood of posterior capsular opacification formation [3]. Another potential benefit of 360° overlap is the decreased incidence of lens tilt and its induced optical aberrations such as coma [4]. Capsulotomy techniques vary in their likelihood of uniform optic anterior capsule contact points and subsequently their optical consistency.

Finally, the capsulotomy design should be such that it minimizes the likelihood of radialized tears. All capsulotomy techniques, outside of the continuous curvilinear capsulorrhexis (CCC), have components of their design made of noncontinuous linear anterior capsule tears. Any capsule tears, with the exception of the completed circle, have the potential of extension, radialization, and propagation to the posterior capsule with its potential complications. However, through careful consideration of the number, orientation, and the angles which tears intersect the zonules, the likelihood of posterior propagation of tears is decreased.

It may seem counterintuitive that multiple tears in a capsulotomy could decrease the likelihood of posterior propagation of tears; however this principle has long been utilized in cataract surgery. One safety benefit of the can opener capsulotomy comes from the multiple tears that allow stresses on the capsule to be shared among the multiple points of weakness. The antithesis example of this concept is seen when a CCC has a single tear, which allows only a single point where forces may be distributed. When a single tear in the anterior capsule is noted, additional relaxing incisions may be placed to allow a shared distribution of forces, decreasing the likelihood that applied forces would induce posterior extension of the capsule tears.

Another important, but less well-known consideration of capsulotomy construction is the angle which a tear intersects the zonules. When a tear reaches the zonules, the likelihood of posterior capsular extension is directly related to the angle the tear engages the zonules. When the angle of engagement is parallel or, in other words, in the same direction the zonules radiate outward, the tear can easily extend between the zonular fibers and continue posteriorly. When the angle of the tear intersects the zonules at angles closer to 90°, it is far less likely a tear can split between the zonules and propagate posteriorly.

Each of the capsulotomy techniques described can be appropriately sized to allow safe removal of the nucleus while providing overlap of the anterior capsule. Their safety results from utilizing either multiple tears to distribute forces, orienting tear direction perpendicular to the zonular orientation, or a combination of both.

Continuous Curvilinear Capsulorrhexis (CCC)

In the 1980s, Gimbel and Neuhann both independently developed the CCC out of a desire for a capsular opening that would facilitate efficient cataract removal and accommodate reliable implantation of modern IOLs [5, 6].

Description of Technique

Using either a cystotome needle or capsulorrhexis forceps, a puncture is made in the central anterior capsule (Fig. 1). This initial puncture is then directed peripherally either in a clockwise or counterclockwise fashion depending on surgeon preference.

Either the tip of the cystotome or a forceps is used to fold over the capsular flap akin to a folded napkin (Fig. 2).

Next, the tear is led in a circular fashion (Fig. 3) to complete the opening (Fig. 4). Control is achieved by grasping about 2 clock hours away from free flap edge closest to the leading fold of the capsule. If possible, avoid grasping the fold itself or very close to the leading edge which could lead to an unpredictable tear path. If using a cystotome to complete the CCC, use enough downward friction force to tear the flap around. Too much downward force could lead to an inadvertent puncture of the underlying capsule and/or cortex. While frequent regrasping of the flap will offer exquisite control, experienced surgeons find that up to 3–4 clock hours can be completed before regrasping the flap.

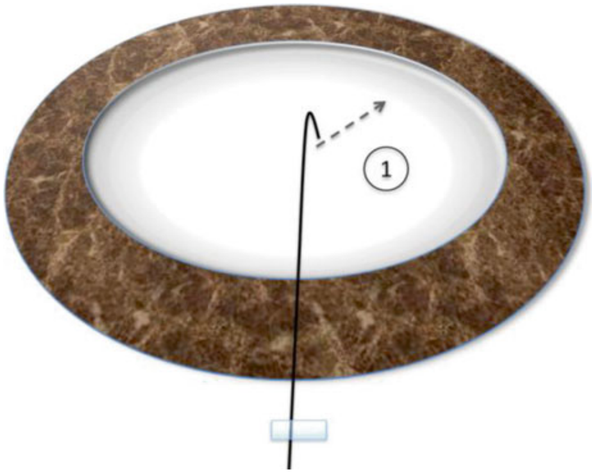

Fig. 1 Initiation of CCC with central puncture

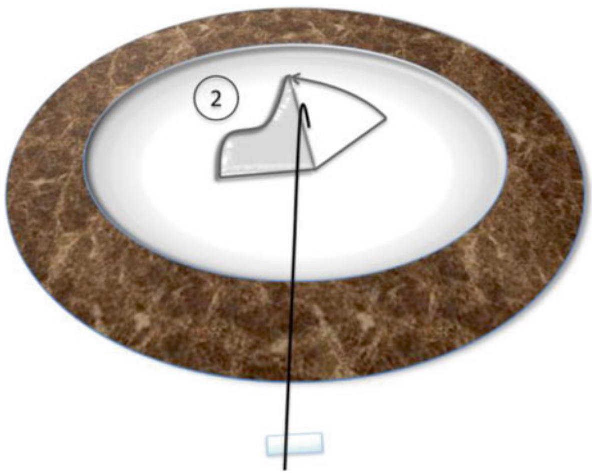

Fig. 2 Turning over the flap

Additionally, an understanding of shearing and ripping vector forces described by Seibel is key to directing the path of the tear [7]. In short, a shearing force is applied in the direction of the tear which requires less force. In contrast, a ripping force is applied more centrally to the direction of the tear which offers less control but can redirect the path of a straying tear.

Advantages of the CCC

- Resists anterior capsular radial tears which could lead to posterior capsular rupture (PCR).
- Allows for safe hydrodissection and in-the-bag lens rotation.

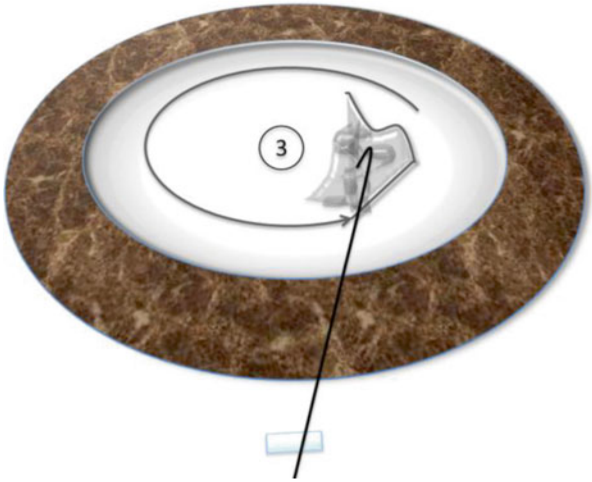

Fig. 3 Leading the tear around

Fig. 4 The completed CCC with PCIOL

- Permits easier cortical clean up without concerns for aspiration of anterior capsular tags.
- Tolerates meticulous anterior capsular polishing of lens epithelial cells.
- Can be sized appropriately depending on the size of the lens.
- Promotes stability and centration of the IOL.
- Continuous overlap of the anterior capsular over the optic may help to reduce formation of posterior capsular opacification (PCO).
- In the event of PCR, it allows for sulcus IOL implantation with optional optic capture.

Disadvantages of the CCC

- It takes more experience to adequately master.
- A small CCC can preclude safe prolapse of the lens into the anterior chamber.

- An overly large CCC may promote IOL dislocation from the capsular bag.
- Excellent visualization of the anterior capsule is required and may not be possible without capsular stains.

Instrumentation

- Bent cystotome needle – can be used either through a paracentesis or main scleral tunnel incision.
- Capsulorrhexis forceps – some unique designs are available with longer shafts for scleral use or micro designs to be used through a paracentesis.
- Capsular stains should be available during cases with poor red reflex or used after puncture of the capsule to visualize the tear (e.g., when cortical material fluffs up and obscures the view).
- The CCC can be performed with either a cystotome or forceps, while the AC is stabilized with viscoelastic or using a cystotome with a fluid handle connected to continuous irrigation fluid.

Unique Complications

- If a tear radializes beyond rescue, another tear from the opposite direction can be led around to complete the capsular opening. At this point, the surgeon should assume that an anterior capsular rent is at risk of extending to the zonules and care should be taken during hydrodissection and lens delivery.

Can Opener

The can opener capsulotomy was widely used during the era of cataract surgery when large incision extracapsular cataract surgery was in vogue. In the 1980s, a transition from the can opener to the CCC occurred as the risk of anterior capsule run outs was decreased with the use of the CCC [8].

Description of Technique

The can opener capsulotomy and its variations such as the postage stamp capsulotomy are made by connecting individual breaks, or tears, in the anterior capsule. The eye should be fixated with either a toothed .12 mm forceps or via other fixation techniques that do not exert undue pressure on the globe or distort the cornea. The tears may be created with a needle, bent cystotome, or other sharp instrument. In Fig. 5, an initial puncture with a subsequent pulling motion to enlarge the initial puncture is displayed.

The initial direction of the pulling motion can be toward the center or more tangential in the direction of the subsequent capsule puncture to the left or right. In Fig. 6, the can opener is continued to the right, and the subsequent puncture is connected to the initial puncture. The surgeon should connect each puncture with the previous puncture, which can be done by sweeping the instrument in the direction of the previous tear.

Subsequent punctures are made in a circumferential manner connecting each puncture. Figures 7 and 8 show this continuous circumferential tearing. Note the size of the capsule tears is exaggerated in the figures for illustrative purposes (Fig. 9). The number of punctures in a can opener capsulotomy can vary widely depending on the technique; however, many feel larger numbers of tears may decrease the risk of radial extension of the capsulotomy. Generally 10–15 tears per quadrant are recommended.

Advantages of the Can Opener Capsulotomy

- Although a learning curve is present, the can opener is considered to be technically easier to master than CCC.
- Allows for some hydrodissection and in-the-bag lens rotation.
- Tolerates some anterior capsular polishing of lens epithelial cells.
- Can be sized appropriately depending on the size of the lens.
- The high number of tears in the anterior capsule allows a sharing of forces reducing the risk of a single tear radialization.

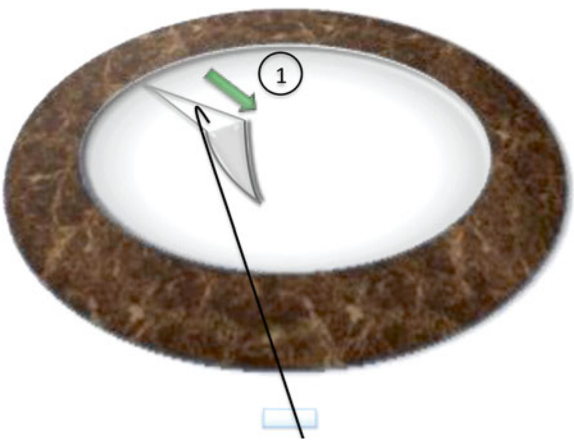

Fig. 5 Initial puncture into capsule with cystotome

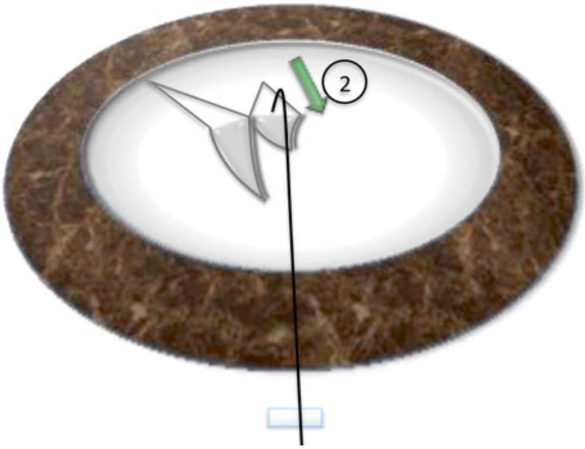

Fig. 6 Subsequent capsule puncture adjacent to initial tear

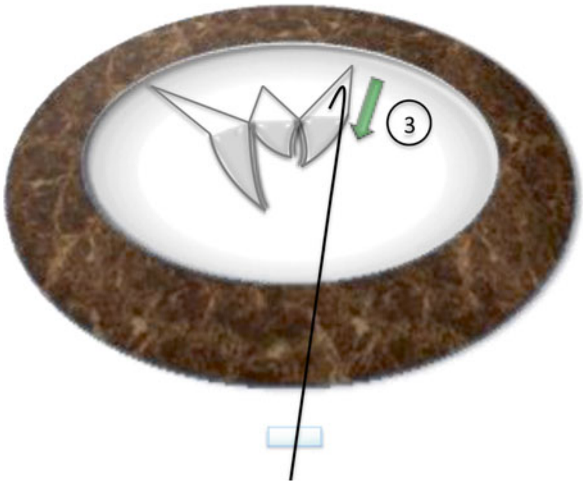

Fig. 7 Connecting each puncture with previous

Disadvantages of the Can Opener Capsulotomy

- Risk of radialization is always present at each subsequent step of surgery, particularly during hydrodissection and delivery of lens.
- Cortical clean up risks aspiration of capsule tags.
- Time consuming compared to other techniques.
- Generally does not allow complete overlap of the optic while accommodating lens delivery.
- Anterior capsule polishing is limited.
- Very limited opportunity for optic capture with sulcus lens placement.
- Some visualization of the anterior capsule is required and may not be possible without capsular stains.

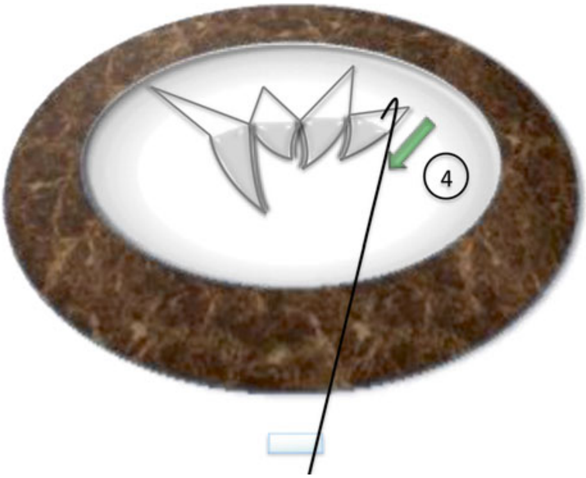

Fig. 8 Connecting punctures in a circumferential manner

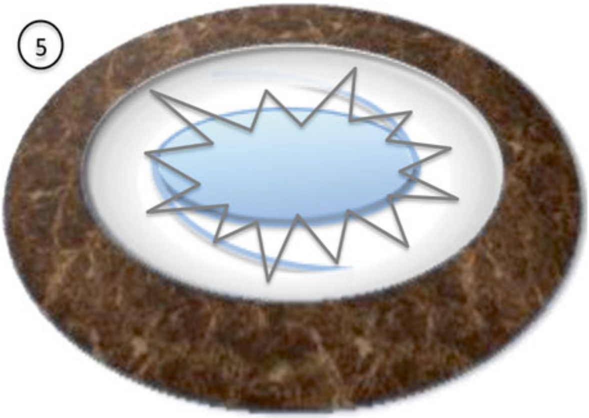

Fig. 9 Completed can opener capsulotomy. Note the size of the individual punctures is exaggerated for illustrative purposes

Instrumentation

- Bent cystotome needle – can be used either through a paracentesis or main scleral tunnel incision.
- Straight needle or other sharp instrument may be used; however, cystotome is generally preferred.
- Capsular stains should ideally be available during cases with poor red reflex or when milky cortical material may obscure the capsule tears.
- Viscoelastic to stabilize the anterior chamber. Alternatively, infusion of BSS via a Simcoe cannula or anterior chamber maintainer may be used to stabilize the chamber; however, the additional fluidics can interfere with the technique.

Unique Complications

- Like all other non-CCC techniques, the can opener is at risk for anterior capsule radialization. Additionally cortical removal is challenging, as the capsule tags are difficult to differentiate from cortical fibers.

V-Shaped Capsulotomy

Ruit et al. have been instrumental in demonstrating how cost-effective MSCIS can be performed in challenging conditions and with limited resources. One innovation born out of their work has been the V-shaped capsulotomy [9].

Description of the Technique

Essentially, a straight needle is used to connect two linear incisions in a triangular fashion with the apex pointing toward the surgeon and the base of the triangle facing away from the surgeon.

First, a straight needle connected to a fluid-filled syringe is passed through the base of the midway point of the sclerocorneal tunnel entering just past the vascular arcades (Fig. 10). Of note, entering at the apex of the tunnel will lead to corneal striae and poor visualization of the sub-incisional area. Entering at the beginning of the clear cornea will provide the best maneuverability and view.

Once the needle is safely in the anterior chamber, it is rotated with the sharp bevel of the needle on its side and advance diagonally across the capsule to one direction (Fig. 10). The sharp tip of the needle is used to pierce the capsule approximately 3 mm away from the center of the capsule. Using short chopping strokes, a straight line is scored toward the sclerocorneal tunnel ending approximately 3 mm away from the center of the capsule. Avoid a sawing motion which can lead to uncontrolled tears and radialization of tears.

Next, the second linear incision is created in a similar fashion from the other side, which will connect the two incisions at the apex of the V shape (Fig. 11). In the event that the incisions are obscured by lens material, injecting irrigation fluid through the needle or aspirating material can be used to clear the view.

Next, the apex of the flap is lifted with the needle and gently directed away from the surgeon toward the base of the triangular flap (Fig. 12). Up until the IOL implantation, the flap will be folded over at the base.

Folding the flap over at the base provides a landmark to ensure correct implantation of the leading haptic into the capsular bag. After both haptics have been delivered into the capsular bag, the base of the flap can amputated to complete the capsulotomy (Fig. 13).

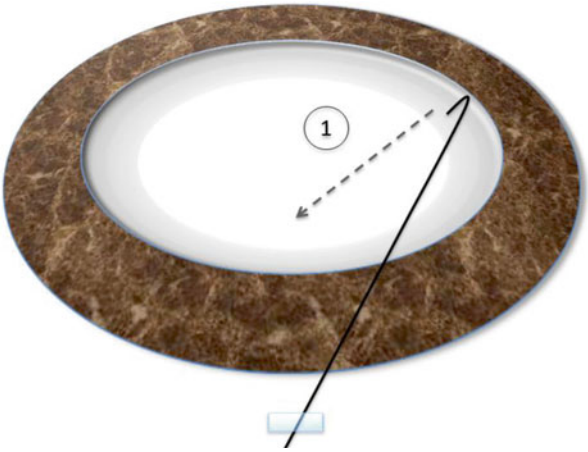

Fig. 10 The first linear incision is created and drawn toward the surgeon

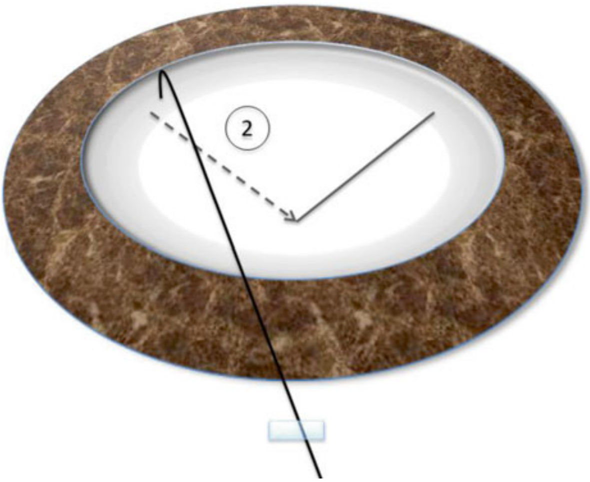

Fig. 11 The second linear incision is created connecting with the first linear line at the apex (pointing toward the surgeon)

This is achieved by using a capsulotomy scissor to initiate a cut at the base of the flap on one side. The flap can either be torn with capsulotomy forceps or by employing the suction grip of a Simcoe I/A tip.

Advantages of the V-Shaped Capsulotomy

- Easier to learn.
- Can be used when visualization is poor or capsular stains are not available.
- Can accommodate large cataracts allowing the points of the triangular opening to function as release valves.
- Requires minimal equipment.

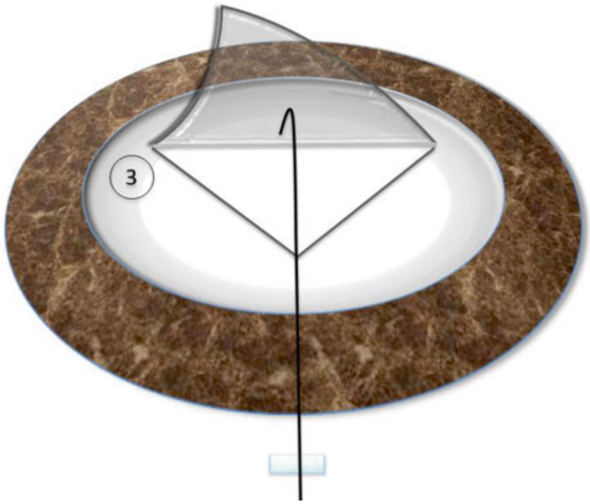

Fig. 12 The apex of the triangular flap is lifted and advanced toward the base of the flap

Fig. 13 The base of the triangular flap is amputated after the IOL implantation

- Can be performed with a sharp needle only or capsulotomy scissors for a more controlled and complete cut. Note however that the opening of the sclerocorneal tunnel is required before inserting scissors. On the other hand, using a sharp needle only allows maximum chamber stability before the sclerocorneal incision is opened.

Disadvantages of the V-Shaped Capsulotomy

- The straight needle can be difficult to maneuver in patients with deep set brows.
- Discontinuous incisions because of inconsistent chopping can lead to inadvertent tears.

Instrumentation

- 27 g straight needle
- 2 or 3 ml syringe filled with irrigation fluid
- Capsulotomy or long shafted iris scissors for cutting the base of the flap and creating more controlled incisions

Unique Complications

- Occasionally the flap may find itself in the capsular bag, or it may be captured by the IOL haptic. In either case, care should be taken to identify an edge of the flap to fold the flap back over toward the iris.
- If a small triangular opening is created, it is more difficult to enlarge a V-shaped capsulotomy. Capsulotomy scissors may be able to enlarge the opening outside the boundaries of the original incisions, or relaxing incisions may need to be performed along the incisions to avoid large capsular rents when prolapsing large cataracts.

Envelope or Linear Capsulotomy

Reportedly suggested by Sourdilla and Baikuff in 1979 [10], the linear capsulotomy is a commonly used capsulotomy technique. The technique, popularized by Galand, is a simple technique through which the lens may be delivered directly from the capsular bag into the main wound. All other discussed techniques require delivering the lens into the anterior chamber prior to delivery into the wound.

Description of Technique

The envelope capsulotomy involves making a horizontal, linear capsule opening on the proximal portion of the capsule (Fig. 14). The opening can be made through the unopened scleral tunnel with a cystotome or straight needle. Alternatively, the opening can be created after the tunnel is opened using the same instruments or with the keratome itself. The capsule is incised with the instrument, and then the opening is extended laterally using the sharp edge of the instrument.

The nucleus may be rotated and mobilized within the capsular bag as the cystotome, Simcoe, or other instrument engages the lens within the capsular bag. It is important to reiterate the lens remains in the capsular bag until delivery of the lens into the main

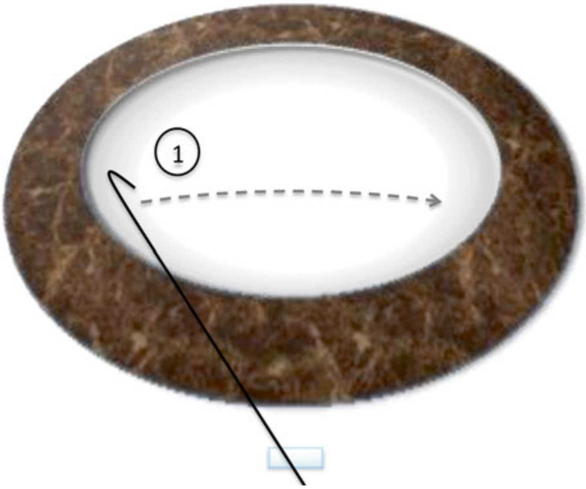

Fig. 14 Initial incision and lateral extension of the opening

wound and out of the eye. Although it may be possible to deliver the nucleus into the anterior chamber prior to removal from the eye, a large amount of stress is placed on the lateral margins of the envelope as the lens is elevated into the anterior chamber.

After lens removal, cortical clean up is undertaken and the lens is inserted. The roof of the capsule overlying the lens must be removed to avoid opacification of the anterior capsule and obstruction of the visual axis. Two cuts are made at the lateral margins of the envelope opening with a cystotome or Vannas scissor as in Fig. 15.

After the lateral incisions are made, one corner is engaged with the aspiration port of a Simcoe cannula, and the anterior capsule is torn in the same manner as a CCC (Fig. 16). The tear is made and eventually connected to the other edge of the capsulotomy forming a horseshoe-shaped opening as shown in Fig. 17. Alternatively, the edge may be engaged with Utrata forceps or a cystotome.

Advantages of the Linear-Shaped Capsulotomy

- Simple construction
- Efficient
- Better for poor visualization or when capsular stains are not available
- Can accommodate very large cataracts
- Requires minimal equipment

Disadvantages of the Linear-Shaped Capsulotomy

- Laterally oriented incisions at risk for anterior capsule tear out
- Incomplete optic overlap
- Delivery of nucleus directly from bag exposes posterior capsule to risk of rupture

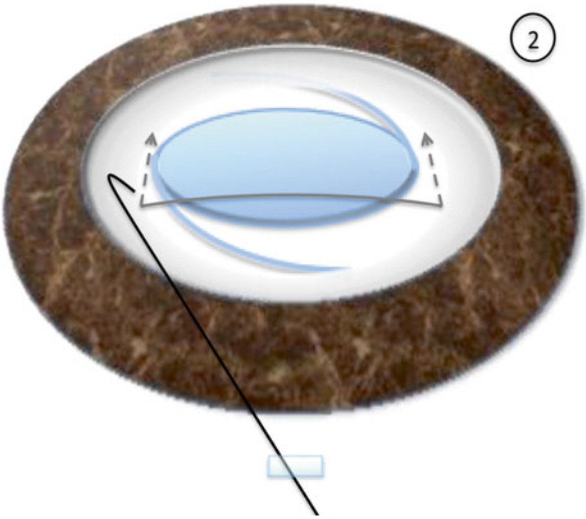

Fig. 15 Lateral cuts are made at the margins of the linear opening to facilitate removal of anterior capsule

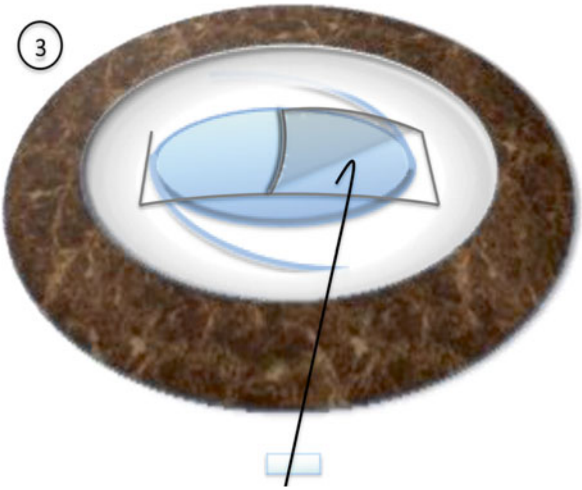

Fig. 16 The lateral edge of the capsulotomy is engaged with the Simcoe cannula, a cystotome, or Utrata forceps

Instrumentation

- Opening can be created with keratome, cystotome, or straight needle
- Vannas scissor, long shafted iris scissor, or cystotome for lateral cuts
- Simcoe cannula, cystotome, or Utrata forceps to complete anterior capsule tear and removal

Fig. 17 A continuous tear is made circumferentially to the tear at the lateral margin of the linear opening forming a horseshoe opening

Unique Complications

- Delivery of the nucleus directly from the capsular bag requires a Simcoe, fish-hook, or other instruments to be placed beneath the lens for delivery to the wound. This places the posterior capsule at risk for rupture during this step.
- The two lateral cuts can extent posteriorly, particularly if the opening is made close to the center of the lens, rather than proximal toward the wound.
- During removal of the anterior capsule, the tear is susceptible to anterior capsule run out as is the case with CCC.

Summary

Though there exist a variety of capsulotomy styles, an ideal capsulotomy should have several key features. First, the capsulotomy opening should be able to withstand the hydraulic stress of cataract surgery. Next, it should facilitate the safe delivery of the nucleus from the capsule. Finally, it should ideally allow for in-the-bag IOL implantation but permit safe sulcus IOL insertion in the event of posterior capsular rupture. Depending on the available equipment and unique patient characteristics, a surgeon may find more than one style of capsulotomy to be valuable.

References

1. Skuta GL, Cantor LB, Cioffi GA, et al., editors. American academy of ophthalmology basic clinical science course: lens and cataract, vol. 11. San Francisco: American Academy of Ophthalmology; 2013. p. 489–96.
2. Jampel RS. The four eras in the evolution of cataract surgery. In: Kelman C, Kwitko M, editors. The history of modern cataract surgery [e-book]. Hague: Kugler Publications; 1998. p. 31–3.

3. Aykan U, Bilge AH, Karadayi K, Akin T. The effect of capsulorrhexis size on development of posterior capsule opacification: small (4.5 to 5mm) versus large (6.0 to 7.0mm). Eur J Ophthalmol. 2003;13(6):541–5.
4. Mihaltz K, Knorz MC, Alio JL, Takacs A, Kranitz K, Kovacs I, Nagy ZZ. Internal aberrations and optical quality after femtosecond laser anterior capsulotomy in cataract surgery. J Refract Surg. 2011;27(10):711–6.
5. Gimbel HV, Neuhann T. Development, advantages, and methods of the continuous circular capsulorrhexis technique. J Cataract Refract Surg. 1990;16:31–7.
6. Gimbel HV, Neuhann T. Continuous curvilinear capsulorrhexis. J Cataract Refract Surg. 1991;17:110–1.
7. Seibel BS. Physics of capsulorrhexis. In: Seibel BS, editor. Phacodynamics : mastering the tools and techniques of phacoemulsification surgery. 4th ed. Thorafare: SLACK Inc; 2005. p. 315–39.
8. Assia EI, Apple DJ, Barden A, Tsai JC, Castaneda VE, Hoggatt JS. An experimental study comparing various anterior capsulectomy techniques. Arch Ophthalmol. 1991;109(5):642–7.
9. Sanduk Ruit, Geoffrey Tabin, Reeta Gurung, Govinda Paudyal, and Michael Feilmeier. Fred Hollows Foundation Australia, Himalayan Cataract Project USA. Standard operating procedure manual for: modern small incision cataract surgery (SICS) (NON-PHACO). Tilganga Institute of Ophthalmology, Kathmandu, Nepal 2006.
10. Basti S, Vasavada A, Thomas R, Padhmanabhan P. Extracapsular cataract surgery: surgical techniques. Indian J Ophthalmol. 1993;41(4):195–210.

Hydrodissection

Priya Narang and Amar Agarwal

Introduction

The term "hydrodissection" was coined by Faust [1] in 1984, and it was described as an injection of fluid designed to separate the lens nucleus from cortex during planned extracapsular cataract extraction surgery. Cortical cleaving hydrodissection [2] was first defined by Howard Fine in 1992, and he concluded that a fluid wave can be injected just under the anterior capsule in such a way that it separates the cortex from the capsule. In addition to permitting endonuclear rotation, it also facilitates epinuclear and cortical cleanup by loosening their adhesion to the capsule.

Technique

Prior to beginning hydrodissection, the posterior lip of the main incision is compressed so as to remove a small amount of viscoelastic from the eye. This is a step forward towards creating a space for the fluid wave to make its way in the eye while performing hydrodissection. Failure to do so may often lead to overinflation of the

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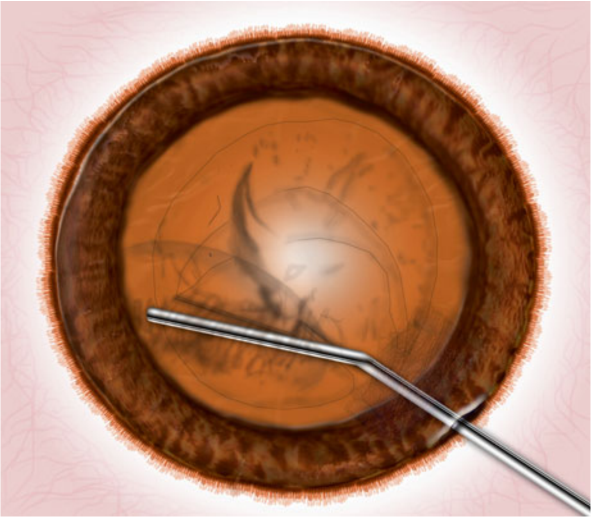

Fig. 1 The hydrodissection cannula is placed beneath the margin of anterior capsule and fluid is injected. Initiation of the fluid wave is seen

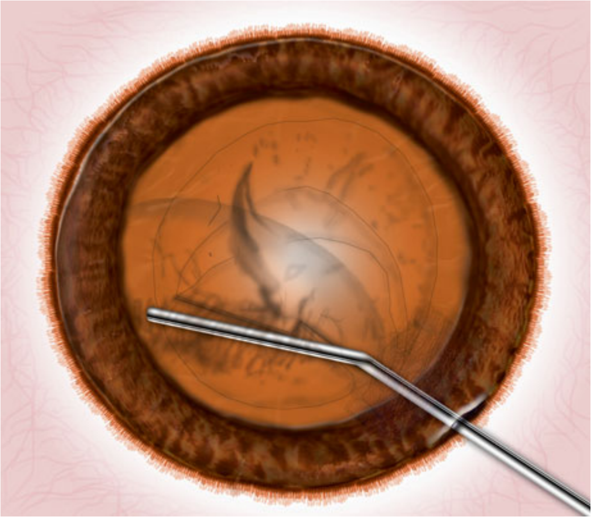

Fig. 2 Fluid wave progresses and reaches the posterior pole of the nucleus

eye with fluid and may often eventually lead to increased pressure and a posterior capsule rupture.

Following completion of capsulorhexis, the rhexis margin edge is lifted with the tip of the cannula which is then inserted beneath the edge of the capsule. Fluid is injected gently (Figs. 1 and 2) which is seen passing circumferentially along the capsule. This ensures that adequate cleavage is achieved between the capsule and the adjoining cortex. As the fluid wave passes along the posterior aspect of the lens (Figs. 3 and 4), entrapment of the fluid occurs between the capsule and the lens. If fluid injection is continued, then the fluid crosses the entire posterior aspect of the

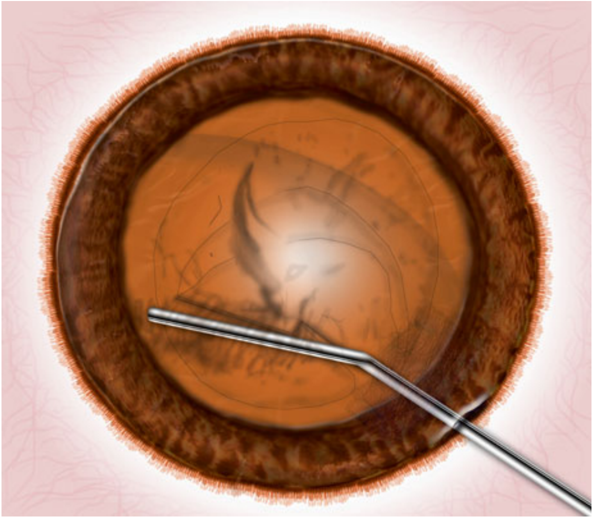

Fig. 3 Fluid wave advances further

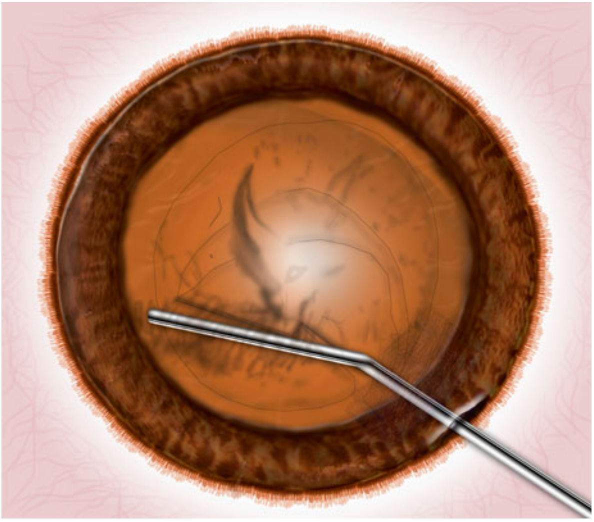

Fig. 4 Fluid wave is about to cross the posterior plane of the lens and reach the equator

lens, and it emanates from all around the margin of rhexis. This leads to prolapse of the lens into the anterior chamber which is a desirable situation for small incision cataract surgery and in supracapsular phacoemulsification. The flat portion of the cannula can be used to decompress the lens complex, forcing posteriorly entrapped fluid to come around the equator of the lens and rupture cortical/capsular connection. Once adequate cortical dissection has been achieved, fluid injection is continued without decompressing the bag, until one part of the equator of nucleus is forced out of the capsular bag. The purpose of continued injection of fluid is to increase the hydrostatic pressure within the bag to pop out the nucleus and is an essential part of manual small incision cataract surgery (MICS).

Successful hydrodissection will be evident through visualization of a propagating posterior wave. If a wave is not evident after continuous irrigation for a brief period, stop injecting, and redirect the cannula to a new position for a repeat attempt.

Discussion

If properly executed, hydrodissection is a simple, safe, and an inexpensive method of optimizing the surgical outcome in a routine cataract surgery. After the injection of fluid beneath the anterior capsule, the capsule is decompressed by pressing the central portion of the lens with the shaft of the cannula. This forces the fluid to come around the lens equator from behind and break the cortical/capsular connections in the capsular fornix and under the anterior capsular flap [2, 3]. The cleavage of cortex from the capsule allows fluid to exit from the capsular bag via the capsulorhexis and mobilize the lens in such a way that it can spin freely within the capsular bag [2, 3].

Safe hydrodissection can be achieved by injecting the fluid slowly and decompressing the nucleus after each wave. Apart from this, CCH also helps to control the incidence of posterior capsule opacification (PCO). The shearing effect of the fluid wave created during procedure is believed to be helpful in removing lens epithelial cells (LECs), reducing the incidence of PCO [4–10]. In a study, conducted on human cadaver eyes [9], it was confirmed that this force detaches equatorial LECs from the adjacent equatorial capsule, allowing their easy removal from the eye.

Depending upon the surgeons' choice, a single-site hydrodissection or a multiple-quadrant hydrodissection can be performed, although the latter is considered to be more effective in obtaining a maximum fluid shear effect [11–13]. Multiple-quadrant hydrodissection also helps break cortical/capsular adhesions, which are commonly associated with senile cataract in the developing world. Some surgeons prefer doing hydrodissection from the paracentesis opening. This can increase pressure buildup within the eye, which can lead to posterior capsule "blowout" or iris prolapse [12]. If the hydro procedures are being carried out through the side port, it is absolutely necessary to use the minimum fluid possible so that integrity of the posterior capsule is maintained. These procedures may be carried out with the anterior chamber maintainer in the on or off position. Certain conditions like high myopes, vitrectomized eyes, traumatic cataract, pseudoexfoliation, posterior lenticonus, and complicated cataracts require undue care during hydro procedures as they are especially prone to develop complications if hydro procedures are not carried out with due precautions.

Various types of cannula are available for performing hydrodissection. They vary from round tip to flat tip. A flat tip cannula allows easy access under the capsule and minimizes fluid egress from the anterior capsular lip as well. It is essential to maintain the flat portion of the cannula parallel with the anterior capsule. The tip of the cannula should be extended peripherally to allow for adequate anterior capsular coverage, ensuring proper posterior delivery of fluid. J-shaped cannula are also available for injection at the subincision site. Also, a cannula with a long shaft facilitates the reach of the cannula at the distal capsulorhexis margin.

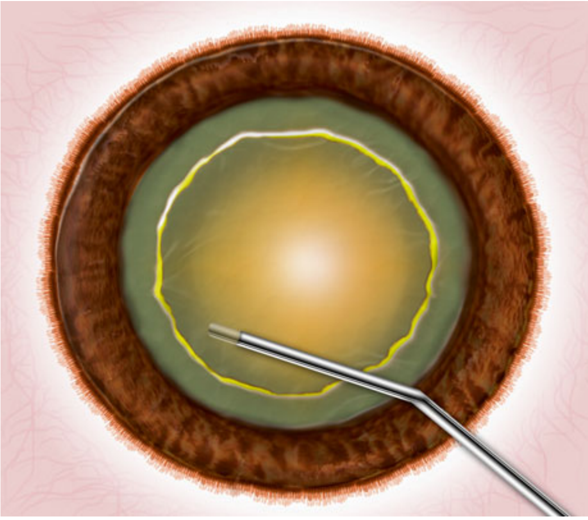

Fig. 5 Hydrodelineation is performed in a case of posterior polar cataract and the "golden ring" is visible

Complicated Scenario

Special precautions are necessary while handling posterior polar cataracts as they are often associated with weakness of the posterior capsule. Hydrodissection is contraindicated in such a scenario [14, 15], and hydrodelineation (Fig. 5) is recommended to preserve an epinuclear cushion to work on. Brunescent cataracts require specific precaution because the nucleus occupies the entire crystalline lens. Multiple-quadrant hydrodissection with minimal amount of fluid should be done in such cases.

Capsular block syndrome is a condition which can arise due to uninhibited injection of fluid during hydro dissection procedure where an excessive forward lens bulge blocks the anterior capsular opening and traps fluid in the capsular bag [16]. In extreme cases, it can lead to posterior capsular rupture. Intraoperative anterior capsular block can be recognized by the forward bulge of the lens, prominence of the capsulorhexis margin, and shallowing of the anterior chamber that are not relieved by attempted lens decompression. The blockage at the anterior capsule does not allow fluid to egress, and in such a scenario, frequent attempted rotation could damage the zonular integrity. When such a condition arises during MICS, few peripheral nicks can be given onto the capsulorhexis margin. This helps to relieve the pressure buildup and in the capsular bag which is followed by deepening of the chamber and backward movement of the lens.

Tips

- Always perform multiple-quadrant hydrodissection.
- Place the cannula beneath the edge of anterior capsule after tenting it up and slowly inject fluid in a well-controlled manner.

- Repeat hydrodissection, in cases of nonvisualization of the fluid wave or in cases of inadequate nucleus rotation.
- Avoid hydrodissection in cases of posterior polar cataract and in cases of brunescent and dense cataract as they might be associated with inherent weakness in the posterior capsule.
- To avoid capsular block syndrome, the amount of fluid injection must be titrated and the anterior chamber must not be overfilled with viscoelastics. In dense, bulky nuclei, having too much space in the capsular bag must be avoided; therefore, gentle hydrodissection is preferred.

To conclude, accomplishment of a proper hydrodissection reduces the risk of posterior capsular rupture, and cleaving the cortical attachments reduces the rate of posterior capsule opacification. Consistent results can be achieved repeatedly by optimizing the technique and instrumentation.

References

1. Faust KJ. Hydrodissection of soft nuclei. J Am Intraocul Implant Soc. 1984;10:75–7.
2. Fine IH. Cortical cleaving hydrodissection. J Cataract Refract Surg. 1992;18:508–12.
3. Fine IH. Cortical cleaving hydrodissection. (letter). J Cataract Refract Surg. 2000;26:943–4.
4. Apple DJ, Peng Q, Visessook N, et al. Eradication ofposterior capsule opacification; documentation of a marked decrease in Nd: YAG laser posterior capsulotomy rates noted in an analysis of 5416 pseudophakic human eyes obtained post-mortem. Ophthalmology. 2001;108:505–18.
5. Apple DJ, Solomon KD, Tetz MR, et al. Posterior capsule opacification. Surv Ophthalmol. 1992;37:73–116.
6. Nishi O. Posterior capsule opacification: Part 1: experimental investigations. J Cataract Refract Surg. 1999;25:106–17.
7. Tetz MR, Nimsgern C. Posterior capsule opacification: Part 2: clinical findings. J Cataract Refract Surg. 1999;25:1662–74.
8. Apple DJ, Peng Q, Visessook N, et al. Surgical preventionof posterior capsule opacification: Part 1: progress in eliminating this complication of cataract surgery. J Cataract Refract Surg. 2000;26:180–7.
9. Peng Q, Apple DJ, Visessook N, et al. Surgical preventionof posterior capsule opacification: Part 2: enhancement of cortical cleanup by focusing on hydrodissection. J Cataract Refract Surg. 2000;26:188–97.
10. Peng Q, Visessook N, Apple DJ, et al. Surgical preventionof posterior capsule opacification. Part 3: intraocularlens optic barrier effect as a second line of defence. J Cataract Refract Surg. 2000;26:198–213.
11. Hurvitz LM. Posterior capsular rupture at hydrodissection. (letter). J Cataract Refract Surg. 1991;17:866.
12. Koch DD, Liu JF. Multilamellar hydrodissection in phacoemulsification and planned extracapsular surgery. J Cataract Refract Surg. 1990;16:559–62.
13. Gimbel HV. Hydrodissection and hydrodelineation. Int Ophthalmol Clin. 1994;34(2):73–90.
14. Vasavada A, Singh R. Phacoemulsification in eyes with posterior polar cataracts. J Cataract Refract Surg. 1999;25:238–45.
15. Osher RH, Yu BC-Y, Koch DD. Posterior polar cataracts: a predisposition to intraoperative posterior capsule rupture. J Cataract Refract Surg. 1999;25:157–62.
16. Miyake K, Ota I, Ichihashi S, Miyake S, Tanaka Y, Terasaki H. New classification of capsular block syndrome. J Cataract Refract Surg. 1998;24(9):1230–4.

Lens Delivery

K.V. Satyamurthy and Arup Chakrabarti

Introduction

The main objective of modern cataract surgery is to achieve good unaided vision with early visual rehabilitation and minimal morbidity. One of the means of achieving this objective is by reducing the incision size. Over the years cataract surgery has evolved through progressively decreasing incision size from 10 to 12 mm of extracapsular cataract extraction (ECCE) to 4.0–6.0 mm of small incision cataract surgery (SICS) and to 2.2 mm of phacoemulsification. Though instant visual recovery with least astigmatism is possible with phacoemulsification, the cost of equipment and consumables has made this procedure less affordable to some surgeons and patients in many parts of the developing world. Good result comparable to what can be achieved with phacoemulsification is possible with manual small incision cataract surgery (MSICS). The crux of the surgery is nucleus management and this determines the size of the incision. This chapter deals with various methods of prolapsing the nucleus into the anterior chamber and extraction of the nucleus out of the eye with various types of instrumentation. The problems associated with each technique and the tips and pearls to overcome these problems are also discussed.

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Nucleus delivery involves two steps:

1. Prolapsing nucleus into anterior chamber
2. Nucleus delivery through scleral tunnel

Since nucleus delivery necessitates a lot of manipulation within the anterior chamber, copious amounts of ophthalmic viscosurgical devices (OVD) should be used to protect the corneal endothelium. It has been the standard practice to employ hydroxypropyl methylcellulose (HPMC) 2 % which is a low-viscosity dispersive OVD that is readily available in the developing world.

Nucleus Prolapse (Luxation) into Anterior Chamber (AC)

The first step in the nucleus management is to prolapse the nucleus from the capsular bag into AC. After thorough hydrodissection, the nucleus can be prolapsed into AC by the following methods:

1. Hydroprolapse
2. Viscoprolapse
3. Prolapse with Sinskey hook: single hook method/bimanual method
4. Prolapsing nucleus in special situations

The prerequisite for nucleus luxation into AC is adequate capsulorrhexis, the size of which depends on the density of the nucleus. It may not be possible to prolapse all kinds of nucleus employing one technique. The technique that can be employed in a given case depends upon the type of cataract, the size of nucleus, the zonular integrity, the size of the pupil and the depth of the AC. A brief description of various nucleus-prolapsing techniques that can be adopted based on the various variables mentioned above is as follows:

Hydroprolapse

Instruments: 25 G hydrodissection cannula and Sinskey hook

After performing an adequate-sized capsulorrhexis (5.5 mm) and hydrodissection, the hydrodissection cannula (25 G) is passed under the anterior capsule perpendicular to the capsulorrhexis margin, and a bolus of fluid is injected (forceful hydrodissection). This lifts up the pole of the nucleus on the opposite side out of the capsular bag (Fig. 1). Once one pole of the nucleus is manoeuvred out of the bag, the remaining part of the nucleus can be prolapsed into AC by rotating the nucleus (cartwheeling) anteriorly and out of the bag. The nucleus may be tyre levered out of the bag using the same cannula or a Sinskey hook (under adequate OVD cover). The advantage of this procedure is the ease with which it can be done. This is ideal for prolapsing soft nucleus which cannot be easily prolapsed with a Sinskey hook. The main disadvantage is that it requires a large-sized capsulorrhexis. The same technique can be employed for prolapsing any type of nucleus. A harder nucleus may need a larger capsulorrhexis, and the nucleus may be reduced in size by hydrodelineation before hydroprolapse is attempted.

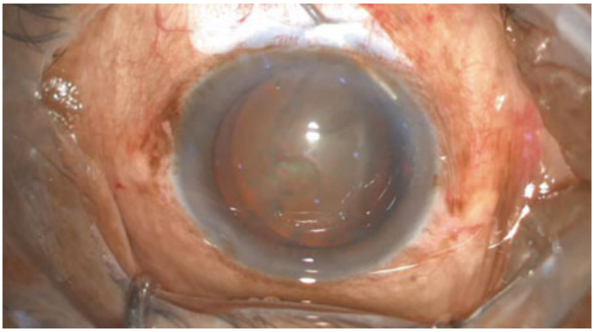

Fig. 1 Prolapsed lateral pole of the nucleus

Viscoprolapse

One pole of nucleus can be prolapsed by injecting 2 % hydroxypropyl methylcellulose (HPMC) under the capsulorrhexis near the capsular fornix. The technique is similar to hydroprolapse. This technique is also useful for soft cataracts. Prerequisite is adequate pupillary dilatation and adequate size of capsulorrhexis.

Prolapsing with Sinskey Hook

This technique is suitable for moderate to hard nucleus. This can be performed with a single Sinskey hook or with two hooks bimanually.

Single Hook Method

After thorough hydrodissection and hydrodelineation, the AC is inflated with a dispersive OVD like HPMC/chondroitin sulphate. The Sinskey hook is passed through the main incision. The centre of the nucleus is felt with the hook which is then taken up to the equator of the nucleus tracing the surface of the nucleus. Once the equator is reached, the Sinskey hook is passed into the surrounding epinucleus or cortex. The pole of the nucleus is lifted out of the capsule (Fig. 2) and cartwheeled anteriorly and out of the bag till the entire nucleus comes into AC. This procedure may be difficult in small rigid pupils and small capsulorrhexis or when zonules are weak.

Bimanual Method

This technique requires two Sinskey hooks or one hook and an iris repositor. There are two ways of doing this:

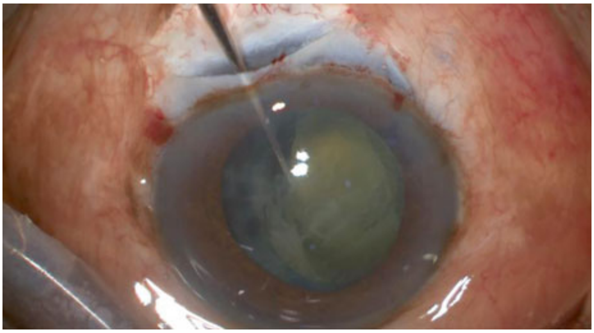

Fig. 2 Nucleus prolapse with the Sinskey hook

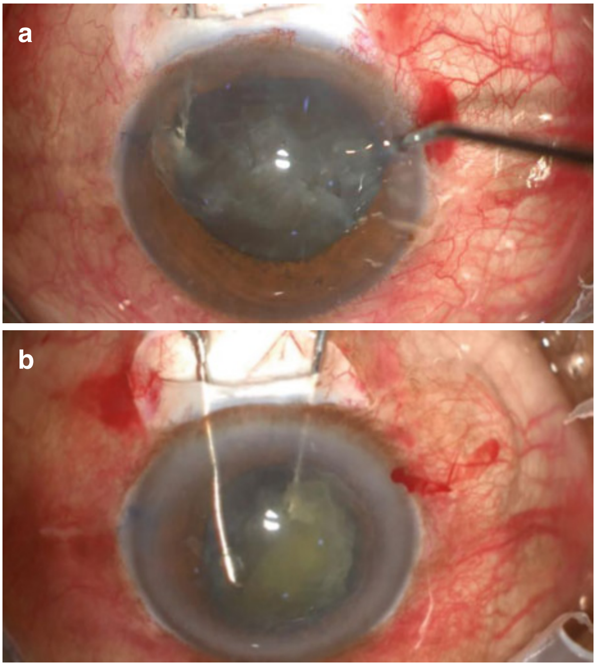

Fig. 3 (**a**) Bimanual prolapse of the nucleus. (**b**) Bimanual prolapse of the nucleus

1. The hook or iris repositor is passed through the side port on the left side. The edge of the nucleus on that side is gently pushed posteriorly. When this is done the opposite pole of nucleus prolapses out of the bag. With the second Sinskey hook nucleus can be rotated anteriorly like in previous techniques (Fig. 3a).
2. In the second technique, AC is inflated with OVD. Nucleus is carefully displaced inferiorly with one Sinskey hook introduced through the side port on the left side or the main incision, thereby exposing the superior pole. OVD is injected under the exposed superior pole of the nucleus. The hook is placed under the superior pole of the nucleus and lifted to a plane in front of the anterior capsule. Then

more OVD is injected under the exposed superior pole of the nucleus to create enough space for placement of a second Sinskey hook, and the nucleus is prolapsed into the AC by cartwheeling technique (Fig. 3b). This technique is more useful in mature cataract, brown cataract, myopia, pseudo-exfoliation, zonular dialysis and moderately dilated pupil. Instrument inserted under the upper part of the nucleus offers support and the required counter resistance to prolapse the nucleus into AC.

Prolapse in Special Situations

Small Pupil

If the pupil is not rigid, it can be stretched to one side with the help of an iris repositor inserted through the side port on the left side (Fig. 4). With Sinskey hook inserted through the main wound, the nucleus can be prolapsed in the usual manner. If the pupil is rigid one may have to resort to stretch pupilloplasty or multiple sphincterotomies or pupil expanders like Malyugin ring. It is not possible to prolapse the nucleus with iris hooks in place, but hooks can be used to make adequate-sized capsulorrhexis.

Large Hard Nucleus

It may be difficult to prolapse a large hard nucleus through regular-sized capsulorrhexis of 5.5 mm. Either a large capsulorrhexis has to be performed or it may be prudent to give multiple relaxing incisions to the capsulorrhexis margin to minimise stress on zonules. The same technique can be adopted in situations where large capsulorrhexis cannot be performed due to fibrosis of the anterior capsule and in zonular weakness.

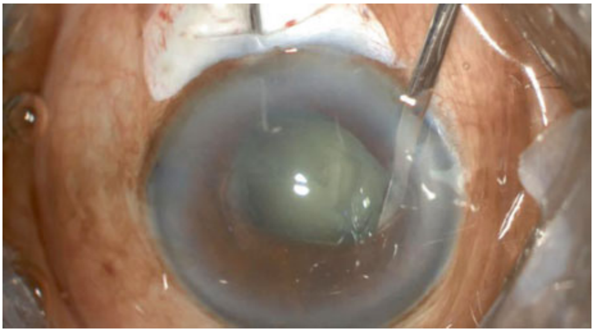

Fig. 4 Bimanual prolapse in small pupil

Posterior Polar Cataract

Posterior polar cataracts are associated with primary dehiscence of the posterior capsule in 20 % of the cases [1], and hydrodissection is contraindicated. The majority of these cataracts present with soft nucleus which is difficult to prolapse by the regular methods. A special technique has been described called 'lollipop technique' where the visco cannula is passed into the centre of the nucleus like the stick inside a lollipop, and the whole nucleus is lifted out of the bag. In those cases of posterior polar cataracts with moderately hard and very hard nuclei, luxation can be achieved with Sinskey hook(s).

In cases of hypermature Morgagnian cataract, there is no counter support for the nucleus. AC is filled with OVD. An iris repositor is used to gently press at the capsulorrhexis margin at 9 o'clock position. The small nucleus, freely floating in the bag, will easily come into AC.

Nucleus Delivery Through Scleral Tunnel

Nucleus delivery out of the bag and the AC retaining integrity of the scleral tunnel and intactness of the internal structures of anterior segment including the corneal endothelium are an important aspect in MSICS. Various techniques have been in practice all over the world, and many surgeons have modified the original technique to develop their individual methods which work well in their hands. A sincere effort has been made to describe most of these techniques, and a link to videos demonstrating a few popular techniques is available at the beginning of the chapter. Various techniques that have been in practice may be classified as follows:

A. Nucleus delivery techniques
   1. Nucleus delivery in toto
      (a) Hydroexpression
         – Blumenthal technique
         – With irrigating vectis
      (b) Viscoexpression
         – Phaco-punch technique
      (c) Sandwich technique
         – With Sinskey hook
         – With visco cannula
      (d) Hennig fish hook technique

2. Nucleus delivery by phacofragmentation
   (a) Bisection or trisection
      – With metal bisector or trisector
      – With visco cannula
      – With metal wire snare
      – With nylon wire snare
      – Kongsap technique
      – Jaws slider pincer technique
   (b) Multifragmentation
      – Manual multifragmentation
      – Chop multisection and chopstick technique
      – Closed chamber manual phacofragmentation of Boramani
      – Prechop manual phacofragmentation
      – Quarter extraction technique

Each technique is described on the following lines: instruments, method and tips for a safe technique.

Nucleus Extraction In Toto

Hydroexpression

The basic principle of this procedure is to elevate hydrostatic pressure in the AC. As the main wound is opened and the floor of the tunnel is depressed, the nucleus comes out through the tunnel following the pressure gradient.

Blumenthal Technique [2]

This method is among the few methods that have withstood the test of time. Michael Blumenthal started this technique in 1990. Scores of ophthalmologists have adopted this technique and have modified the steps to suit their comfort levels. The concept of hydrodynamic delivery of the nucleus caught the imagination of many cataract surgeons worldwide. The concept of AC maintainer (ACM) which was introduced by Blumenthal is still widely used in various situations. The beauty of this technique lies in the fact that every step in SICS is performed without the use of OVD.

Instruments
1. AC maintainer
2. Sheet’s glide

AC Maintainer (ACM) This is a 2.5 mm long metal cannula with a serrated external surface and a bevel. ACM is a very versatile instrument with 1 mm external diameter and 0.6 mm internal opening. With a 20 G MVR knife, a 1.5–2 mm intrastromal entry is made at 6 o'clock in a temporal to nasal direction. The ACM is introduced without flow with bevel up. After entering the AC, bevel is rotated down and BSS flow is resumed.

Sheet's Glide [3] This is a transparent plastic strip about 3–4 mm wide, 0.3 mm thick and about 3 cm long with a rounded and smoothened tip. Function of the glide is twofold:

1. To glide the nucleus into the tunnel
2. To provide a smooth surface for sliding of the nucleus

Procedure Once the nucleus is luxated into AC, the tip of the Sheet's glide is gently introduced through the section under the upper pole of the nucleus up to 1/3 of the way. With an iris spatula/McPherson forceps the tunnel is depressed by pressing on the glide. The nucleus gets engaged in the tunnel. The bottle height is increased to 70 mm, thereby increasing the hydrostatic pressure in the AC. Further continued pressure on the glide will cause the nucleus to shave off the epinucleus and mould itself into the tunnel till it is finally expelled out. This procedure is repeated again to expel the epinucleus.

Caution The glide should be inserted under the nucleus and is pushed towards 6 o'clock and not posteriorly to prevent PC rent.

Sometimes the nucleus may get stuck at the corneal end of the tunnel. The nucleus can be engaged with a Sinskey hook and dialled out. The whole nucleus may come out or a pie-shaped piece will break from it. In that case one can rotate the nucleus so that the new reduced diameter engages and the nucleus expelled.

Hydroexpression with Irrigating Vectis

Instruments

1. Irrigating vectis: 5 mm wide, with one to three 0.3 mm forward irrigating ports with a gentle superior concavity
2. 2.5 cm^3 disposable syringe filled with BSS

Hydroexpression with an irrigating vectis is a simple technique using a combination of mechanical and hydrostatic forces. This is a single instrument technique and with OVD usage, safe for corneal endothelium.

Procedure

A superior rectus bridle suture may be placed which helps in applying counter resistance while extracting the nucleus. After luxation of the nucleus into AC, OVD is placed above and below the nucleus. The patency of the irrigating vectis is tested (Fig. 5a) before the surgery. The vectis without injecting fluid is introduced under the nucleus following the curve of the posterior surface of the nucleus till the vectis is seen over the iris inferiorly. It is important to avoid engaging iris between it and the nucleus in order to prevent iridodialysis. Margins of vectis can be seen through the nucleus except perhaps in dense white and black cataracts. The following manoeuvres should happen in quick succession for the safe removal of nucleus (Fig. 5b):

1. Irrigating vectis should be withdrawn slowly without irrigating. This helps in engaging the superior pole of the nucleus in the tunnel.
2. Superior rectus bridle suture should be pulled tight to fix the globe.
3. Fluid is injected slowly from the syringe while pressing the floor of the tunnel with the irrigating vectis. Hydrostatic pressure builds up in the AC as the nucleus, engaged in the tunnel, blocks the tunnel. The vectis is slowly pulled out and the nucleus also comes out with the vectis. Once the maximum diameter of the nucleus comes out of the tunnel, irrigation should be reduced to prevent forceful expulsion of the nucleus and sudden decompression and shallowing of AC.

Advantages of the Technique AC remains formed throughout the surgery, and as the tunnel is depressed, the nucleus comes out without damaging the endothelium.

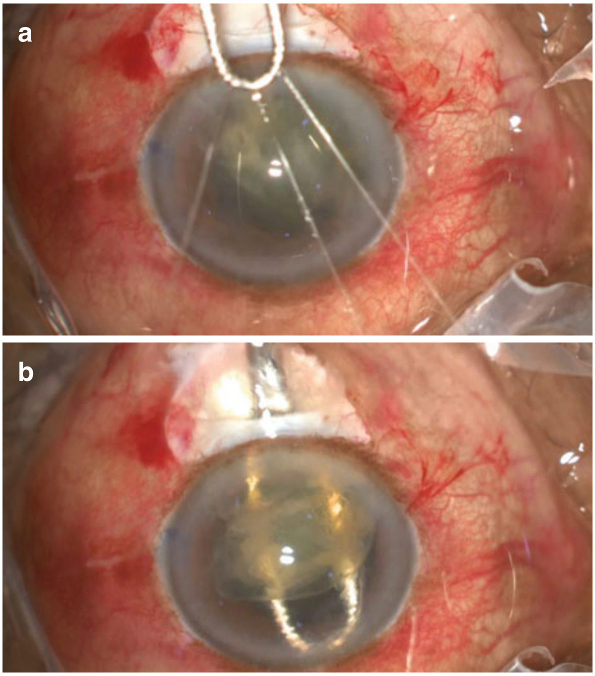

Fig. 5 (**a**) Testing patency of the irrigating vectis. (**b**) Nucleus extraction with irrigating vectis

Management of Hard Cataract

Once the brown/black nucleus is engaged in the tunnel, the heel of the vectis is lifted. This breaks off the superior 1/3 to ½ of the nucleus. Alternatively one can remove the vectis completely when the nucleus locks the tunnel. The part of the nucleus outside the tunnel is chopped with a Sinskey hook. The remainder can be pushed back into AC with longitudinal axis oriented along the axis of the tunnel and is removed using the vectis.

Phaco Sandwich Technique [4, 5]

Instruments

1. Vectis: 5 mm wide with superior concavity or with serrations
2. Sinskey hook
3. OVD

Phaco Sandwich with Sinskey Hook

After adequate hydrodissection and hydrodelineation, the nucleus is luxated into AC which is then filled with copious amounts of OVD (HPMC in most cases, chondroitin sulphate is preferred in very hard cataracts and old age). Next the floor of the tunnel is depressed with the vectis held in the left hand. The superior pole of the nucleus gets engaged in the tunnel. Some more OVD is injected under the nucleus which pushes the iris back (bedsheeting of iris). The vectis is carefully advanced under the nucleus so that the tip appears on the opposite side anterior to the iris, thereby ensuring the iris is not caught between the vectis and the nucleus. The vectis is slightly depressed posteriorly to create more space in the AC. Some more OVD is pushed between the nucleus and endothelium. Now the Sinskey hook in the right hand is introduced into the AC over the nucleus. The hook is pressed against the nucleus to sandwich the nucleus between it and the vectis (Fig. 6). The superior rectus bridle suture is tightened and the sandwiched nucleus is pulled out of the AC. In the process the surrounding epinucleus gets shaved off from the nucleus as it emerges from the AC by the inner lips of the tunnel. If the nucleus is soft, it comes out in one piece. If it is hard it may break off at the tunnel. At this stage the tunnel needs to be slightly enlarged. The nucleus is pushed back and the smallest diameter of the reduced nucleus is aligned longitudinally (6–12 o'clock position), and the whole process is repeated to sandwich the nucleus and extract it. The drawback of this procedure is that tunnel size may have to be increased if the nucleus is large. Once the nucleus is extracted, the epinucleus can be extracted with viscoexpression.

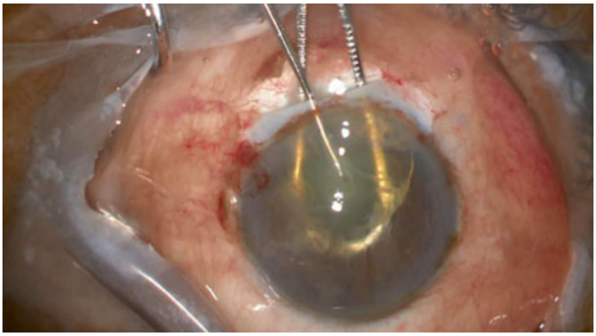

Fig. 6 Phaco sandwich with Sinskey hook

Fig. 7 Phaco sandwich with visco cannula

Phaco Sandwich with Visco Cannula [4, 6] (Fig. 7)

Alternatively cannula (20 G) of visco-filled syringe can be used instead of Sinskey hook, and visco is constantly injected into AC as the nucleus is delivered, so that AC remains formed and endothelium is protected.

Advantages of Phaco Sandwich Technique This technique is easily adaptable, with a short learning curve and reduced surgical time, and this ensures the removal of the nucleus in one piece. Using a visco cannula, instead of a Sinskey, ensures further endothelial protection.

Disadvantage
Tunnel size may have to be increased more than 6.5 mm in very hard cataracts with large nucleus.

Viscoexpression (Phaco-Punch Technique)

Thorough hydrodelineation is done to minimise the nucleus size. Nucleus is luxated into AC. AC is filled with OVD. Superior rectus bridle suture is tightened. The curved visco cannula is inserted under the nucleus so that the tip of the cannula appears over the iris at 6 o'clock position. OVD is injected and simultaneously the floor of the tunnel is depressed with the cannula itself. Along with OVD, nucleus also comes out through the tunnel.

Advantages of the Technique Short learning curve.
Endothelium is protected throughout the surgery.
PC tears are very rare.

Disadvantages This procedure is suitable for soft cataracts and smaller nuclei. The size of the tunnel has to be increased depending on the nucleus size.

Hennig Fish Hook Technique [7]

This technique was introduced in 1997 by Dr. Albrecht Hennig in Lahan Eye Hospital in southeast Nepal. It is known as 'Lahan technique' or 'Hennig technique' or popularly known as 'fish hook' technique. This is the only technique where the nucleus is extracted directly from the capsular bag through the tunnel avoiding corneal endothelial touch.

Instruments
The fish hook (Fig. 8a) is made of 30 G (1/2 in.) disposable needle bending it with needle holder. There are two bends:

(a) Tip of the needle which will insert into central nucleus
(b) A slight bend over the middle of the needle shaft to facilitate easy insertion into the capsular bag under the nucleus

Procedure
AC is filled with OVD (HPMC). OVD is injected into the capsular bag between the nucleus and the posterior capsule. The upper pole of the nucleus is partially prolapsed into AC. The hook is introduced, with the sharp tip of the needle facing the right side, into the capsular bag between the nucleus and the posterior capsule. Then the hook is turned up and slightly pulled back, so that the needle tip is engaged into the central lower portion of the nucleus.

Without lifting, the nucleus is pulled out of the capsular bag and through the tunnel. The cortex remains in the AC, acts as a cushion and thus protects the endothelium from any contact with the nucleus.

Advantages
Short learning curve.

Safe, fast and inexpensive technique.

Only technique to extract the nucleus directly from the bag avoiding endothelial touch.

Nucleus extraction requires a smaller tunnel size than nucleus removal by hydroexpression.

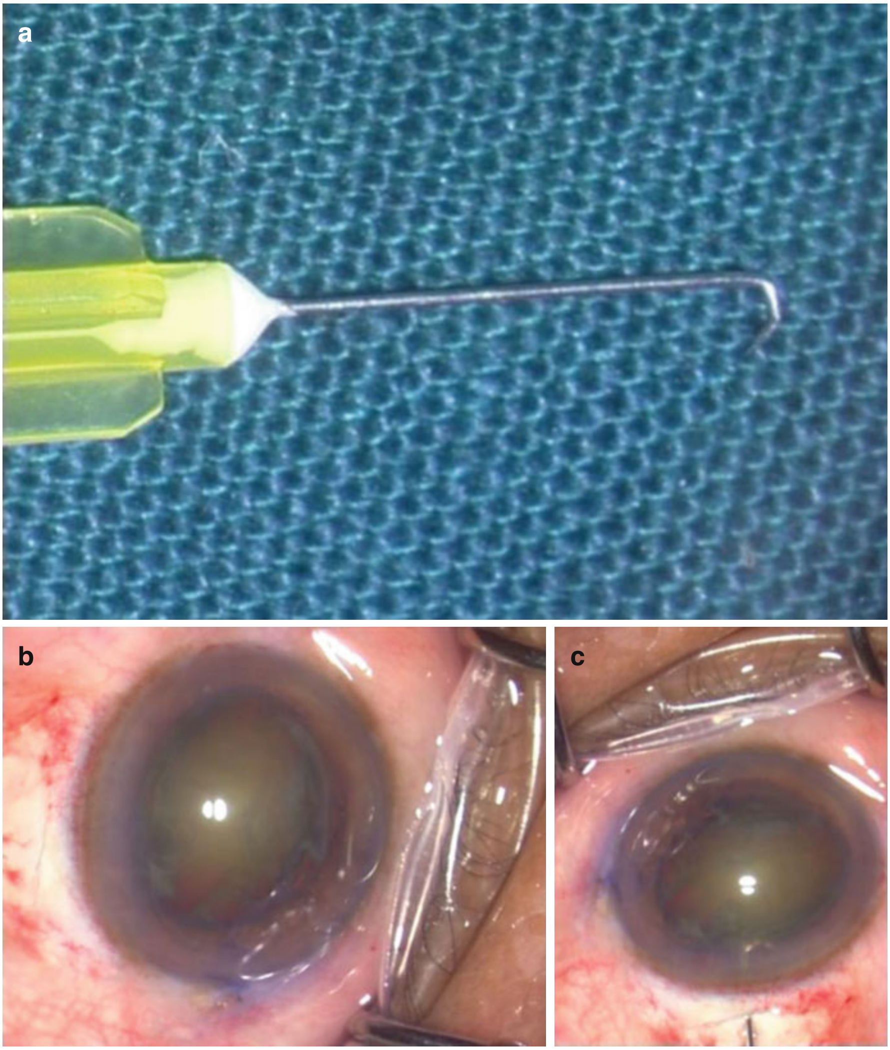

Fig. 8 (**a**) Fish hook. (**b**) Partially prolapsed nucleus. (**c**) Fish hook being introduced under nucleus. (**d**) Nucleus being extracted with fish hook. (**e**) Fish hook embedded into the nucleus

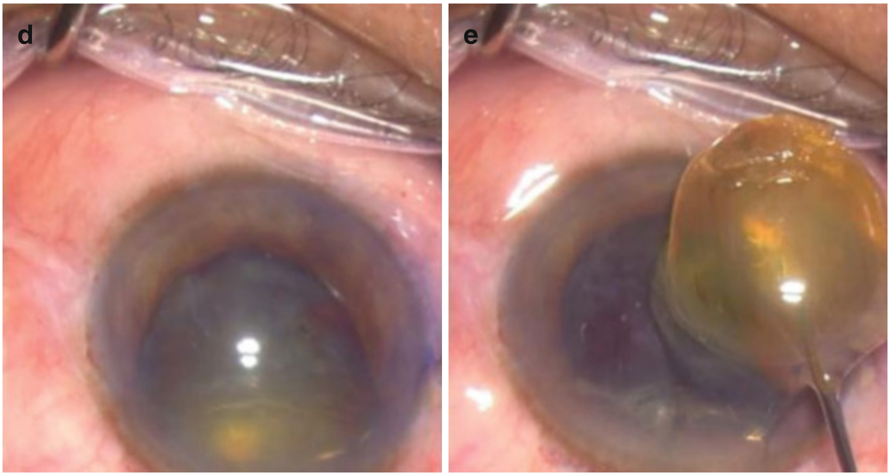

Fig. 8 (continued)

Nucleus Delivery by Phacofragmentation

Phacosection or Phacofragmentation Techniques [8]
A wide variety of techniques have been practised, many of them are personalised techniques. We will describe the techniques that are commonly practised world-wide, while a brief note on other techniques will also be given. Phacofragmentation or phacosection is the only way of minimising the tunnel size to as small as 4 mm where foldable IOL can be implanted, and in experienced surgeon's hands, the results may be comparable to phacoemulsification [9–11].

Surgery
Most of the steps are common to all techniques; only the phacosection methods are modified.

Phacofragmentation with Trisector

Instruments
1. Trisector
2. Wire vectis which acts as a cutting board
3. Kansas fragment removal forceps which has long serrated tips

Procedure (Fig. 9a–c)
The nucleus is luxated into AC employing any of the methods described in the earlier sections. It is advisable to inflate the AC to its maximum with a dispersive OVD. The trisector is first introduced into the AC over the nucleus taking care not to touch the endothelium. This prevents the nucleus from rubbing the corneal endothelium. Then

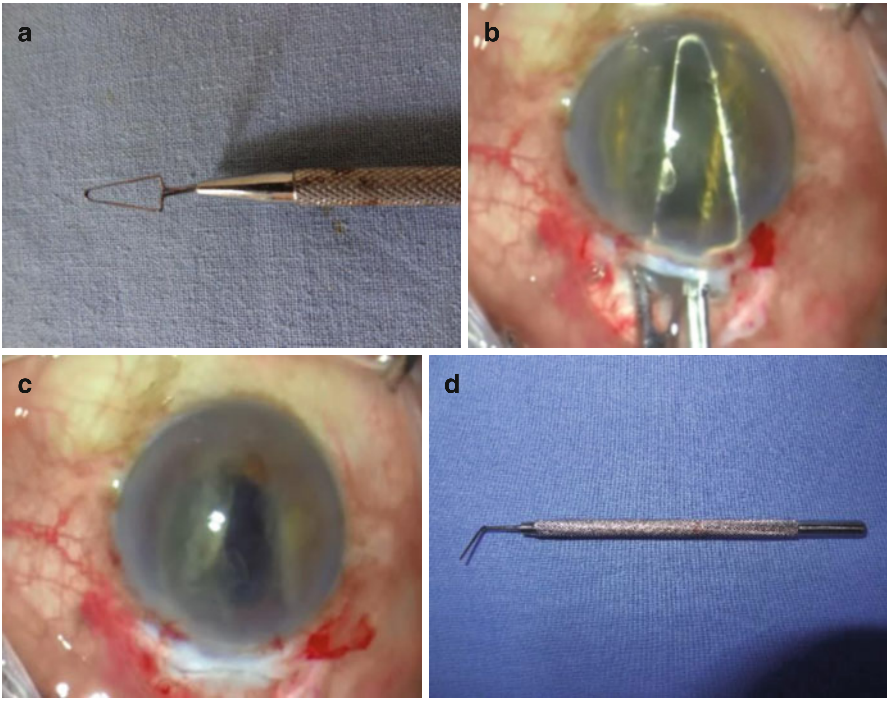

Fig. 9 (**a**) Trisector. (**b**) Nucleotomy with trisector. (**c**) After extraction of the central fragment. (**d**) Bisector

wire vectis is introduced into the AC by negotiating the curve of the back surface of the nucleus. Care is taken to ensure that the tip of the vectis is seen on the opposite side (6 o'clock position) over the iris. This is to prevent the iris getting caught between the vectis and the nucleus. Now at this stage the vectis is slightly depressed posteriorly to create space in the AC. The trisector is pressed over the nucleus which cuts the nucleus into three pieces with the vectis acting like a cutting board. The central piece is then sandwiched between the trisector and the vectis, and as both the instruments are withdrawn from the eye, the central piece of the trisected nucleus comes out. AC is filled with OVD and the remaining two fragments are aligned with the longitudinal axis in 6–12 o'clock orientation. These two pieces are removed by sandwich technique independently under adequate OVD cover. Alternatively the fragments may be removed with Kansas serrated fragment removal forceps. A little lift of the superior tunnel roof with a fine-toothed forceps is usually helpful while extracting fragments. As the fragments are extracted through the scleral tunnel, very light posterior pressure on the floor of the tunnel will facilitate fragment removal. If the remaining fragment or fragments seem too large for the width of the existing tunnel, then the fragments can be further reduced in size by the bisector.

The nucleus can be sectioned using a bisector also (Fig. 9d). This technique of sectioning the nucleus with a bisector is similar to the use of a trisector and has been described previously (in the preceding section). If the nucleus is divided into two pieces, the tunnel size has to be bigger (at least 6 mm) to extract the fragments. Instead of this, one can cut the nucleus into many pieces by passing the bisector in the same way multiple times. OVD is used generously during all the steps to protect the corneal endothelium. Fragmentation of the nucleus into multiple pieces with a bisector is similar to bread slicing.

In case of unhealthy endothelium like Fuchs' dystrophy, a large tunnel with bisection of nucleus is advisable.

Phacosection with 26 G Visco Cannula

Instruments

1. Wire vectis with serrated margins
2. 26 G cannula mounted on 2 cc syringe filled with OVD

Procedure

Once the nucleus is prolapsed into AC, the wire vectis is taken in the left hand and the 26 G (1/2 in.) cannula in the right hand. Adequate OVD is injected into the AC. Then the vectis is passed under the nucleus. Care is taken to follow the posterior curve of the nucleus to reach the opposite iris surface. If the curve of the posterior surface of the nucleus is not followed, the vectis tends to hit the central bulge of the nucleus, and this pushes the nucleus towards 6 o'clock. The vectis should be placed under the centre of the nucleus and the visco cannula over the centre of the nucleus (Fig. 10). OVD is injected into the AC whenever needed. The cannula is pressed towards the vectis slowly and steadily. The shaft of the cannula bisects the nucleus. There is no need for seesaw movement. By this technique the cannula can bisect any nucleus irrespective of the hardness. OVD is injected between the two halves of the nucleus to make sure that the two pieces are fully separated. If there is any connection remaining, it should be severed with the cannula. If the fragments are still connected posteriorly, the second half tends to follow the first half during extraction complicating the whole process. Next the vectis is shifted under the left severed half of the nucleus and the visco cannula over it. This fragment is removed by the sandwich technique. The second fragment is also removed in a similar manner. The tunnel size is maintained small with phacosection.

If any resistance is encountered during extraction of the nuclear fragment, it is better not to persist with extraction. One should check if the upper pole of the nucleus has gone under the scleral valve through the opening in the vectis. If that is the situation, the nuclear fragment is pushed back into AC and the sandwich technique is repeated.

Tip Phacosection in very soft and very hard cataracts should be avoided early in the learning curve.

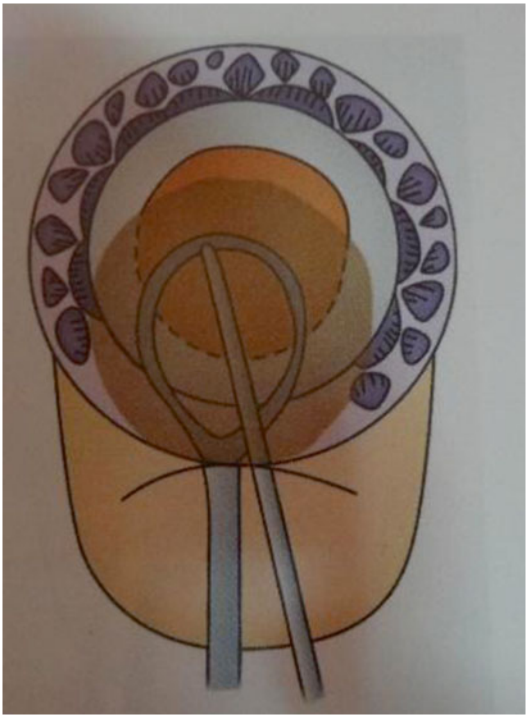

Fig. 10 Phacosection with 26 G visco cannula

Phacosection with Snare [12]

Basic Principle A thin metal or nylon wire loop is passed around the nucleus to enclose it in the vertical meridian. As the wire is pulled, the loop becomes smaller and in the process cuts the nucleus. Depending upon the number of loops, the nucleus is divided into two or multiple fragments.

This technique has found varied acceptance and has undergone various modifications, most of these based on the surgeon's concept and preference.

Instrumentation

1. Snare (Fig. 11a, b)

   Basically a metal wire loop or a nylon sling of 13–15 mm diameter mounted on a handle and the wire is attached to the piston. As the piston is pulled back, the snare gets shortened; with the forward movement of the piston the snare widens. The snare can have a single loop which acts as a bisector or can have two loops which act as a trisector. This is autoclavable.
2. Vectis
3. Sinskey hook

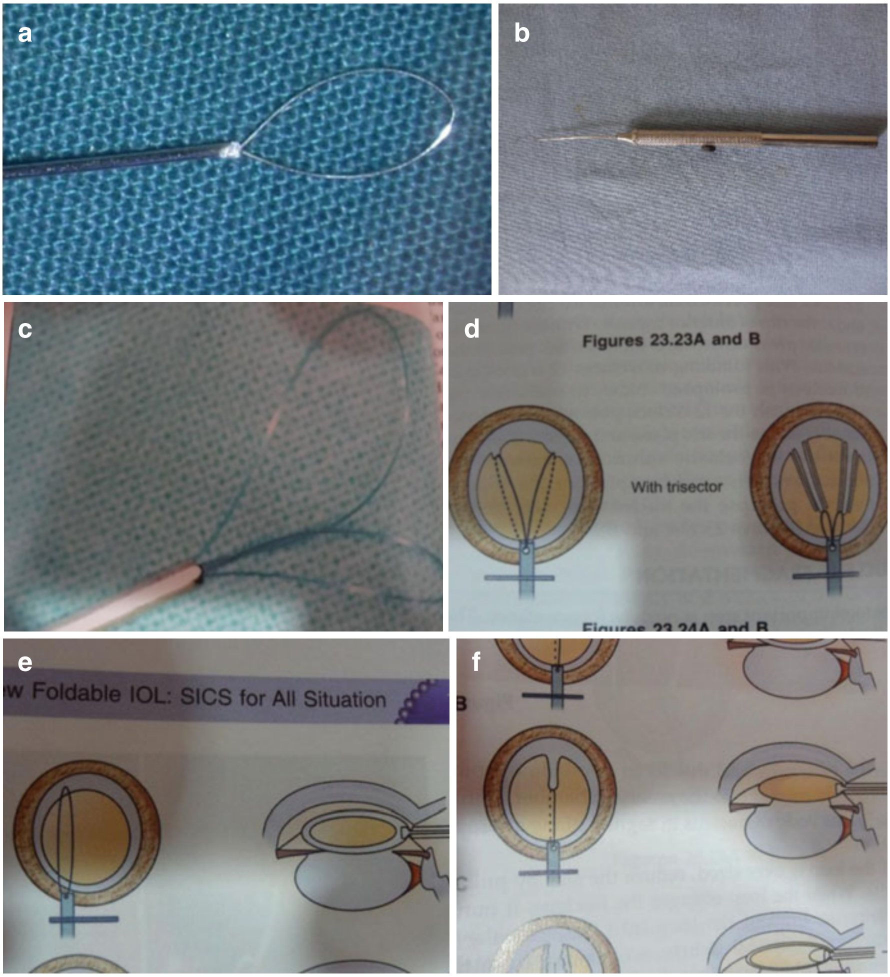

Fig. 11 (**a**) Phaco snare – single loop. (**b**) Snare with handle. (**c**) Phaco snare – 2 loops. (**d**) Trisection with snare. (**e**) Bisection with single snare. (**f**) Bisection with single snare

Procedure (Fig. 11b–d) After thorough hydrodissection and hydrodelineation, the nucleus is properly delineated from the epinucleus. The nucleus is prolapsed into AC. Adequate amount of OVD is injected into AC and also beneath the nucleus. Before using the snare it is essential to check the following things:

- Push and pull the handle of the snare and observe the smooth movement of wire loop.
- Before using the metal snare, shape the loop and make it oval.
- Make sure the loop of the snare is not kinked or damaged.

Bisection

The snare handle is held in the right hand while it is stabilised with the left hand. The loop is partially closed before passing it into AC. The loop should be passed in a slightly tilted position. It is opened and passed around the nucleus and manipulated in such a way that the loop encircles the nucleus longitudinally at its widest part. Now the anterior limb of the loop is in front of the nucleus and the posterior limb is behind the nucleus. At this point in time, the anterior limb of the loop is well buried in the cortex, and OVD thus stays away from the endothelium. The posterior limb of the loop is away from the posterior capsule. Next the snare is constricted by pulling the button on the handle. As the loop becomes smaller, it cuts the nucleus into two halves. OVD is injected between the nuclear fragments which are then separated.

The same single snare can be reintroduced to cut the nuclear fragment again or double snare may be used which has concavity of the snares facing each other. Once the double snare constricts, the nucleus is divided into three fragments.

These fragments can be removed either with viscoexpression if the nucleus is soft or with Kansas fragment removal forceps or by sandwich technique. One can also use McPherson forceps instead of Kansas fragment forceps.

Though this technique sounds simple, it has a learning curve. Once familiarity with this technique improves, the results are excellent.

Closed Chamber Manual Phacofragmentation of Boramani

Instruments

1. AC maintainer.
2. Boramani's axe chopper: this looks like a lens or IOL manipulator with the distal portion a little thicker, and the tip resembles a small axe measuring 0.6×0.6 mm with a curved cutting edge.
3. Stiletto 0.9 mm knife.
4. Iris repositor.

Procedure (Fig. 12a, b)

ACM is inserted at 6 o'clock position. The nucleus is partially prolapsed with the left and upper part of the nucleus being out of the bag and the rest of the nucleus within the bag. A scleral tunnel is made without opening the tunnel. A side port is made at 10 o'clock position. A 0.9 mm entry is made at the left end of the tunnel using stiletto knife to admit the iris repositor. Iris repositor is introduced through this opening and is gently inserted under the left portion of the nucleus without damaging the posterior capsule. Now Boramani's axe chopper is introduced through the side port over the right portion of the nucleus. Both the instruments are moved in a continuous curvilinear fashion first to fragment the nucleus and then to push the fragments away from each other. Although the movements are continuous curvilinear initially, the instruments are bought closer to fracture the nucleus, and in the later part they move away from each other to separate the fragments. Now the scleral tunnel is completely opened and the fragments are extracted over Sheet's glide using Blumenthal mini-nuc technique. The fragments need not be of equal size.

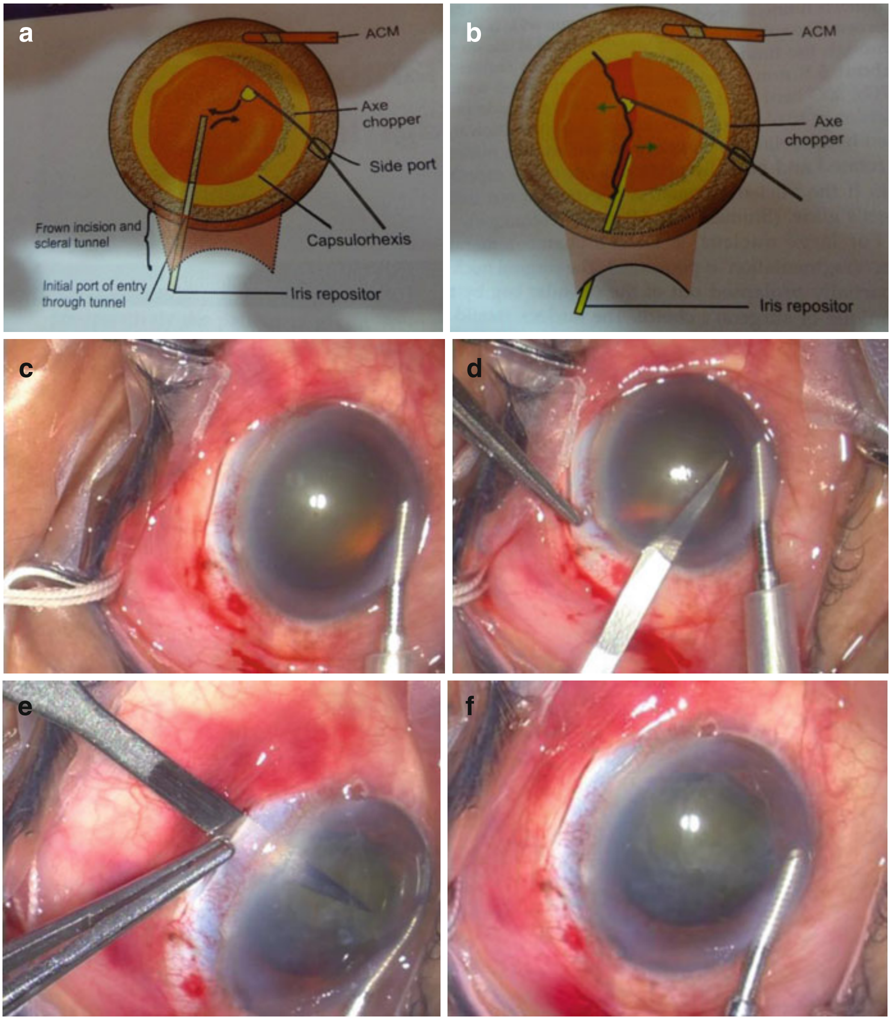

Fig. 12 (**a**) Nucleotomy. (**b**) Fragment separation. (**c**–**j**): (**c**) AC maintainer in place, (**d**) side port at 10 o'clock position, (**e**) entry of scleral tunnel with 0.9 mm knife, (**f**) partially prolapsed nucleus, (**g**) nuclear fragmentation with chopper, (**h**) fragmented nucleus, (**i**) extraction of the first fragment, (**j**) extraction of the second fragment

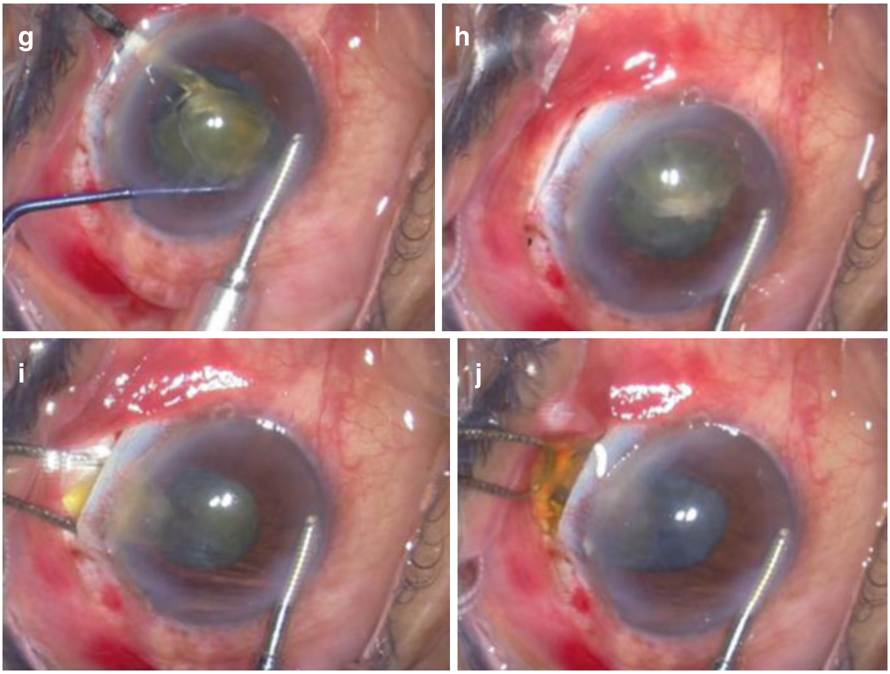

Fig. 12 (continued)

Sometimes the fragments may not come out as easily as an intact nucleus. In such a situation the fragments can be pushed out with a Sinskey hook passed through the side port.

Tips

1. Nucleus should only partially be prolapsed.
2. A phacofragmentation is done with fine instruments. The movement of the instruments should be strictly followed to avoid sudden tumbling of the nucleus which can be hazardous.
3. As the capsulorrhexis is performed with a needle through the side port, only a small entry is made to admit only the needle and to minimise the egress of fluid.

Manual Multi-Phacofragmentation (MPF) [13]

This technique is described by Francisco J G Carmona of Spain. Manual multi-phacofragmentation allows cataract surgery through a 3.2 mm clear corneal or 3.5 mm scleral tunnel incision. The nucleus is fragmented into multiple 2×2 mm fragments.

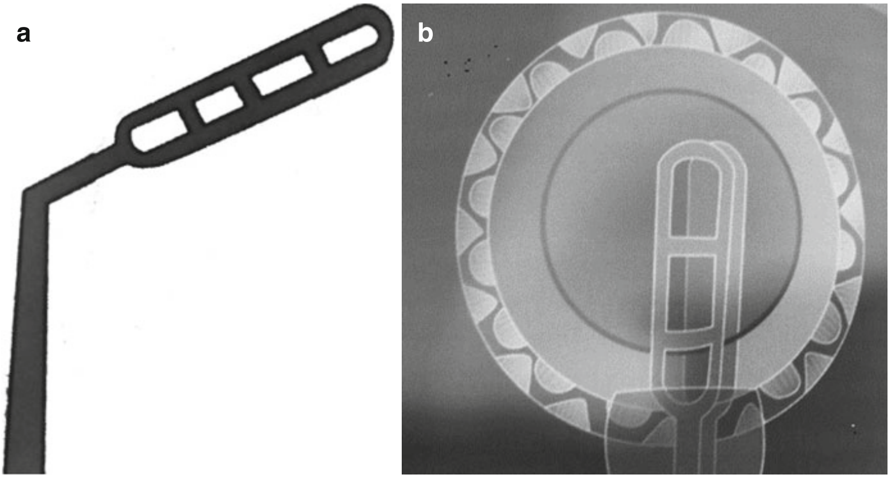

Fig. 13 (**a**) Nucleotome. (**b**) Multi-phacofragmentation

Instruments

1. Racquet-shaped nucleotome (Fig. 13a): this is 8 mm long and 2 mm wide divided along its short axis by 3 thin transverse bars 2 mm apart at 45° to a long straight handle.
2. A spatula 8 mm long by 2 mm wide, the same shape as the nucleotome used as a cutting board.
3. Two straight-handled manipulators. Right and left used to collect the nuclear fragments.

Surgical Technique

Nucleus is luxated into AC. Spatula is introduced under the nucleus and nucleotome is introduced over the nucleus (Fig. 13b). The nucleotome is pressed against the spatula, thereby fragmenting the nucleus. The sandwiched section of the nucleus is fragmented into four pieces which remain within the nucleotome and are extracted from AC with sandwich technique. The other two pieces of the nucleus are aligned, and the same procedure is repeated till the nucleus is completely extracted.

Tip AC has to be repeatedly filled with high-viscosity OVD to protect corneal endothelium.

Conclusion

There are various methods of nucleus delivery each with its own pros and cons. Depending on the type of cataract, the surgeon can adopt any technique that suits him or her best to optimise his or her postoperative results.

Surgical Video List

The following edited videos with narration are available via the link at the beginning of the chapter to demonstrate various nucleus prolapse techniques.

1. Phaco sandwich with visco cannula
2. Irrigating vectis
3. Phacosection with trisector
4. Fish hook technique
5. Closed chamber phacofragmentation

Nucleus bisection with visco cannula and bisection with snare could also be added to the video list.

References

1. Osher RH, Yu BC, Koch DD. Posterior polar cataracts: a predisposition to intraoperative posterior capsular rupture. J Cataract Refract Surg. 1990;16:157–62.
2. Blumenthal M. Surgical principles and techniques for Small Incision ECCE. Mini Highlights of Ophthalmology. 1992;21:5(1–8).
3. Bluementhal M, Askenazi I, Fogel R, et al. The gliding nucleus. J Cataract Refract Surg. 1993;19:435–7.
4. Fry LL. The phacosandwich technique. In: Rozakis GW, editor. Cataract surgery: alternative small incision techniques. Thorofare: Slack; 1990. p. 71–110.
5. Bayramlar H, Cekic O, Totan Y. Manual tunnel incision extra capsular cataract extraction using sandwich technique. J Cataract Refract Surg. 1999;25(3):312–5.
6. Singh K. The Phacosandwich technique. In: Singh K, editor. Small incision cataract surgery (manual phaco). India: Jaypee Brothers; 2002. p. 101–7.
7. Hennig A, Kumar J, Yorston D, Foster A. Sutureless cataract surgery with nucleus extraction: outcome of a prospective study in Nepal. BRJ Ophthalmol. 2003;87(3):266–70.
8. Kansas PG, Sax R. Small incision cataract extraction and implantation surgery using a manual phaco fragmentation technique. J Cataract Refract Surg. 1988;14:328–30.
9. Sacca SC, Patrone G, Macri A, Rolando M. Small incision nucleus capture: results of 200 cases. J Cataract Refract Surg. 1999;25:969–74.
10. Carmona FJ. Manual multi-phacofragmentation through a 3.2 mm clear corneal incision. J Cataract Refract Surg. 2000;26:1523–8.
11. Vajpayee RB, Sabarwal S, Sharma N, Angra SK. Phacofracture versus phacoemulsification in eyes with age-related cataract. J Cataract Refract Surg. 1998;24:1252–5.
12. Hepsen IF. Small incision extracapsular surgery with manual phaco trisection. J Cataract Refract Surg. 2000;26:1048–51.
13. Gutierrez-Carmona FJ. Nueva tecnica e instrumental de phacofragmentation manual para incision escleralestunelizadas de 3.5 mm. Arch Soc Esp Optalmol. 1999;74:181–6.

Cortex Removal

Sandra C. Ganesh, Ganesh V. Raman, and Kalpana Narendran

> **Key Points**
> 1. During manual small incision cataract surgery, cortical cleanup is by and large affected by Simcoe cannula.
> 2. The most accessible parts of the eye are tackled first, such as the inferior 3–4 clock hours.
> 3. 60–90° (one quadrant) of cortex is removed in one attempt.
> 4. The side port not only helps to reform the chamber at the end of the surgery but also helps to aspirate cortex from the subincisional region.
> 5. Eyes with positive ocular pressure during cortical aspiration pose a threat to successful cataract surgery outcome.
> 6. In cases with breach of the posterior capsule, dry cortical aspiration alternating with vitrectomy is required, simultaneously taking care to prevent cortical matter from dropping into the vitreous cavity.
> 7. Aspirating cortex in a shallow chamber is fraught with complications and assessing and adjusting to the surgical situation accordingly helps in bringing out a successful outcome.

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Introduction

Cortex removal after nucleus delivery and epinucleus removal is a prerequisite for proper in-the-bag implantation of an intraocular lens (IOL) during cataract surgery. A satisfactory cortical cleanup ensures well-centred IOL, clear visual axis, superior visual outcome and less inflammation in the early postoperative period and less chances of posterior capsular opacification in the long term.

The Device

During manual small incision cataract surgery, cortical cleanup is by and large affected by Simcoe cannula.

The Simcoe cannula is made of two small hollow metal tubes connected side by side. The one on the right is flat and the one in the left is round. Each tube has a hub for attachment of the infusion line (infusion hub – right tube) and syringe (needle hub – left tube). The infusion enters from the right tube and exits from the opening made on the right side of the tube (see Fig. 1a, b). The aspiration port is on the upper surface of the left tube and is connected via silicon tubing to the syringe for

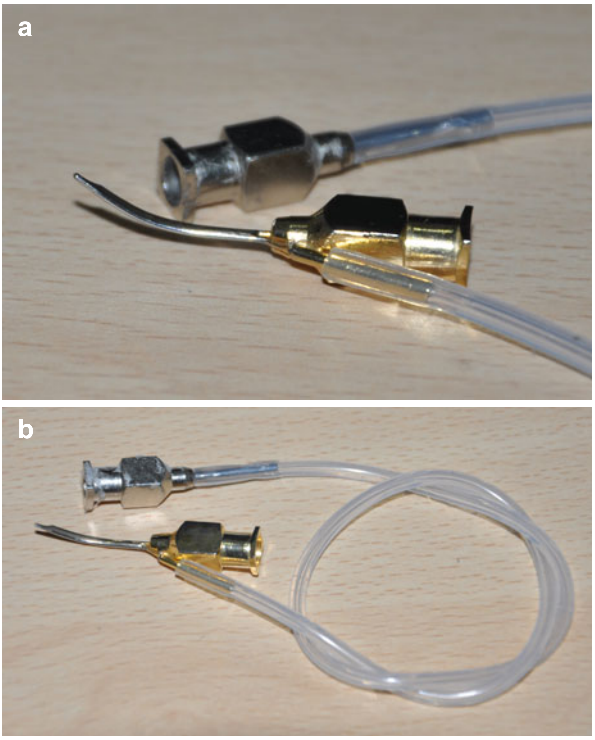

Fig. 1 (**a**) Simcoe cannula tip and hub. (**b**) Simcoe cannula

aspiration of cortex. The tip of the cannula is blunt and slightly bulbous to prevent injury while manipulating within the eye. The main principle of the design is that, as the Simcoe cannula is directed to a particular quadrant and the cannula is appropriately positioned, the jet of fluid emanating from the right tube will open up and inflate the fornix of the capsular bag. The anterior-facing port on the left tube can then be used to aspirate the cortical matter from beneath the anterior capsule.

This design is the regular Simcoe design, whereas a similar device known as the reverse Simcoe cannula has the irrigating port facing anteriorly on the right tube, shooting out a jet of fluid superiorly, and the aspirating port on the left tube facing the left side.

The Procedure

Once the nucleus is removed from the anterior chamber, there remains the epinucleus. This is a shell around the nucleus and usually comes along with the nucleus. Rarely the epinucleus has to be removed separately. Once the anterior chamber is free of nucleus and epinucleus, the chamber is again reformed with viscoelastics, and cortical cleanup is begun. This step needs to be done with utmost gentleness and care. Some surgeons prefer to use a 5 cc/2 cc syringe with a cannula filled with balance salt solution to irrigate the cortical matter before removal. This helps to loosen the cortex from the capsule and facilitates easy removal. This can be done through the main incision or the paracentesis. During small incision cataract surgery, the best available tool for cortical cleanup is the Simcoe cannula. The most accessible parts of the eye are tackled first, such as the inferior 3–4 clock hours. A side port incision at 3 o'clock helps in aspirating cortex from the 9 o'clock region, and the 3 o'clock region can be accessed via the superior main port if one is operating from a superior incision. The side port not only helps to reform the chamber at the end of the surgery but also helps to aspirate cortex from the subincisional region. Alternatively a J-shaped cannula can also be used for removal of subincisional cortical matter.

The cortex material is a loosely adherent covering around the nucleus and the epinucleus, and it consists of 2 leaves with the body adherent to the fornix of the bag. The principle of cortex removal is to gain purchase of the anterior leaf of the cortex and tear it away from the capsule in such a manner that it peels off from the rest of the capsule. Traditional teaching has been to gently tear the anterior cortex perpendicularly to the centre of the eye away from the fornix of the capsular bag. The idea being 60–90° (one quadrant) of cortex is removed in one attempt (see Fig. 1). Once the anterior leaf of the cortex is held, then side-to-side motion of the Simcoe cannula helps in stripping the cortex from the capsule (see Fig. 2). A more efficient method would be to gain purchase of the anterior leaf of the cortex and pull downward towards the posterior capsule (but not towards the centre of the eye) gently tearing the cortex away from the anterior capsule and in this way not putting too much stress on the zonules in the periphery of the capsular bag (see Fig. 3). This technique is very useful in eyes with pseudo-exfoliation syndrome and eyes with angle-closure glaucoma with inherent weakness of the zonules.

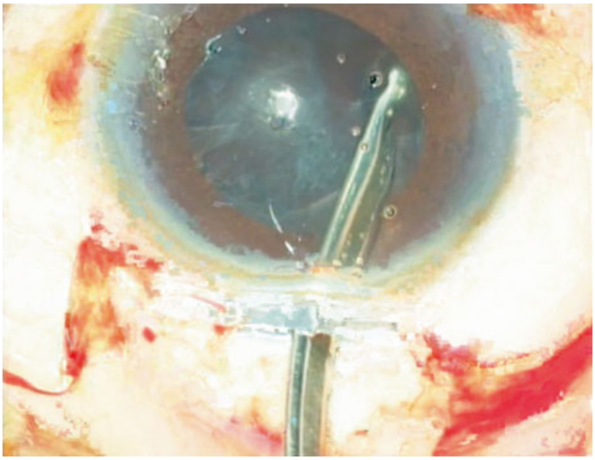

Fig. 2 Cortex removal at 3 o'clock meridian

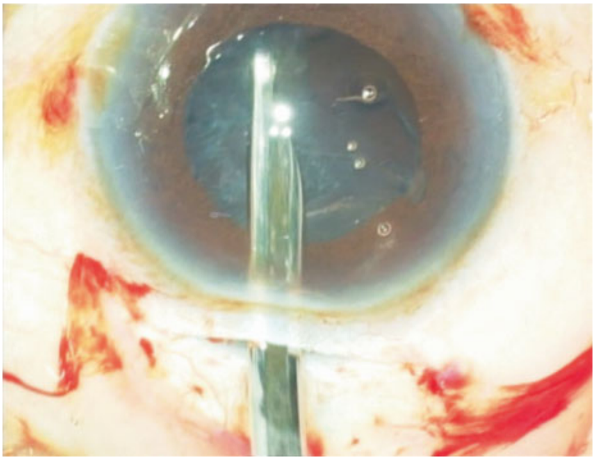

Fig. 3 Cortex removal at 6 o'clock meridian

Cortical Cleanup in Special Situations

Subincisional Cortical Removal

The subincisional region is the area below the main incision at the 12 o'clock meridian (see Fig. 4). The cortex present there is quite difficult to remove, more so if the capsulorrhexis is centred away from the 12 o'clock region or if the capsulorrhexis is small. The safest technique of removal of subincisional cortex is to use a side port incision at 9 o'clock position (see Fig. 5). Another technique is to use a J-cannula or U-cannula to aspirate the cortex subincisionally. As a last resort, when minimal cortical material is left in the bag, one can implant the intraocular lens in the bag and rotate the IOL once or twice in the bag, so as to use the haptics of the IOL to shear away the cortex from the capsular adhesion (merry-go-round technique).

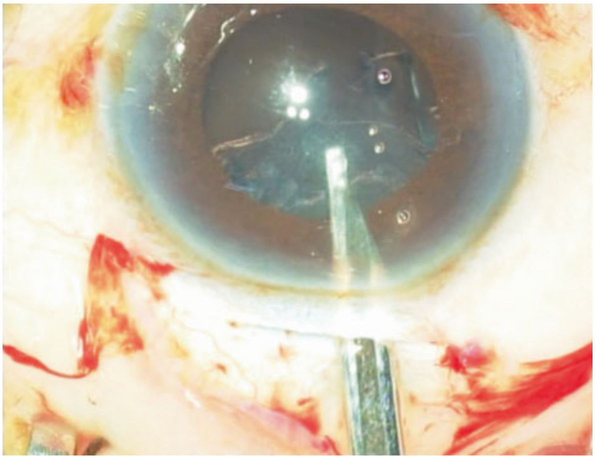

Fig. 4 Cortex aspirated from the inferior hemisphere

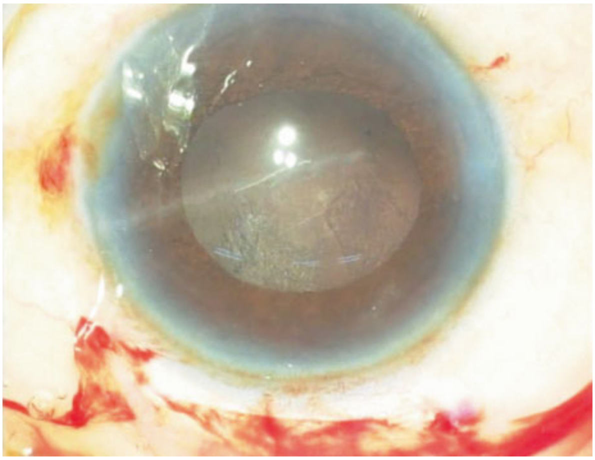

Fig. 5 Central cortical sheet with subincisional cortex

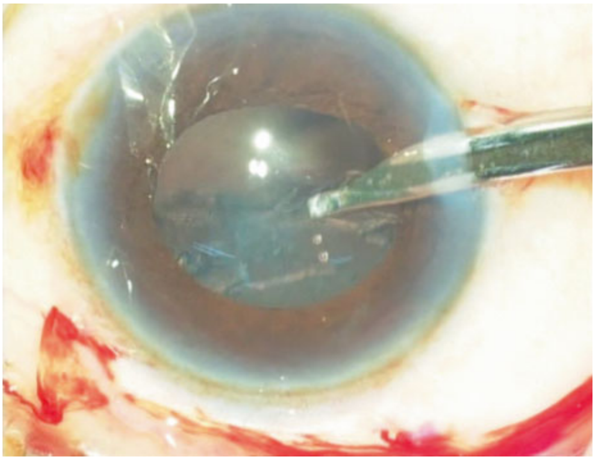

Fig. 6 Subincisional cortex aspiration through side port

Small Pupil and Poor Visualisation

Immediately after nucleus removal there is likely to be a resultant small pupil. Pupillary constriction is usually induced by hypotony. Good visualisation is a must for proper cortical aspiration. Viscoelastics can be injected to reform the chamber. It is wise to remove any loose cortical matter form the anterior chamber and also to remove any material adherent to the posterior surface of the cornea to improve the visualisation. The Simcoe cannula is used in such a manner that it slightly lifts the roof of the tunnel, thus maintaining a semi-closed chamber throughout the procedure. Sudden collapse of the chamber or excursion of the capsular bag-iris complex causing the chamber to shallow and deepen will cause the pupil to constrict further and must be avoided. The Simcoe cannula if introduced through the main port should be used to remove the cortex from the inferior and nasal and temporal regions. Next, the subincisional cortex can be tackled through the side port. Very rarely one may require the use of iris hooks for pupil dilatation.

Pseudo-Exfoliation Syndrome

In pseudo-exfoliation (PXF) syndrome there is inherent weakness of the zonular apparatus, and any manipulation has to be gentle. While entering the eye the jet of fluid emanating out from the Simcoe cannula can cause localised area of zonular weakness. The anterior chamber must be entered when it is fully formed and chamber fluctuation must be avoided. Although PXF syndrome is associated with small pupil, the pupil size stays the same in many patients throughout surgery. Sometimes to stabilise the weak zonules, an endocapsular ring may be used, and in such a condition the cortex is removed in a circumferential/tangential manner. Pulling at the cortex and attempting to bring it towards the centre of the eye will destabilise the whole capsular bag along with the endocapsular ring resulting in serious complications.

Positive Pressure

Eyes with positive ocular pressure during cortical aspiration pose a threat to successful cataract surgery outcome. The cause of such a positive pressure should be identified and if possible corrected during surgery. Some of the causes are (a) positive Valsalva manoeuvre by the patient in response to pain, cold environment in the operation room, full bladder, (b) tight eyelid speculum, (c) obese patient with short neck and (d) excessive regional aesthetic injection. Such situations have to be handled delicately, and it is recommended that cortical aspiration is done through the paracentesis as much as possible. If the intraocular pressure is too severe, then dry aspiration using a Simcoe cannula can be performed. The anterior chamber is inflated with viscoelastics and the Simcoe cannula is introduced into the eye and the cortex is aspirated without switching on the irrigation (dry aspiration). This is repeated multiple times till the entire cortex is aspirated.

Mature Cataract

Cortical aspiration in white mature cataract presents certain difficulties, more so, because the capsulorrhexis is sometimes difficult to achieve. The capsular tags which remain are confused with the white cortex and when pulled at, may extend the capsular tear till the posterior capsule leading to a rupture. A well-stained anterior capsule prior to anterior capsulorrhexis helps in visualisation and avoidance of such accidental tears of the capsule. There may be sheets of lens material adherent to the posterior capsule, and they can be difficult to remove with a Simcoe cannula. They can be swept away using a jet of fluid from 30G cannula attached to a 2 cc syringe filled with BSS.

Uveitic Cataract

Cortex removal in patients with cataracts associated with uveitis is usually not very difficult. The cataract itself is quite soft and the cortex is aspirated as in an eye with soft cataract. In patients with chronic uveitis, the cortex presents as large chunks and has to be mechanically manipulated out of the fornix of the capsular bag using an iris spatula or such other blunt instrument. Repeated, sector-wise, stretching of the pupil using a Y-manipulator helps in identification of areas of cortical remnants.

Traumatic Cataract

Traumatic cataract presents in a variety of ways and can be associated with breach in the anterior capsule, posterior capsule and in very severe cases rupture of both anterior and posterior capsules. In such situations the outcome of surgery is usually unpredictable, and during steps of cortex removal, care is to be taken to prevent further extension of the capsular tear, vitreous prolapse into the anterior chamber and cortical matter falling into the vitreous cavity. Gentle cortical aspiration with low flow into the anterior chamber and/or alternate dry aspiration of cortex material with repeated injection of viscoelastic agents into the anterior chamber helps in successful intraocular lens implantation.

Posterior Polar Cataract

Once the nucleus has been extracted from the eye with posterior polar cataract, the chamber is quickly reformed with viscoelastic devices. The eye is inspected to rule out the possibility of breach of the posterior capsule. Once the posterior capsule is found to be intact, the cortex is removed in a usual manner. In cases with breach of the posterior capsule, dry cortical aspiration alternating with vitrectomy is required, simultaneously taking care to prevent cortical matter from dropping into the vitreous cavity.

Cortex Aspiration in the Presence of Rupture of Posterior Capsule (PCR)

Early identification of posterior capsular tear is very important for proper management of cataract surgery subsequent to a PCR. The aim is to minimise vitreous loss anteriorly and loss of lens material into the vitreous cavity. Once the PCR is noted and identified, the anterior chamber is filled with viscoelastics, and dry aspiration is done using the Simcoe cannula. Vitreous strands are cut using an automated vitrectomy device. Care must be taken to preserve as much of the posterior capsule as possible and not to cut away the iris tissue using the vitrectomy cutter inadvertently. The remaining capsular bag is inflated with viscoelastic devices and the cannula is used to slowly aspirate the cortex. This has to be done in multiple attempts since the vitreous strand will invariably be aspirated as well.

Cortex Aspiration in Lens-Induced Glaucoma

Phacomorphic and phacolytic glaucomas are important causes of lens-induced glaucoma in the developing world. The definitive treatment of these glaucomas is the removal of the cataract and implantation of an intraocular lens, wherever feasible. Cataract surgery is performed as per standard procedure. After nucleus removal care is taken to check the integrity of the lenticular bag and the posterior capsule. It is important to note that the zonular complex is very weak because of sustained high IOP, and sudden deepening and collapse of the anterior chamber should be avoided. The cortical aspiration is preferably done through side port, with low-flow irrigation. In the presence of tenacious cortex sticking to the fornix of the bag, the IOL may be implanted, and then the remaining cortex can be removed subsequently. In phacolytic glaucoma there is significant amount of leaked cortical matter in the anterior chamber. This should be cleared first before attempting capsulorrhexis. The Simcoe cannula is used with low-flow irrigation and the jet of fluid is directed towards the angle of the anterior chamber. The cortical matter is washed off the iris and the central dense cataract with wrinkled capsule becomes evident. The cataract itself is a small disc-shaped mass, free floating in the capsular bag amidst liquefied cortical material. There is no cortex to wash, and as soon as the nucleus is extracted from the eye, it is advisable to place the intraocular lens in the bag.

Conclusion

For beginners cortex aspiration is a formidable task. In the initial stages of training, supervision is required, and the trainee slowly gains confidence with more exposure to cataract surgery. It is always important to proceed sector-wise or clock hour-wise and to remember which area has been cleaned off the cortex. Also, the technique of maintaining a closed chamber is very important and should be practised regularly. Aspirating cortex in a shallow chamber is fraught with complications, and assessing and adjusting to the surgical situation accordingly helps in bringing out a successful outcome.

References

1. Natchiar G. Manual on small incision cataract surgery, Madurai, Aravind Publications, 2nd ed. 2004.
2. Luther L. Fry, Ashok Garg, Francisco Guitérrez-Camona, Suresh K. Pandey, Geoffrey Tabin. Clinical practice in small incision cataract surgery. New Delhi, Jaypee Brothers Medical Publishers (P) 2004.

IOL Insertion

Fathima Allapitchai, Shivkumar Chandrashekaran, and Ramakrishnan Rengappa

Introduction

Several types of intraocular lenses (IOLs) are available for implantation following cataract surgery. Following Manual Small Incision Cataract Surgery (SICS) procedure, where a wider incision is made, it is rational to use a cost-effective rigid IOL. Considering the other advantages of foldable IOLs apart from it foldability, these lenses can also be used in this procedure, if cost is not a limiting factor. This chapter will describe the different types of IOLs and describe the technique for insertion of the IOL and removal of viscoelastic solution.

IOLs can be classified into different types based on type of the material used, design, shape, and size (overall length and diameter of optic). Optics can be made of polymethyl methacrylate (PMMA), silicone, acrylic or collamer. Haptics are made of PMMA, polypropelene, polyamide or polyvinyldifluride. The design of the optics can be described as spherical, aspheric or toric and further described as monofocal or multifocal. The haptics can be designed as a single or multipiece and shaped in a “J” or “C” shape with an open, closed or foot plate configurations.

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In most developing countries, the IOL of choice for an SICS surgery is usually a non-foldable IOL made of PMMA because of the low cost. PMMA IOLs are also chosen for implantation in children due to proven long-term stability in implanted eyes [1]. Although surgeons in the industrialized world and in selected areas in the developing world have largely transitioned to foldable IOL biomaterials such as silicone, acrylics and hydrophilic materials, PMMA does remain in widespread use in many regions. Optic glistenings, small vacuoles which appear with in lens optic, are rarely found in PMMA IOLs but have been reported [2].

Tips for Centration

IOL Implantation Technique

One has aim is to create a good capsule opening and place the IOL inside the bag because that will maintain the long-term centration of the IOL.

Ideally, the anterior capsule opening should be slightly smaller than the IOL optic, so that a continuous rim of anterior capsule covers the peripheral optic. This creates a shrink-wrap effect that improves PC IOL stability and has also been shown to reduce the incidence of posterior capsule wrinkling and fibrosis [3].

Usually SICS procedure needs a bigger rhexis, as the nucleus is taken out as a whole. The rhexis of 5–5.5 mms size could be attempted in case of soft cataracts, and an oval rhexis could be aimed for harder cataract to allow at least partial overlap of rhexis (Fig. 1).

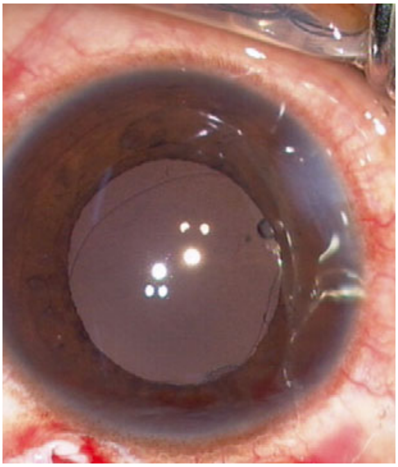

Fig. 1 Partial overlap

Rigid IOL

Polymethyl methacrylate has good structural memory and rigidity that resists optic decentration due to capsular fibrosis but it has a tendency to break if handled roughly.

Technique of IOL Placement in bag

- Comprises two steps
  - Technique of insertion of leading haptic into bag
  - Technique of insertion of trailing haptic

The IOL placement can be done under viscoelastics, under continuous irrigation, or under an air bubble. The image displacement by the air bubble may confuse the trainee surgeons.

Technique of Leading Haptic Insertion

For insertion of a rigid IOL, hold the optic and trailing haptic with a lens holding forceps such as a McPherson forceps, and place the IOL into the eye, directing the leading haptic towards inside the capsular bag.

Next, to ensure that the optic is seated into the bag, partially release the grip over the optic and allow clockwise rotation of the optic in to the bag.

Once the optic and leading haptic are in the bag, the trailing haptic can be inserted into the bag in two ways.

Technique of Trailing Haptic Insertion

Using Forceps

Inject additional viscoelastic to inflate the capsular bag and anterior chamber. Hold the trailing haptic near the tip and move it to the 3 o’ clock position by folding the haptic over the optic. The haptic is depressed and released below the capsular margin (Fig. 2a–h). This is accomplished by the surgeon abducting the arm and pronating the forearm more while placing the haptic in to the bag. This maneuver is more suitable for a multipiece IOL.

Using Sinskey Hook

This step can be done through the main tunnel or through the sideport. If maneuvering through the main tunnel, one has to be aware that viscoelastics may leak out which can lead to a shallow anterior chamber.

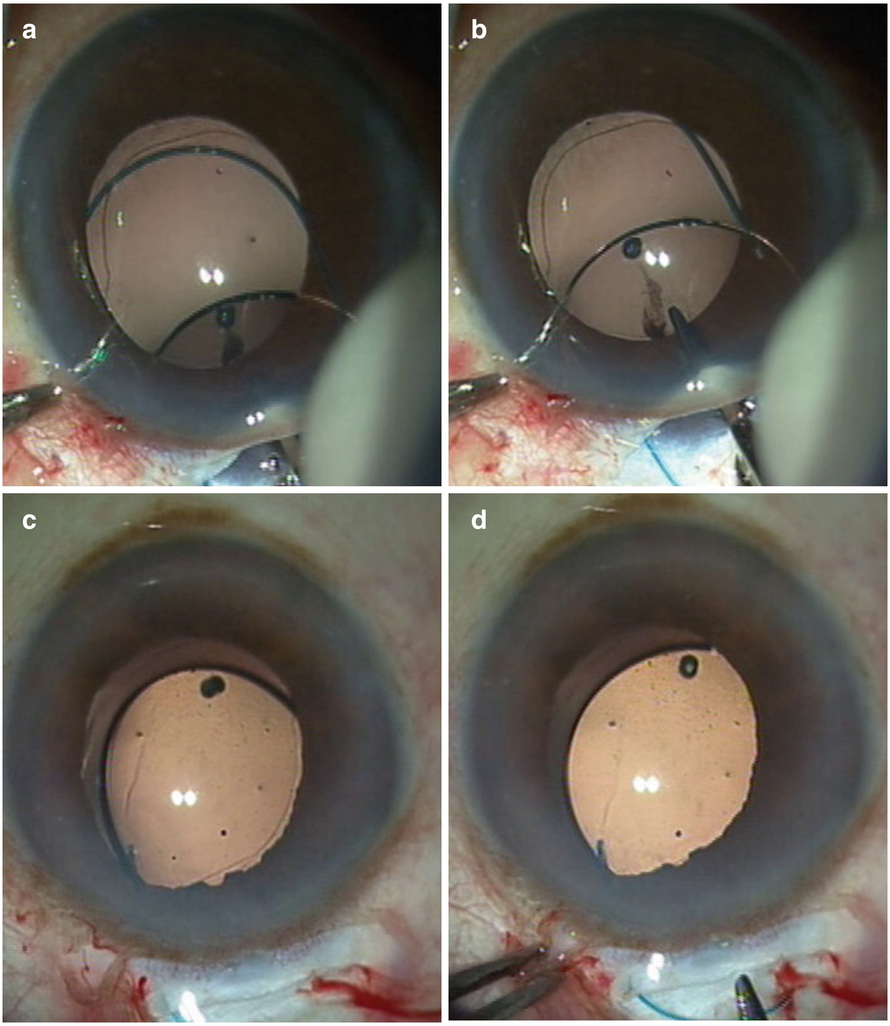

Fig. 2a–h IOL placement using forceps

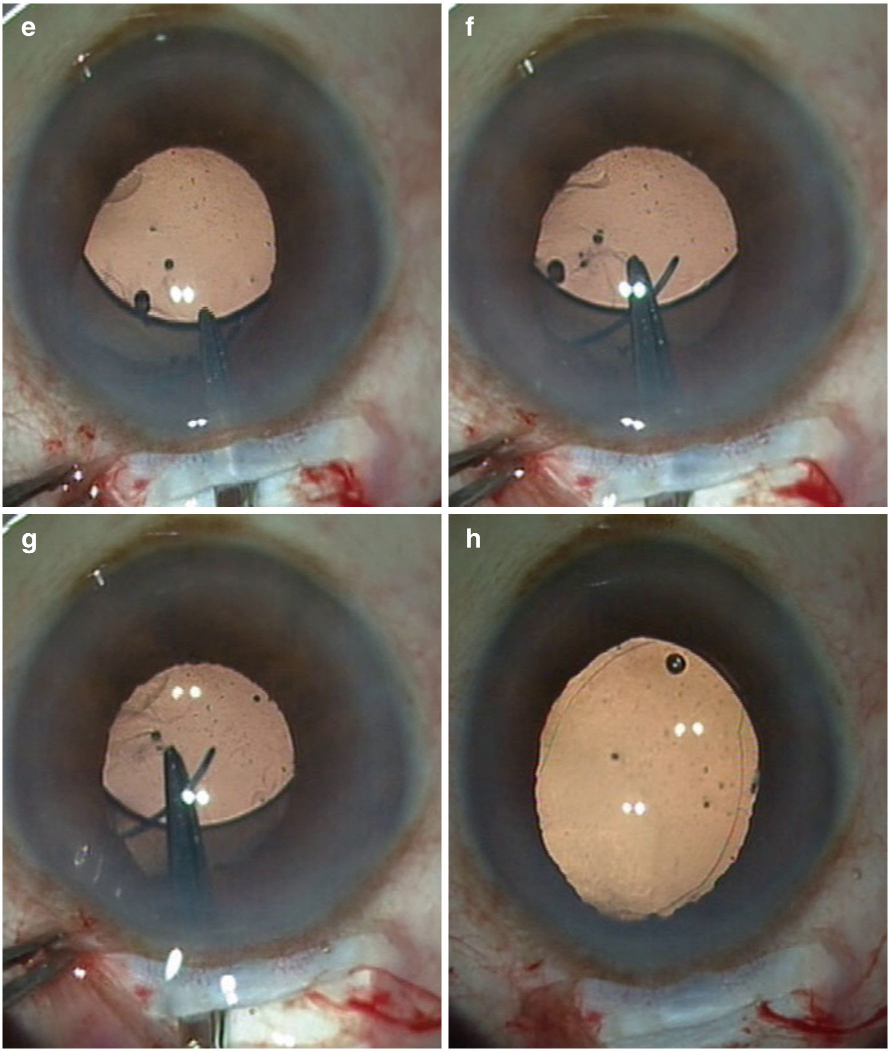

Fig. 2 (continued)

IOLs with a dialing hole can easily be dialed in to the bag by placing sinskey hook in the dialing hole and by rotating the IOL with a downward movement for 2–3 clock hours preferably from 3 o'clock to 6 o'clock hour (Fig. 3a–f).

IOLs without a dialing hole can also be dialed using sinskey hook. Here the sinskey hook is positioned at optic-haptic junction and rotated to 3 o'clock hour over the iris and then rotated with a downward movement aiming the optic-haptic junction to go under rhexis which will eventually take the whole haptic inside. Here the surgeon's forearm position has to change from pronation to a little supination. Care should be taken to inflate the bag with viscoelastics so that the sinskey hook will not tear the posterior capsule.

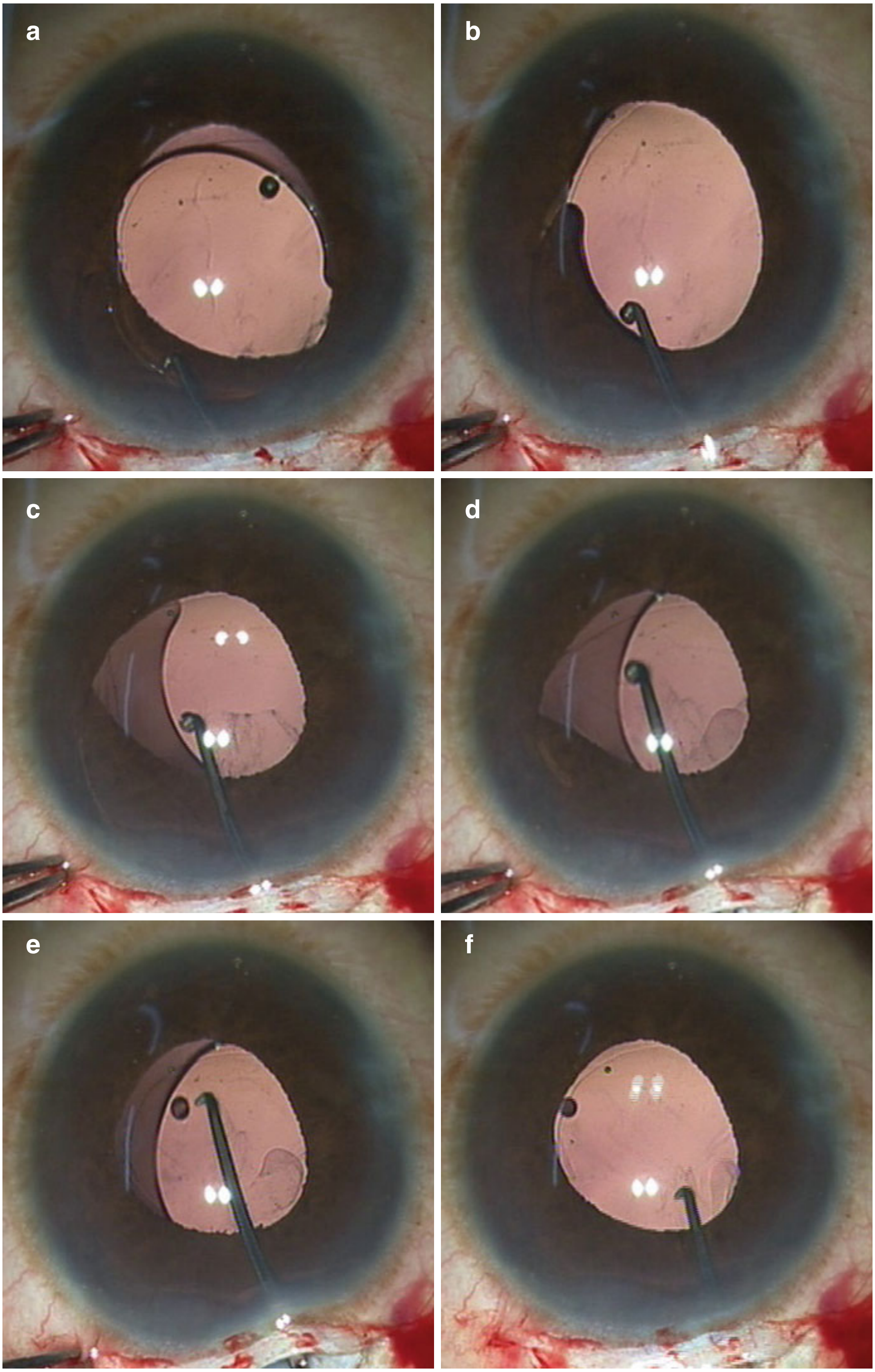

Fig. 3a–f IOL placement using sinskey book

Since, rigid non-foldable IOL placement (compared to preloaded foldable IOL) needs more manipulation and handling of the IOL, care should be taken to minimize the contamination of IOL by conjunctival flora.

Confirmatory Signs

The appearance of stretch lines in the center of the posterior capsule confirms that the capsular bag is maximally distended due to the correct placement of the optics and haptics (Fig. 4b). This sign is particularly useful when the pupil becomes constricted and the haptics are difficult to visualize.

In cases where the haptic is inadvertently in the sulcus, no stretch line will be seen. Another method of determining whether the haptic is in the bag is to visualize the shiny appearance of the anterior capsular rim over the haptic (Fig. 4a) or to use a blunt instrument to push on the IOL to ensure that it is under the capsule.

Technique of IOL Placement in Special Situations

In case of hard or calcified cataract where a large rhexis opening is made or if any dehiscence of posterior capsule happens, positioning IOL haptics in cilary sulcus can be beneficial. It is wise to choose a longer multipiece IOL (13.5 mm) for better centration. A single piece IOL should not be placed in the sulcus.

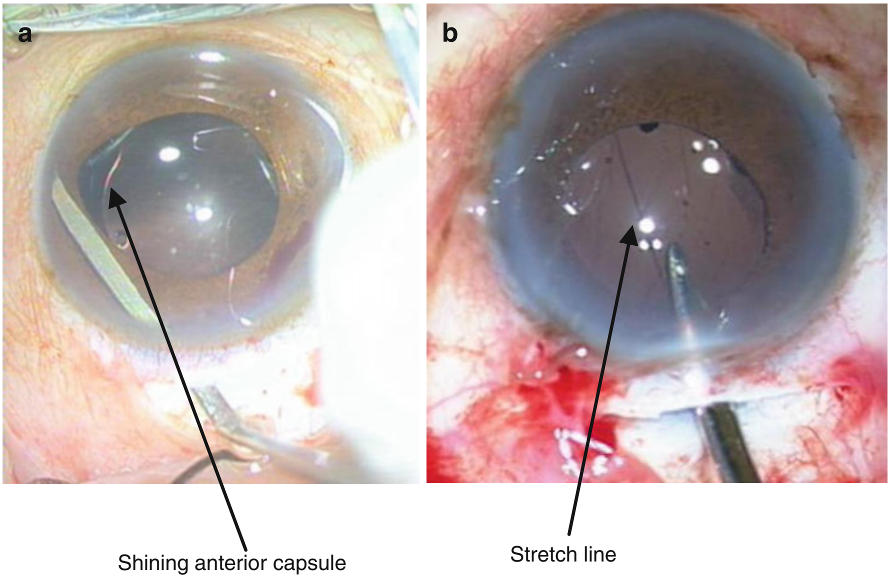

Fig. 4a–b Confirmatory signs of IOL in capsular bag

Posterior Capsular Rupture

The optic is grasped using forceps and the leading haptic is placed in the sulcus by lifting the iris with the haptic and tracing it into sulcus. The optic is then released. The trailing haptic can be placed inside using forceps or a sinskey hook.

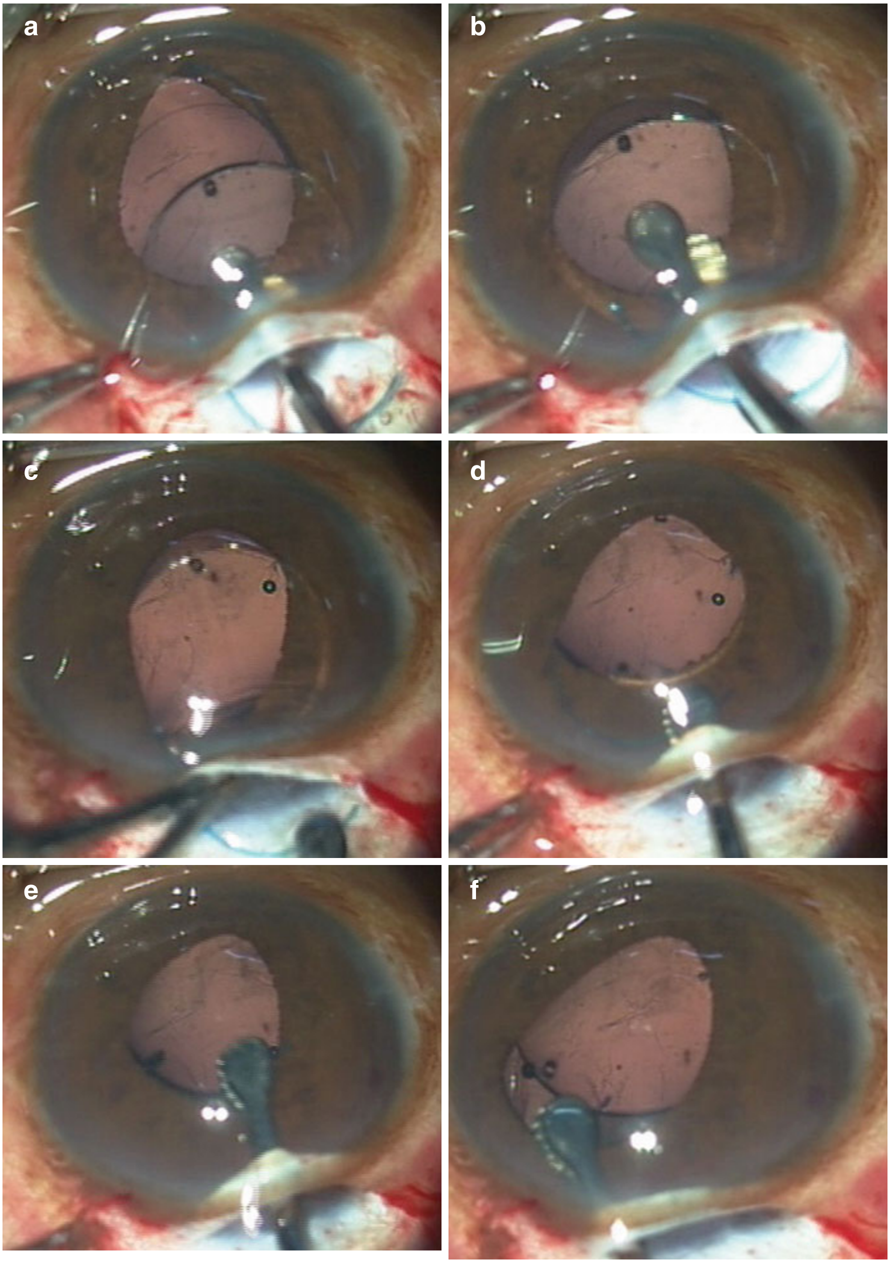

Fig. 5a–j IOL Placement in sulcus

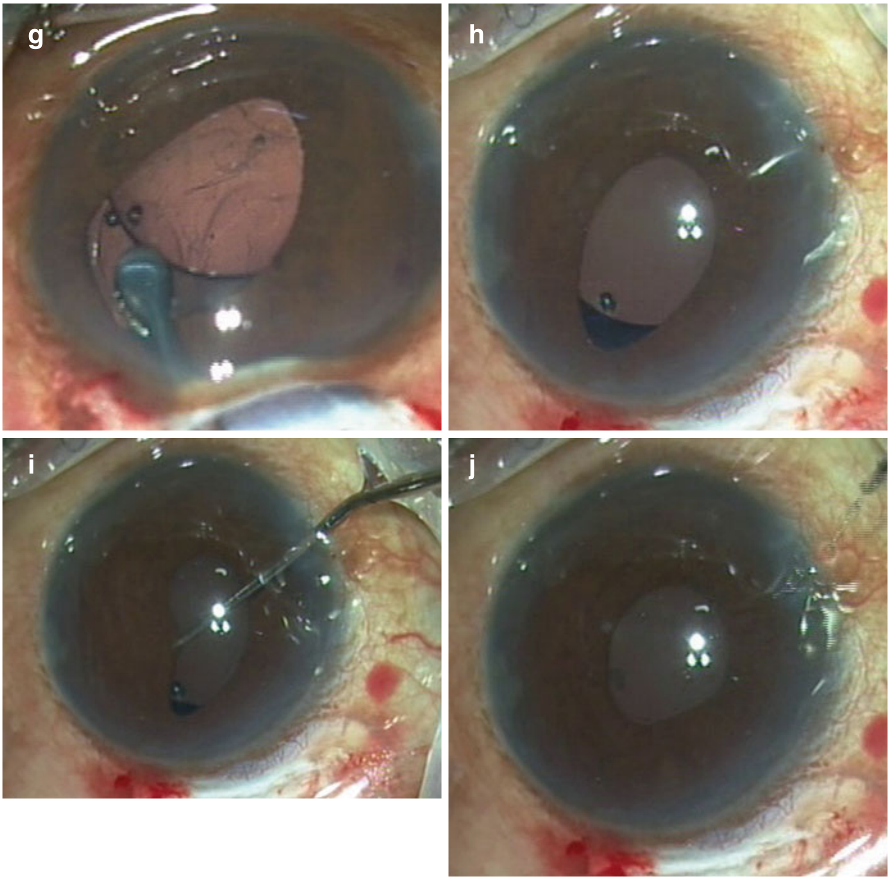

Fig. 5 (continued)

Using the lens holding forceps, the haptic is held near the tip and taken inside by folding over the optic (in the same manner for bag placement) and placed by lifting up the iris with the haptic (Fig. 5a–g).

The IOL can also be dialed in to sulcus using sinskey hook. Here with sinskey hook is positioned at optic-haptic junction and rotated with a slight upward movement. After placing IOL in sulcus, there may be pupillary ovalization near the dialing hole which corresponds to the maximum convex portion of the haptic (Fig. 5h). This could be due to haptic tucking the root of the iris, which can be released by gently pulling the iris with sinskey hook towards the pupil (Fig. 5i). Pupillary peaking due to vitreous should not be confused with this.

Zonular Dialysis

If there is zonular dialysis of more than 2–3 clock hours, capsular supporting devices such as a capsular tension ring, modified Cionni ring, or capsular tension segment should be used and the IOL can be placed in the bag by the usual technique. Whereas in case of a small dialysis less than 2–3 clock hours (Fig. 6a), a multipiece IOL can be placed in the bag by the usual technique and one of the haptics could be dialed and placed at the site of zonular dialysis to tamponade in the area of weakness (Fig. 6b–h). Adding capsular tension devices will aid the centration of the lens and prevent future shrinkage of the capsular bag.

Foldable IOL

In situations where foldable IOLs are chosen, it can be injected in the usual way. But since the wound is large, the chamber may collapse while injecting IOL and increase the chance of posterior capsular rupture. It is better to avoid single-pieced IOL with

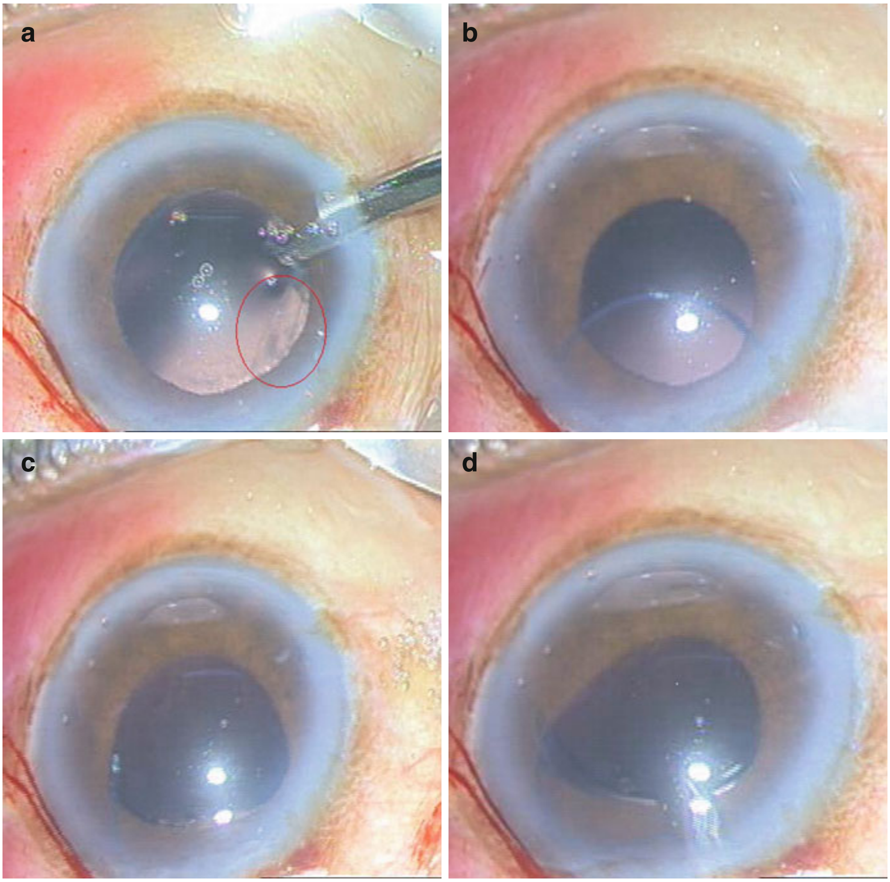

Fig. 6a–h IOL placement in zonular dialysis

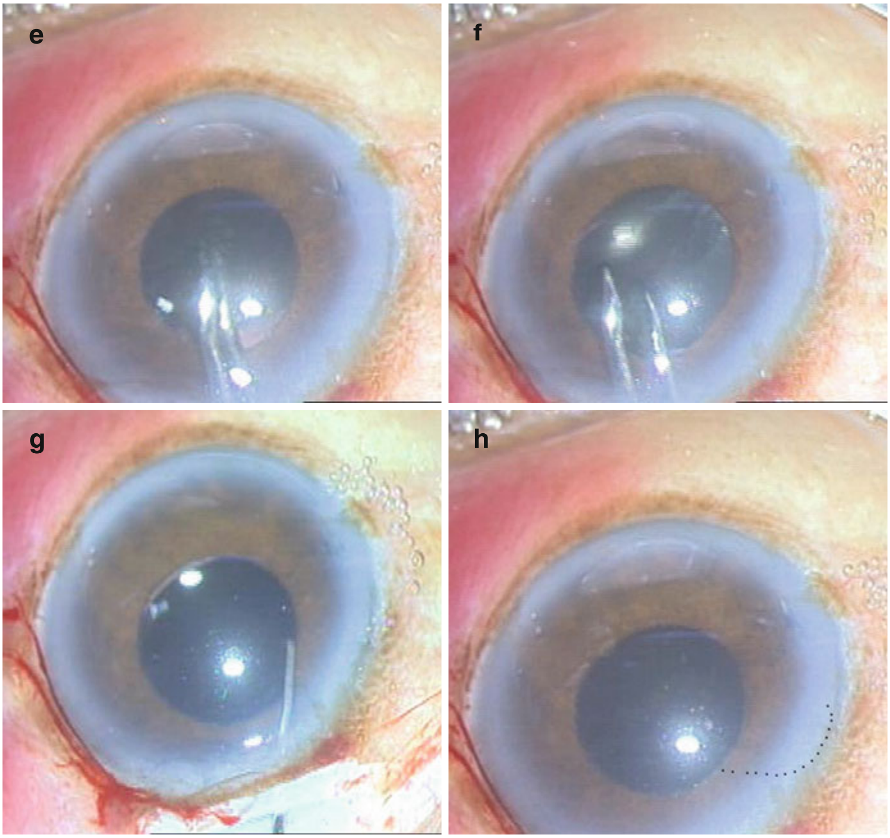

Fig. 6 (continued)

square edge-haptics in SICS, where the rhexis size is large or irregular, due to the possibility of iris contact and chaffing. A multipieced foldable IOL can be implanted manually without loading it (using the same method as that of rigid IOL) or it can be injected in the usual manner preferably using cohesive viscoelastics.

Viscoelastics Removal

Though viscoelastics aid the surgery by maintaining the chamber and protecting the endothelium, it needs to be removed thoroughly before completing the surgery to avoid postoperative complications such as elevated intraocular pressure [5] and capsular bag distension syndrome [6].

Technique and Pearls

Since the wound is larger in SICS, viscoelastics can be easily washed with simcoe cannula.

Initially the viscoelastic under the IOL is removed by placing simcoe cannula beneath the IOL with the aspirating port facing up (Fig. 7a). The viscoelastic is displaced simply by the irrigation and often no active aspiration is needed unless dispersive viscoelastics are used.

This is followed by aspiration of the viscoelastics in the anterior chamber. It is accomplished by irrigating with simcoe cannula in the center of the chamber then aspirating starting from inferior part of anterior chamber and then all around with the aspirating port facing up (Fig. 7b–d).

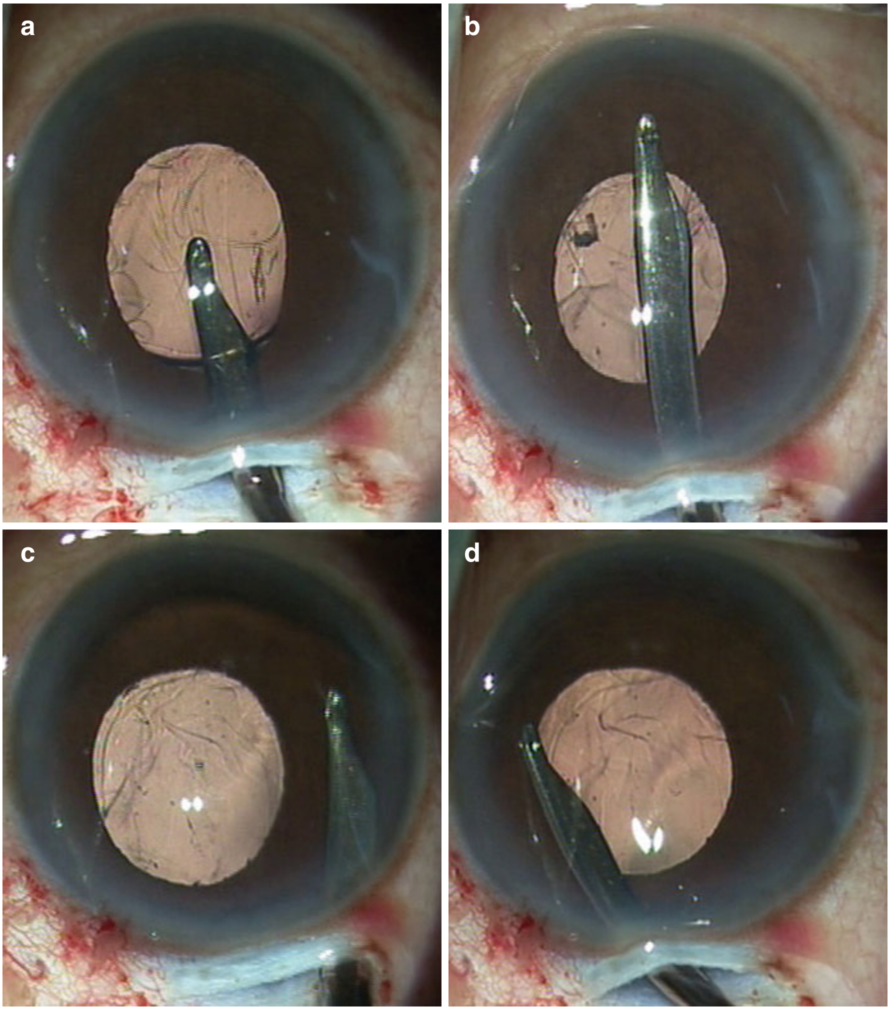

Fig. 7a–d Viscoelastics removal

It would be advisable to use low molecular weight viscoelastics (such as methylcellulose) which is more readily removed from the anterior chamber. More time has to be spent when removing dispersive viscoelastics. If high molecular weight viscoelastics are used, it should be thoroughly removed which can be confirmed on retro-illumination.

References

1. Ram J, Gupta N,Sukhija Js, Chaudhary M, Verma N, Kumar S, Severia S, Out come of cataract surgery with primary intraocular lens implantation in children. BR J Ophthalmol 2011 ; 95: 1086–1090
2. Michelson J , Werner L , Ollerton A, Leishman L, Bodmar Z : Light Scattering and light transmittance in intraocular lenses explanted because of optic opacification. J Cataract Refract Surg 2012 ; 38:1476–1485
3. Chehade M1, Elder MJ.Intraocular lens materials and styles: a review.Australian and New Zealand Journal of Ophthalmology (1997) 25, 255–263
4. Dr.G.Natchiar ; Manual on Small Incision Cataract Surgery, 2nd ed, 2004.
5. Liesegang TJ. Viscoelastic substances in ophthalmology. Surv Ophthalmol 1990; 34:268–293
6. Durak I, Ozbek Z, Ferliel ST, Oner FH, Soylev M. Early postoperative capsular block syndrome. J Cataract Refract Surg 2001;27:555–9.

Wound Closure

Samar K. Basak and Soham Basak

Introduction

There are two (or three) wounds which need to be closed during a a manual SICS procedure, namely:

1. Main wound, i.e., sclerocorneal tunnel
2. Corneal side port(s)
3. Conjunctival flap

Checking the Wound Integrity

Wound leaking is checked at the end of surgery after forming the anterior chamber (AC) with balanced salt solution (BSS) and hydrating the sideport wound.

Technique Gently tap on the dome of the cornea or at the limbus diametrically opposite to the wound with the hydro-cannula. Check the tension status of the AC and wound stability. A well-formed AC gives a firm feeling of resistance and does not give way on applying pressure.

At the same time, the surgeon should look for any leaks from the wound sites.

If folds appear on the Descemet's layer on tapping, it implies that AC is not formed adequately.

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One can also dry the area around the main tunnel or sideport with Weck-cel sponges. Any wetting implies leaking from the wound. Rarely a fluoroscein strip can be used to make the leaks more prominent.

Closing the Sclerocorneal Tunnel

The beauty of the main sclerocorneal tunnel (SC tunnel) lies in its self-sealing nature. A good wound construction is the main prerequisite to ensure a good closure of the wound. This includes making all three parts of the SC tunnel properly – the external sclera groove, the tunnel, and the corneal internal wound.

Ideally, SICS is a sutureless procedure. Just forming the anterior chamber with BSS or Ringer's lactate solution creates a valve effect which opposes the posterior corneal lip to the anterior part of the tunnel, sealing the wound shut. The normal intraocular pressure should be enough to close the inner lip of the corneal valve and keep the tunnel closed.

At the end of the surgery, AC can be formed by either via the main tunnel or through the side port(s) or anterior chamber maintainer (if attached).

Indications for Suturing

There are situations where suturing the tunnel is necessary [1]:

1. A leaking sclerocorneal tunnel.
2. Premature entry or button-holing of the tunnel.
3. Severe positive pressure after making the tunnel.
4. Myopic and pediatric patients because of thinner sclera and lower scleral rigidity – this is to avoid more sagging of the anterior wall of the tunnel and to reduce astigmatism and not necessarily for leaky wound.
5. In combined surgeries (e.g., glaucoma triple procedure – SICS with PCIOL and trabeculectomy).
6. In case of posterior capsular rents with vitreous disturbance, it is advisable to place a suture to avoid any anterior chamber contamination and reduce the risk of postoperative endophthalmitis.
7. To decrease against-the-rule astigmatism in tunnels >6.5 mm or in patients with high preoperative against-the-rule astigmatism.

Types of Suture

1. Vertical
2. Horizontal
   (a) Shepherd's single horizontal suture
   (b) Fine's infinity suture

3. Crossed
4. Box suture

Sutures are usually given with 10-0 monofilament nylon. Some surgeons may prefer absorbable materials like 8-0 Vicryl. But the tensile strength of Vicryl is less than that of nylon. In all cases, the knots must be buried (Watch the video of suturing techniques in SICS).

Vertical Suture

Vertical sutures while easier to apply cause more astigmatism.

Vertical sutures appose the external part of the tunnel only. The tension causes the inner corneal lips to separate and leads to post-op astigmatism. This can be reduced by taking deeper bites in the scleral bed of posterior flap [2]. This anchors the flap to the lower tissue securely. Additionally, it also prevents sagging of the flap, another astigmatism-inducing factor.

Usually, a single suture is enough. But sometimes three or more symmetrical sutures might be required depending on the size of the incision or due to other factors, like poor construction of the tunnel (Fig. 1).

Horizontal Sutures

Horizontal sutures, on the other hand, are more physiological. Being oriented perpendicular to the inner corneal lip, they do not affect it. They close the wound by approximation of the sclera flap with underlying tissue [3].

The following types of horizontal sutures are used.

(a) Shepherd's single horizontal suture
(b) Fine's infinity suture

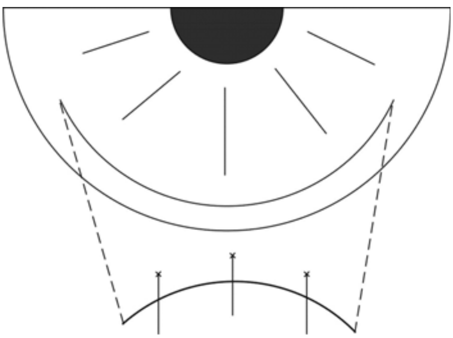

Fig. 1 Vertical sutures

Shepherd's single horizontal suture

This is a vertical mattress suture which is placed horizontally.

It offers two advantages. More area of apposition between the roof and floor of scleral tunnel. Being oriented tangentially to the limbus, the compressive force of the suture does not change the corneal curvature. Hence, astigmatism is minimal (Fig. 2).

The other sutures were developed based on modifications of this suture.

Fine's Infinity Suture

It is just a modification of Shepherd's sutures. To make as the figure of "infinity" (Fig. 3a–c).

Crossed Mattress Sutures

To pass the needle diagonally. The external appearance may be cross (X) type (Fig. 4a) or it appears as two vertical sutures (Fig. 4b). The strength is very good in cross mattress sutures with less sagging of the posterior lip and less astigmatism.

Box Sutures

To pass the needle horizontally against both the lips of the scleral tunnel (Fig. 5).

Tips for Suturing

While suturing, the main idea is approximation of the tissues. Usually one or two interrupted sutures are enough unless there is a lot of positive pressure or vitreous up thrust and the AC is not forming. The sutures should be of correct tension. Too

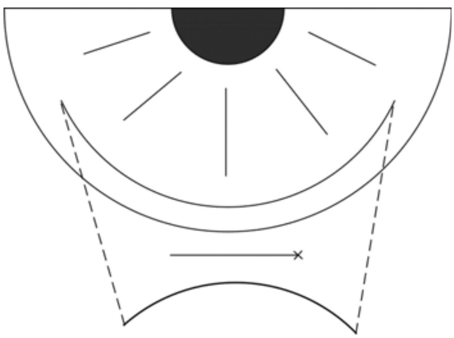

Fig. 2 Horizontal sutures

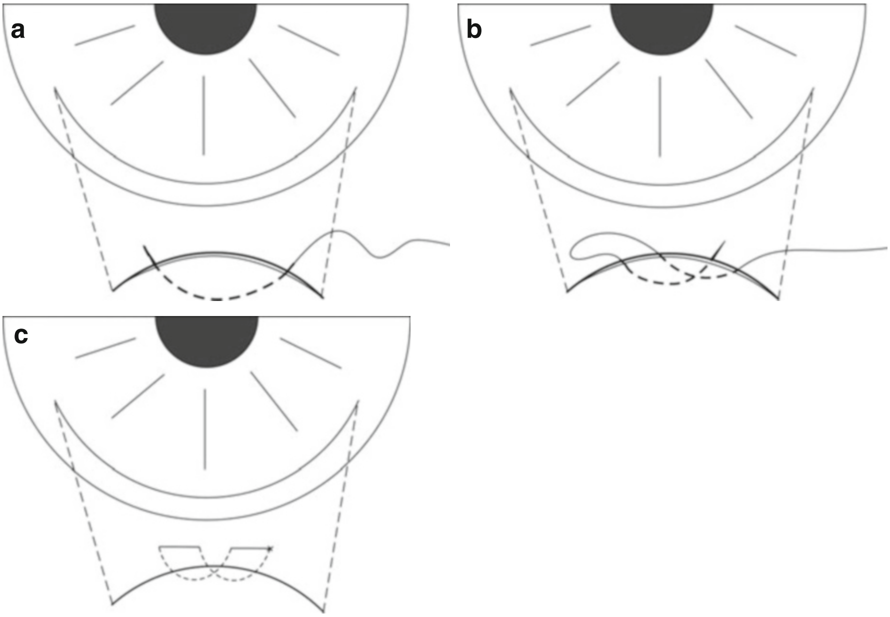

Fig. 3 (**a**) Horizontal infinity sutures. (**b**) Horizontal infinity sutures. (**c**) Horizontal infinity sutures

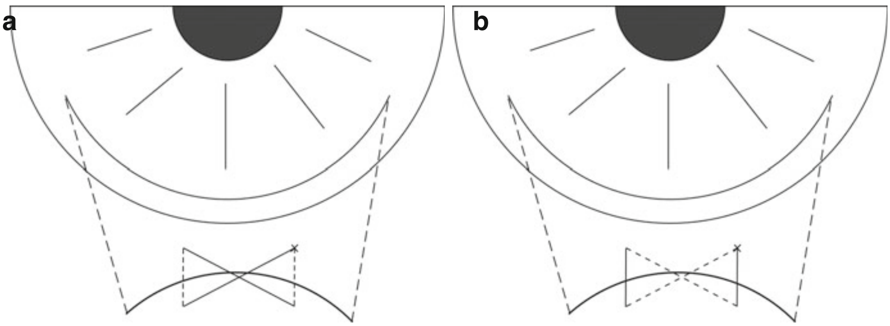

Fig. 4 (**a**) Cross-cross sutures. (**b**) Cross-vertical sutures

loose and the tissues do no appose well; too tight and there is risk of fish-mouthing effect. And both can cause significant astigmatism. Hence, correct tension is of utmost importance (Fig. 6a–c).

It is always better to take bites in the sclera. Corneal (and even limbal) bites usually induce more astigmatism.

As a rule, suture removal is not required in case of main tunnel suturing, except in some cases where the knot(s) may be exposed outside the conjunctiva. Under topical anesthesia, that suture can be removed easily after 4–6 weeks.

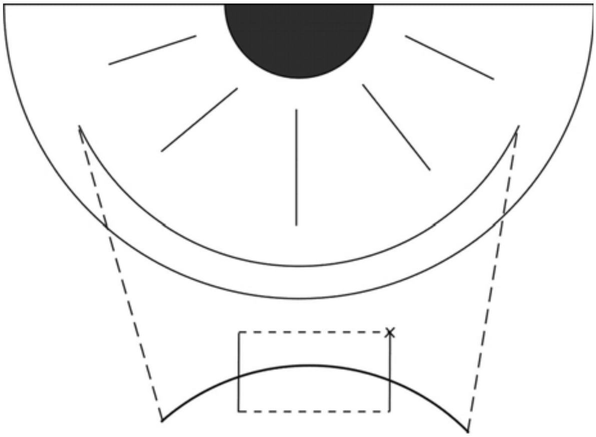

Fig. 5 Box sutures

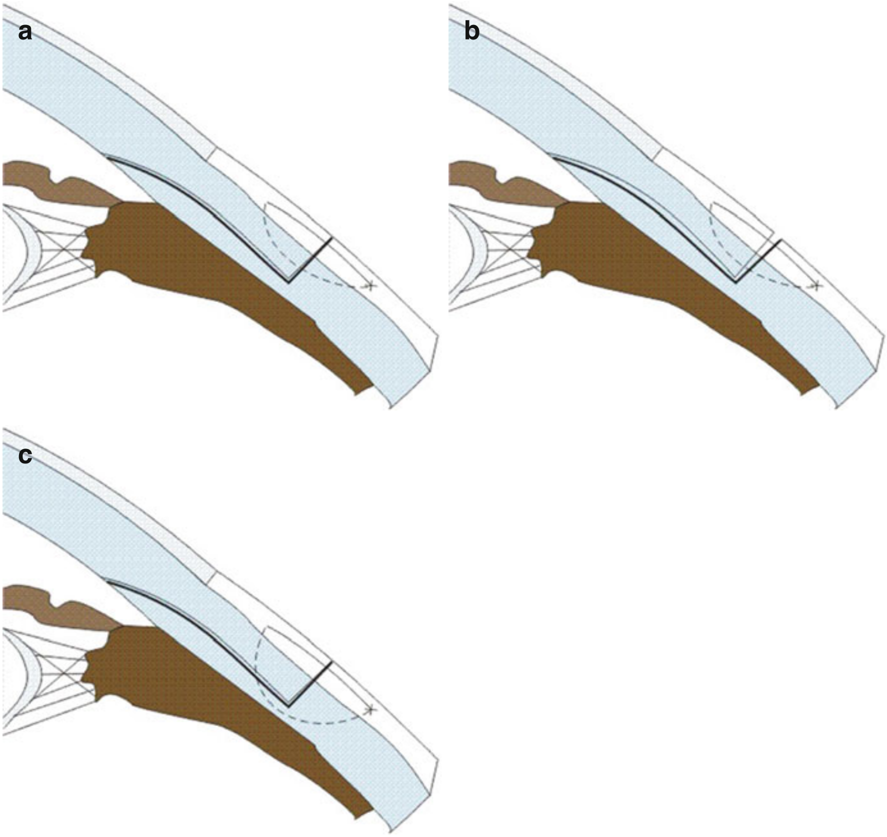

Fig. 6 (**a**) Wrong way to place suture. (**b**) Sagging of wound due to improper depth. (**c**) Right way of giving suture

Side-Port Closure

The side-port wound(s) are closed by hydrating the surrounding corneal stroma.

Technique Take the hydro-cannula and inject small amount of BSS in the stroma gently at the side port. The edema will be visible as a whitening of the stroma. The increased corneal thickness closes the wound. The whitening resolves by itself in few hours.

Complication Be careful to point the cannula away from the Descemet's membrane, by keeping the tip of the cannula at the middle, directing towards limbus (not towards anterior chamber), and avoid injecting with too much force. Otherwise, this can accidentally lead to a Descemet's detachment.

Sutures If the side port is large in size or not closing after adequate hydration or in case of positive pressure, a side-port suture is recommended.

A single interrupted suture with 10-0 nylon is usually sufficient to close the side-port wound. Short bites are taken at about 2/3rd corneal depth. This suture may be removed at a later date after 4–6 weeks or earlier if stable.

Conjunctiva Closure

Conjunctival flap closure is almost always done with wet-field cautery.

Technique The cut ends of the peritomy flap are brought together and held in place with forceps-designed cautery. The ends are then cauterized together. Good closure is very important for temporal sclerocorneal sections where the wound is otherwise exposed with higher infection risks.

Sutures In some cases, the conjunctiva is closed with sutures, e.g., conjunctival shortening for excessive cautery or in glaucoma combined surgeries. Simple interrupted sutures with 8-0 Vicryl are commonly used.

References

1. Natchiar G. Manual on small incision cataract surgery. 2nd ed. Madurai: Aravind Publication; 2004. p. 45–6.
2. Paul KS. Converting to phacoemulsification – a manual for the surgeon in transition. 2nd ed. Thorofare, NJ: Slack inc.; 1988. p. 62.
3. Fine IH, Hoffman RS, Packer M. Chapter 13 – Incision construction. In: Steinert RF, editor. Cataract surgery. 3rd ed. Philadelphia: Saunders Elsevier; 2010.

Post Operative Care in Manual Small Incision Cataract Surgery

Aravind Roy and Prashant Garg

Suture Removal: When and How

The technique of manual small incision cataract surgery (MSICS) is based on the principle of constructing a self-sealing incision which ensures adequate wound integrity without the need for suturing. Therefore, the surgical wound of MSICS routinely does not require suturing. However, if the wound is leaking or the integrity is questionable, surgeon should not hesitate to place sutures to ensure a watertight wound. Suturing of MSICS wound follows the same basic principles as of any other ocular surgery – monofilament nylon suture with a cutting needle of a half circle chord length. Nylon is nonabsorbable and induces little intraocular inflammation. Conventionally it is believed to lose 70 % of its tensile strength by 2 years. In addition, suture removal might be necessary to control suture-induced astigmatism. By convention wound healing takes about 6 weeks; hence, it is customary to remove sutures around 6 weeks postsurgery. However, if a suture is loose, it must be removed early.

Suture removal is an outpatient procedure and can be carried out at slit lamp under topical anesthesia. One must realize that suture removal is an invasive procedure and movement of suture through the tissue can lead to implantation of organisms into ocular tissues or inside the eye. To prevent this it is important to instill 5 % povidone

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iodine in the conjunctival cul-de-sac before suture removal and allow contact time of three minutes. Suture removal must be carried out using sterile instruments. Care should also be taken to prevent passage of exposed part of the suture in ocular tissues. Therefore, always cut the suture near one of the ends, lift the exposed part, and pull it out from other end using sterile pair of forceps. Instill a drop of 5 % povidone iodine at the end of suture removal. Prescribe a broad-spectrum topical antibiotic for 5 days after suture removal. Patients should be informed of warning signals as suture removal can be complicated by wound infection and even endophthalmitis.

Medications: What and How Long

Like any other cataract surgery, logical and appropriate medical therapy plays a vital role in the pre-, peri-, and postoperative care of patients undergoing MSICS. Most of the principles of the use of medications are same as for other forms of cataract surgery. In this section, we shall be revisiting some of the aspects of the use of medications in patients undergoing MSICS. We will be discussing this topic under the following headings:

1. Preoperative medications
2. Perioperative medications
3. Postoperative medications

Preoperative Medications

- Mydriatics: Good pupillary dilatation is very crucial for MSICS. We can use any of the mydriatic agents such as tropicamide or phenylephrine hydrochloride 5 % or cyclopentolate hydrochloride 1 %. Usually three instillations 10 min apart starting an hour before surgery provide good mydriasis.
- Nonsteroidal anti-inflammatory drugs (NSAIDs): Similar to phacoemulsification, NSAIDs such as diclofenac sodium, ketorolac tromethamine, or bromfenac sodium can be used preoperatively to prevent intraoperative constriction of pupil. It is important to instill these drugs at least half an hour before surgery.
- Topical antibiotics: There is no consensus on the preoperative use of antibiotics. Further, there is wide variability in the practice of its use. In our practice, we do not use antibiotics preoperatively.
- Antiseptic preoperative surgical preparations with povidone iodine: Preoperative preparation with povidone iodine is considered as the standard of care for prevention of postoperative endophthalmitis. It has been established conclusively that preoperative instillation of 5 % povidone iodine along with the painting of periocular skin while allowing sufficient contact time prior to surgery disinfects the ocular adnexa thereby reducing the risk of endophthalmitis by a factor of three [1]. Povidone iodine is used universally in ocular surgery unless there is a case of proven allergy to it. There is no consensus regarding the concentration, duration,

and timing of the application; the most common recommended concentration is 5 % [2]. A recent study suggested that repeated irrigation of the surgical field with 0.25 % povidone iodine significantly lowers bacterial contamination rate in the anterior chamber at the completion of surgery [3]. However, this approach is not widely accepted due to the concern of possible intraocular toxicity vis-a-vis the potential benefit. Yet another study found that povidone iodine 5 % solution applied at the conclusion of surgery significantly reduced the number of bacterial colony-forming units and species over the first postoperative day proving that the antimicrobial effect of povidone iodine lasts for at least 24 h after completion of surgery [4]. However, one must keep in mind that we have a poor understanding of the critical number of pathogens below which the risk of endophthalmitis becomes negligible [5]. Overall, the published literature strongly supports the application of povidone iodine to the ocular adnexa and surface before cataract surgery including MSICS.

Perioperative Usage of Antibiotics

To reduce the risk of post operative endophthalmitis (POE), antibiotics have been employed through several routes: topical, subconjunctival, and intracameral either in irrigating fluids or as a bolus at the conclusion of the surgery.

Intracameral injection of antibiotics: After the results of the ESCRS multicenter study on prophylaxis against POE, intracameral injection of cefuroxime in the dose of 10 mg/0.1 ml has become a common practice in the European Union [6]. The study found a significant decrease in the rates of endophthalmitis in patients who were administered intracameral cefuroxime at the end of the surgery along with postoperative topical levofloxacin, compared to patients who received only topical levofloxacin. However, this practice was not widely accepted among physicians of the United States. The concerns for a wider acceptance of this practice were (a) nonavailability of a commercial preparation, (b) risk of dilution errors with consequent toxic anterior segment syndrome, and (c) endothelial toxicity. Intracameral moxifloxacin, a fourth-generation fluoroquinolone with potent bactericidal properties is considered to be a safe and efficacious alternative [7–10]. Although several practice patterns are prevalent with regard to the type of intraoperative use of antibiotics, physicians are advised to make an informed decision as to the regimens of their choice.

Postoperative Medications

- *Anti-inflammatory agents* – Topical corticosteroids and nonsteroidal anti-inflammatory agents (NSAID) are commonly used anti-inflammatory agents in the postoperative period after cataract surgery including MSICS. We can choose from any of the topical corticosteroid preparations including prednisolone, dexamethasone, or betamethasone. However, in a suspected steroid responder, a low-potency steroid such as loteprednol and fluorometholone may be advised. Corticosteroids are tapered over a 4–6 weeks period.

- Topical NSAIDs such as nepafenac, ketorolac tromethamine, and bromfenac act by inhibiting the synthesis and release of prostaglandin E2 thereby reducing intraocular inflammation. Most important application of these NSAIDs is for prevention of postoperative cystoid macular edema. In high-risk cases, these agents are prescribed in thrice-daily doses along with corticosteroids for a period of 4–6 weeks.
- *Antibiotics* – While preoperative use of topical antibiotics has not been conclusively proven to decrease the rate of POE, there is less controversy on the postoperative use of antibiotics. Fluoroquinolones are the most commonly prescribed medications. Newer molecules (moxifloxacin, levofloxacin, gatifloxacin, and besifloxacin) are commercially available as ophthalmic preparations, have a broad spectrum of activity covering both Gram-positive and Gram-negative organisms, and have a good intraocular penetration on topical administration [2]. We do not advocate the use of preparations containing a combination of corticosteroids and antibiotics because corticosteroids need to be tapered over 4–6 weeks in the postoperative period, and antibiotics preferably should not be tapered because of the concern of emergence of drug resistance.
- *Mydriatics and cycloplegics* – These groups of agents are generally not required in an uncomplicated cataract surgery. However, if the anterior chamber reaction is moderate, mydriatic and cycloplegic drugs can be used. Wherever possible, it is important to keep the pupil mobile.
- *Other medications:*
  In addition to the drugs mentioned above, the following groups of agents are used based on the need:
    Anti-glaucoma agents: if intraocular pressure is high
    Topical lubricants: if a patient shows evidence of ocular surface disease

Complications and Management

Manual small incision cataract surgery (MSICS) is a popular surgical technique for the management of cataract especially in the developing world. Higher patient volumes, comparable safety, efficacy, and cost-effectiveness make it a preferred choice over phacoemulsification [11–13]. MSICS is a variant of extracapsular cataract surgery (ECCE), the important differences being construction of a self-sealing scleral tunnel wound, capsulorhexis, in toto prolapse of nucleus through capsulorhexis into anterior chamber, and delivering it out of the eye in a closed chamber state. The surgical steps require considerable manual dexterity [14]. Like any other surgical procedure, MSICS is also associated with complications. In this section, we will discuss various complications associated with MSICS. The topic will be discussed under following headings:

A. Anesthesia-related complications
B. Anterior segment complications
C. Posterior segment complications
D. Surgically induced astigmatism and refractive surprises

Anesthesia-Related Complications

Though the procedure can be performed under any type of anesthesia, most ophthalmologists use peribulbar or retrobulbar anesthesia for MSICS [15]. While both techniques provide required anesthesia and akinesia for this relatively extensive surgery, the following complications are documented (Table 12.1):

- *Globe perforation* – Globe perforation is a dreaded complication of peri-/retrobulbar anesthesia. This complication can occur in any eye, but the risk is high in patients of high myopia associated with an increased axial length, post scleral buckle surgery, uncooperative patients, and improper technique in the hands on an inexperienced anesthetist [16]. The risk of globe perforation is variable and has been reported to be from 1 in 1000 to 1 in 10,000, with the risk of perforation increasing from 10 to 25 times in eyes with axial lengths of >26.00 mm [17]. This complication manifests with sudden severe pain accompanied either by a very high or low intraocular pressure, poor red reflex, subretinal hemorrhage, vitreous hemorrhage, or rhegmatogenous retinal detachment [18].
- *Retrobulbar hemorrhage* – The reported incidence varies from 0.4 to 1.7 %. It necessitates rescheduling of the surgery. The eventual visual outcomes are, however, comparable to an uncomplicated case [19–21].
- *Chemosis and subconjunctival hemorrhage* – These are rather common complications after periocular anesthesia. They are more frequently encountered after peribulbar anesthesia due to anterior spread of anesthetic agent and bleeding from episcleral or conjunctival vessels secondary to needle injury [21, 22]. These complications do not need any treatment except patient reassurance.
- *Injury to the optic nerve* – Injury to optic nerve is a rare but possible complication of peri- and retrobulbar anesthesia. It occurs due to direct needle injury, secondary to hemorrhage or pressure necrosis from accumulation of local anesthetic agent within and around the nerve [22]. Some anatomic studies have found that the risk of optic nerve injury is highest with orbits smaller than 45 mm [23].

Table 12.1 Anesthesia-related complications

Globe perforation
Retrobulbar hemorrhage
Chemosis and subconjunctival hemorrhage
Injury to the optic nerve
Injury to extraocular muscles
Drug allergy

In such situations, it is recommend to use shorter needles of lesser than 31 mm. In addition, the anesthesia must be administered while patient looks in the primary gaze. These suggestions were also validated in CT and MRI studies [24, 25]. In a recent audit of regional ocular anesthesia, needle-related injuries were not found to be linked to axial length and needle length [26].

- *Injury to extraocular muscles* – Injury to the extraocular muscles during periocular anesthesia may occur due to direct needle injury, ischemic necrosis from the volume of anesthetic agent, or its toxicity [27]. The extraocular muscle injury primarily manifests as strabismus or ptosis. One must keep in mind that the injury to extraocular muscles can also occur during the actual surgical procedure. In addition, cataract surgery can unmask a prior latent strabismus. Ptosis may occur due to mechanical damage to levator muscle secondary to insertion of tight speculum or to the placement of the bridle suture [28].
- *Drug allergy* – Allergic responses to local anesthetics are rare but can occur. If a history of allergy to lidocaine or any anesthetic drug is reported, a prior patch testing is recommended [29]. Postanesthetic allergic reaction – The enzyme hyaluronidase has also been attributed to allergic reactions [30]. Further, allergy-like response can also occur due to anxiety or vasovagal response during the procedure [31].

Anterior Segment Complications

We will be discussing intraoperative anterior segment complications (Table 12.2) of this surgery under the following broad categories:

1. Complications related to construction of scleral tunnel incision
2. Complications during prolapse of nucleus through capsulorhexis
3. Complications during extraction of nucleus out of anterior chamber
4. Complications during cortical aspiration
5. Complications during placement of IOL

Complications Related to Construction of Scleral Tunnel Incision

Construction of a self-sealing scleral tunnel incision is the cornerstone of MSICS [32]. A poorly constructed wound not only leads to loss of wound integrity but also provides ingress to microorganisms into the eye. The following complications may occur during construction of scleral tunnel incision:

- Irregular or ragged incision – due to poor blade quality, surgeon inexperience, deep-set eyes, or improper dissection of the tenon's capsule at the site of the incision.

Table 12.2 Anterior segment complications

Wound-related complications	Irregular ragged incision Premature entry Button holing Detachment of scleral spur and tunnel bleed
Intraoperative bleeding	
Corneal complications	Descemet's membrane (DM) detachment
	Corneal edema or striate keratopathy
Capsulorhexis-related complications	Rhexis run out, capsular tear Zonulodialysis
Complications during nucleus delivery through scleral tunnel incision	Iris prolapse Iridodialysis Nucleus drop
Complications during cortical aspiration	Posterior capsular tear Zonulodialysis
IOL-related complications	Decentration Dislocation UGH syndrome

- Button holing of the scleral tunnel – Ideally the plane of sclera tunnel dissection should be mid stromal. A superficial dissection can result in scleral buttonhole with the loss of self-sealing character. Thinner flap and button hole of the superficial scleral flap can also occur while making back-cuts. To prevent these complications, it is important to start scleral dissection at a right depth and keep blade in the same plane as well as parallel to sclera. However, in the event of buttonhole, surgeons can either start fresh dissection at a deeper plane or suture the wound at the end of the surgery.
- Premature entry – If the plane of dissection is too deep, one can inadvertently enter into anterior chamber prior to the completion of dissection of the tunnel. This in turn results in loss of self-sealing character of the wound and wound leak. All such wounds must be carefully examined at the conclusion of the surgery. If the wound is not watertight, one must not hesitate to apply sutures.
- Intraoperative bleeding – The MSICS surgery can get complicated by excessive intraoperative bleeding from the anterior perforating vessels or injury to uveal tissues. If not managed properly, it can also result into postoperative hyphema. It is, therefore, important to identify anterior perforating vessels and cauterize these at point of scleral entry. Similarly, one must ensure to avoid uveal tissue injury during wound construction. Excessive intraoperative bleeding can be managed by air tamponade.
- Detachment of scleral spur – Inappropriate dissection of scleral tunnel can lead to a localized detachment of the scleral spur which in turn leads to wound gape, wound leak, and high surgically induced astigmatism.

Complications During Prolapse of Nucleus Through Capsulorhexis

We all are aware of the advantages of continuous curvilinear capsulorhexis [33, 34]. Classical MSICS incorporates capsulorhexis as one of the important steps of the surgery. However, surgeons need to understand a fundamental difference in the influence of capsulorhexis for phacoemulsification and MSICS. In the former, nucleotomy is performed within the capsular bag, while in the latter, the intact lens nucleus is delivered out through the capsulorhexis before being delivered out of the eye.

Although anterior lens capsule has good elasticity and tensile strength [34, 35], delivering a large nucleus through a small capsulorhexis can put a lot of stress on lens zonules or posterior capsule with its attended complications such as:

- Failure to deliver nucleus
- Zonular dialysis
- Tear in capsulorhexis with consequent extension
- Posterior capsular dehiscence

Complications During Nucleus Delivery Through Sclera Tunnel Incision

Nucleus delivery in MSICS involves engaging nucleus in the internal wound of the scleral tunnel followed by delivery out of the eye by applying pressure on the posterior lip of the external wound. The delivery is facilitated by raised intraocular pressure facilitated by irrigation fluid from anterior chamber maintainer. The success of the procedure depends on the appropriateness of the scleral tunnel [36].

If the wound is not constructed properly, it can result in:

- Iris prolapse
- Iridodialysis
- Hyphema
- Failed delivery
- Posterior capsular tear: If the sheet glide or irrigating vectis is used to facilitate nucleus delivery, then sudden shallowing of anterior chamber can result in posterior capsular tear.
- Endothelial injury: Difficult nucleus delivery can also result in endothelial injury and even DM detachment.
- Injury to iris tissue: Can occur from repeated prolapse and reposition or handling of iris. In cases where the iris is flabby and liable to chaffing with repeated episodes of iris extrusion out of the wound, suturing the wound is a good treatment option.

Complications During Cortical Aspiration

Cortical aspiration is carried out by a single-port aspiration cannula and is facilitated by anterior chamber maintainer. In contrast to phacoemulsification where aspiration pressure is generated by machine, in MSICS cortical aspiration is facilitated by suction of syringe attached to single-port cannula and therefore suffers from disadvantages of being less efficient and less regulated. The following complications can occur during this surgical step:

- Posterior capsular tear or zonular dialysis: This can occur from inadvertently capturing posterior capsule. Management strategies for posterior capsular tear are similar to any other form of extracapsular cataract extraction. It is important to avoid repeated collapse of anterior chamber to avoid extension of the rent and minimize vitreous loss. A good vitrectomy with automated vitrector is necessary. Intraocular lens management is also same as with any other cataract surgery including the selection of intraocular lens, site of placement, and type of fixation. One must ensure that the lens is stable at the end of surgery and the anterior chamber is free of any vitreous strands.
- Incomplete cortical clean-up: Especially the cortical matter present near equator of the capsular bag. Less efficient aspiration system combined with fluid pressure of anterior chamber maintainer is responsible for this complication.

Complications During Placement of IOL

Intraocular lens-related complications are same as with any extracapsular cataract surgery procedure. These are primarily related to asymmetric placement of IOL or wrong choice or selection of IOL and includes:

(a) Decentration
(b) Dislocation
(c) Uveitis glaucoma hyphema syndrome

In addition to the above complications, MSICS can be complicated by the following corneal complications:

- Descemet's membrane (DM) detachment – Compared to phacoemulsification, DM detachment is a relatively more common complication of MSICS. This higher predisposition is due to a larger area of dissection at the main wound and multiple side ports. The detachment can occur at the site of the main wound or side ports including the one used for inserting anterior chamber maintainer. The use of blunt instruments is a potential risk factor for DM detachment. Inserting anterior chamber maintainer while keeping irrigation fluid on can also result in DM detachment. The size of DM detachment varies depending upon the surgical step, time of its identification, and subsequent interventions. If goes unrecognized, it will result in severe postoperative edema depending on the size and location of the detachment. If recognized early, avoiding anterior chamber entry from the affected site will help limit the detachment. To facilitate reattachment, one can fill anterior chamber with air or perfluoropropane gas(C3F8) [37, 38]. Our experience suggests that air descemetopexy is safer and as effective as using C3F8 gas [37, 38].
- Corneal edema or striate keratopathy – The rates of endothelial cell loss between various techniques of extracapsular cataract extraction has been comparable

[39, 40]. The incidence of postoperative corneal edema following MSICS surgery is no different than in phacoemulsification. However, one can encounter this complication in the following clinical scenarios: (a) preoperative compromised corneal endothelium (b) Excessive endothelial cell loss from poor wound, repeated iris prolapse or difficult nucleus delivery. Corneal edema characteristically is most severe in the immediate postoperative period and clears gradually over a period of time without any special interventions. However, if the degree of endothelial injury is severe, the edema might not clear completely requiring endothelial replacement for the restoration of vision [41].

Posterior Segment Complications

Important posterior segment complications (Table 12.3) associated with MSICS are:

- Endophthalmitis – Like any other cataract surgery, MSICS is also associated with the risk of endophthalmitis. The rate of endophthalmitis is variable and depends on the aseptic protocols, intraoperative complications, and surgeons' experience with the procedure [42]. A recent paper reported the incidence of endophthalmitis following MSICS (0.04 %) from a large sample size and with diverse groups of surgeons and found rates to be comparable to phacoemulsification surgery [43]. A variety of microorganisms are reported to cause endophthalmitis, but like phacoemulsification, Gram-positive microorganisms are the most common etiological agents of endophthalmitis following MSICS [44]. A good preoperative evaluation, proper wound construction and closure, and strict asepsis will go a long way in preventing this complication.
- Expulsive hemorrhage – Expulsive hemorrhage is a dreaded complication of extracapsular cataract surgery including MSICS [45]. The condition is diagnosed by sudden loss of red glow, persistently shallow anterior chamber, and prolapse of vitreous/retina/choroid into pupil and wound [45, 46]. Since MSICS is a closed chamber surgery with anterior chamber remaining formed by anterior chamber maintainer, the risk of expulsive hemorrhage is expected to be lower compared to conventional extracapsular cataract extraction surgery [47, 48]. The prognosis following expulsive hemorrhage need not always be poor, if managed

Table 12.3 Posterior segment complications

Endophthalmitis
Expulsive hemorrhage
Vitreous hemorrhage
Choroidal detachment
Retinal detachment
Cystoid macular edema

adequately. This involves timely recognition of the condition, sclerotomy to drain out the hemorrhage, and secondary vitreoretinal procedures [45, 46, 49].

- Vitreous hemorrhage – Vitreous hemorrhage during cataract surgery is extremely rare and is primarily due to globe perforation during peribulbar anesthesia. Suprachoroidal hemorrhage may in addition also cause attendant vitreous hemorrhage. Vitreous hemorrhage in isolation is often mild and self-limiting. A thorough clinical evaluation and serial imaging to ascertain the extent of hemorrhage and associated vitreoretinal pathology is required. Management varies with the extent of hemorrhage and associated vitreoretinopathy and includes observation for spontaneous clearing to vitreoretinal surgery [50].
- Choroidal detachment – Ciliochoridal detachment following MSICS can occur due to a variety of causes that include wound leak, hypotony, severe inflammation, disproportionate vitreous loss, or posterior rotation of the ciliary processes. The condition is characterized by hypotony, shallow anterior chamber, visible dark brown choroids in the vitreous cavity, or evidence of detachment on posterior segment imaging. The management is primarily directed at correcting the hypotony, reformation of anterior chamber, and control of inflammation. It is hypothesized that corticosteroids decrease the uveal inflammation thereby reducing choroidal effusion. In cases refractory to medical management alone, suprachoroidal tap with expression of the fluid is needed [51].
- Retinal detachment – The risks of retinal detachment after MSICS are no different than phacoemulsification. Younger age at surgery, myopia with associated retinal and vitreous degeneration, and intraoperative vitreous loss are important risk factors for postoperative retinal detachment [52, 53]. Fluctuations in the anterior chamber depth with excessive movements of the lens-iris diaphragm can also result in the destabilization of vitreous with traction at the vitreous base with consequent peripheral retinal break and attendant retinal detachment [54].
- Cystoid macular edema – Cystoid macular edema (CME) is a common cause of post-cataract-surgery decrease in vision. The risk factors include posterior capsular rent with vitreous loss, vitreous or uveal incarceration in surgical wounds, excessive postoperative inflammation, and the history of macular edema in the contralateral eye. In addition, other risk factors include old age, diabetes mellitus, and the history of previous ocular inflammation. The condition is diagnosed clinically by slit-lamp biomicroscopy where one needs to look for the evidence of macular edema with cystic spaces or by posterior segment imaging including retinal OCT and fundus fluorescein angiography. Treatment consists of nonsteroidal anti-inflammatory drugs (NSAID's) [55].

Surgically Induced Astigmatism and Refractive Surprises

Since the size of incision in manual small incision cataract surgery is larger than in phacoemulsification, it is always debated if the surgery is associated with higher postoperative astigmatism. However, the risk and the magnitude of the astigmatism are much smaller primarily due to the architecture of the surgical wound and its location farther away from the visual axis. However, the incision size, site, and depth have significant impact on the postoperative astigmatism. MSICS is reported to have a lesser surgically induced astigmatism than conventional extracapsular cataract extraction [56]. Further temporal MSICS has been reported to have lesser surgically induced astigmatism than superior incisions [57, 58].

Conclusions

MSICS is a simple, faster and economically viable alternative for extracapsular cataract extraction in communities where there is a large backlog of cases with limited surgical, economic and technological resources. The post operative care is largely the same as other forms cataract extraction. This technique is easy to impart and acquire. Familiarity with complications and their management will result in outcomes comparable to any other surgical technique of cataract.

References

1. Speaker MG, Menikoff JA. Prophylaxis of endophthalmitis with topical povidone-iodine. Ophthalmology. 1991;98(12):1769–75.
2. Yu CQ, Ta CN. Prevention of postcataract endophthalmitis: evidence-based medicine. Curr Opin Ophthalmol. 2012;23(1):19–25.
3. Shimada H, et al. Reduction of anterior chamber contamination rate after cataract surgery by intraoperative surface irrigation with 0.25% povidone-iodine. Am J Ophthalmol. 2011;151(1):11–7 e1.
4. Apt L, et al. The effect of povidone-iodine solution applied at the conclusion of ophthalmic surgery. Am J Ophthalmol. 1995;119(6):701–5.
5. Ram J, et al. Prevention of postoperative infections in ophthalmic surgery. Indian J Ophthalmol. 2001;49(1):59–69.
6. Endophthalmitis Study Group, European Society of Cataract & Refractive Surgeons. Prophylaxis of postoperative endophthalmitis following cataract surgery: results of the ESCRS multicenter study and identification of risk factors. J Cataract Refract Surg. 2007;33(6):978–88.
7. O'Brien TP, Arshinoff SA, Mah FS. Perspectives on antibiotics for postoperative endophthalmitis prophylaxis: potential role of moxifloxacin. J Cataract Refract Surg. 2007;33(10):1790–800.
8. Galvis V, et al. Cohort study of intracameral moxifloxacin in postoperative endophthalmitis prophylaxis. Ophthalmol Eye Dis. 2014;6:1–4.
9. Matsuura K, et al. Efficacy and safety of prophylactic intracameral moxifloxacin injection in Japan. J Cataract Refract Surg. 2013;39(11):1702–6.
10. Matsuura K, et al. Comparison between intracameral moxifloxacin administration methods by assessing intraocular concentrations and drug kinetics. Graefes Arch Clin Exp Ophthalmol. 2013;251(8):1955–9.
11. Gogate PM, et al. Safety and efficacy of phacoemulsification compared with manual small-incision cataract surgery by a randomized controlled clinical trial: six-week results. Ophthalmology. 2005;112(5):869–74.

12. Riaz Y, de Silva SR, Evans JR. Manual small incision cataract surgery (MSICS) with posterior chamber intraocular lens versus phacoemulsification with posterior chamber intraocular lens for age-related cataract. Cochrane Database Syst Rev. 2013;(10):CD008813.
13. Ruit S, et al. A prospective randomized clinical trial of phacoemulsification vs manual sutureless small-incision extracapsular cataract surgery in Nepal. Am J Ophthalmol. 2007;143(1):32–8.
14. Gogate PM. Small incision cataract surgery: complications and mini-review. Indian J Ophthalmol. 2009;57(1):45–9.
15. Adekoya BJ, et al. Current practice of ophthalmic anesthesia in Nigeria. Middle East Afr J Ophthalmol. 2013;20(4):341–4.
16. Hay A, et al. Needle penetration of the globe during retrobulbar and peribulbar injections. Ophthalmology. 1991;98(7):1017–24.
17. Schrader WF, et al. Risks and sequelae of scleral perforation during peribulbar or retrobulbar anesthesia. J Cataract Refract Surg. 2010;36(6):885–9.
18. Berglin L, Stenkula S, Algvere PV. Ocular perforation during retrobulbar and peribulbar injections. Ophthalmic Surg Lasers. 1995;26(5):429–34.
19. Ahmed S, Grayson MC. Retrobulbar haemorrhage: when should we operate? Eye (Lond). 1994;8(Pt 3):336–8.
20. Edge KR, Nicoll JM. Retrobulbar hemorrhage after 12,500 retrobulbar blocks. Anesth Analg. 1993;76(5):1019–22.
21. Rubin AP. Complications of local anaesthesia for ophthalmic surgery. Br J Anaesth. 1995;75(1):93–6.
22. Kumar CM. Orbital regional anesthesia: complications and their prevention. Indian J Ophthalmol. 2006;54(2):77–84.
23. Katsev DA, Drews RC, Rose BT. An anatomic study of retrobulbar needle path length. Ophthalmology. 1989;96(8):1221–4.
24. Unsold R, Stanley JA, DeGroot J. The CT-topography of retrobulbar anesthesia. Anatomic-clinical correlation of complications and suggestion of a modified technique. Albrecht Von Graefes Arch Klin Exp Ophthalmol. 1981;217(2):125–36.
25. Liu C, Youl B, Moseley I. Magnetic resonance imaging of the optic nerve in extremes of gaze. Implications for the positioning of the globe for retrobulbar anaesthesia. Br J Ophthalmol. 1992;76(12):728–33.
26. Riad W, Akbar F. Ophthalmic regional blockade complication rate: a single center audit of 33,363 ophthalmic operations. J Clin Anesth. 2012;24(3):193–5.
27. Hamed LM. Strabismus presenting after cataract surgery. Ophthalmology. 1991;98(2):247–52.
28. Ropo A, Ruusuvaara P, Nikki P. Ptosis following periocular or general anaesthesia in cataract surgery. Acta Ophthalmol (Copenh). 1992;70(2):262–5.
29. Levy J, Lifshitz T. Lidocaine hypersensitivity after subconjunctival injection. Can J Ophthalmol. 2006;41(2):204–6.
30. Delaere L, et al. Allergic reaction to hyaluronidase after retrobulbar anaesthesia: a case series and review. Int Ophthalmol. 2009;29(6):521–8.
31. Jackson D, Chen AH, Bennett CR. Identifying true lidocaine allergy. J Am Dent Assoc. 1994;125(10):1362–6.
32. Haldipurkar SS, Shikari HT, Gokhale V. Wound construction in manual small incision cataract surgery. Indian J Ophthalmol. 2009;57(1):9–13.
33. Gimbel HV, Neuhann T. Development, advantages, and methods of the continuous circular capsulorhexis technique. J Cataract Refract Surg. 1990;16(1):31–7.
34. Vasavada A, Desai J. Capsulorhexis: its safe limits. Indian J Ophthalmol. 1995;43(4):185–90.
35. Thim K, Krag S, Corydon L. Stretching capacity of capsulorhexis and nucleus delivery. J Cataract Refract Surg. 1991;17(1):27–31.
36. Malik KP, Goel R. Nucleus management with Blumenthal technique: anterior chamber maintainer. Indian J Ophthalmol. 2009;57(1):23–5.
37. Jain R, et al. Anatomic and visual outcomes of descemetopexy in post-cataract surgery descemet's membrane detachment. Ophthalmology. 2013;120(7):1366–72.

38. Chaurasia S, Ramappa M, Garg P. Outcomes of air descemetopexy for Descemet membrane detachment after cataract surgery. J Cataract Refract Surg. 2012;38(7):1134–9.
39. George R, et al. Comparison of endothelial cell loss and surgically induced astigmatism following conventional extracapsular cataract surgery, manual small-incision surgery and phacoemulsification. Ophthalmic Epidemiol. 2005;12(5):293–7.
40. Ganekal S, Nagarajappa A. Comparison of morphological and functional endothelial cell changes after cataract surgery: phacoemulsification versus manual small-incision cataract surgery. Middle East Afr J Ophthalmol. 2014;21(1):56–60.
41. Guzek JP, Ching A. Small-incision manual extracapsular cataract surgery in Ghana, West Africa. J Cataract Refract Surg. 2003;29(1):57–64.
42. Das T. National endophthalmitis survey. Indian J Ophthalmol. 2003;51(2):117–8.
43. Haripriya A, et al. Complication rates of phacoemulsification and manual small-incision cataract surgery at Aravind Eye Hospital. J Cataract Refract Surg. 2012;38(8):1360–9.
44. Pathengay A, et al. Endophthalmitis outbreaks following cataract surgery: causative organisms, etiologies, and visual acuity outcomes. J Cataract Refract Surg. 2012;38(7):1278–82.
45. Sharma YR, Gaur A, Azad RV. Suprachoroidal haemorrhage. Secondary management. Indian J Ophthalmol. 2001;49(3):191–2.
46. Kuhn F, Morris R, Mester V. Choroidal detachment and expulsive choroidal hemorrhage. Ophthalmol Clin North Am. 2001;14(4):639–50.
47. Eriksson A, et al. Risk of acute suprachoroidal hemorrhage with phacoemulsification. J Cataract Refract Surg. 1998;24(6):793–800.
48. Blumenthal M, Grinbaum A, Assia EI. Preventing expulsive hemorrhage using an anterior chamber maintainer to eliminate hypotony. J Cataract Refract Surg. 1997;23(4):476–9.
49. Spaeth GL. Suprachoroidal hemorrhage: no longer a disaster. Ophthalmic Surg. 1987;18(5):329–30.
50. Saxena S, et al. Management of vitreous haemorrhage. Indian J Ophthalmol. 2003;51(2):189–96.
51. Krishnan MM, Baskaran RK. Management of postoperative choroidal detachment. Indian J Ophthalmol. 1985;33(4):217–20.
52. Haug SJ, Bhisitkul RB. Risk factors for retinal detachment following cataract surgery. Curr Opin Ophthalmol. 2012;23(1):7–11.
53. Tielsch JM, et al. Risk factors for retinal detachment after cataract surgery. A population-based case–control study. Ophthalmology. 1996;103(10):1537–45.
54. Coppe AM, Lapucci G. Posterior vitreous detachment and retinal detachment following cataract extraction. Curr Opin Ophthalmol. 2008;19(3):239–42.
55. Sivaprasad S, Bunce C, Wormald R. Non-steroidal anti-inflammatory agents for cystoid macular oedema following cataract surgery: a systematic review. Br J Ophthalmol. 2005;89(11):1420–2.
56. Ang M, Evans JR, Mehta JS. Manual small incision cataract surgery (MSICS) with posterior chamber intraocular lens versus extracapsular cataract extraction (ECCE) with posterior chamber intraocular lens for age-related cataract. Cochrane Database Syst Rev. 2012;(4):CD008811.
57. Mallik VK, et al. Comparison of astigmatism following manual small incision cataract surgery: superior versus temporal approach. Nepal J Ophthalmol. 2012;4(1):54–8.
58. Kongsap P. Visual outcome of manual small-incision cataract surgery: comparison of modified Blumenthal and Ruit techniques. Int J Ophthalmol. 2011;4(1):62–5.

Conversion from Phacoemulsification to MSICS

John Welling, John Y. Kim, and Maria M. Aaron

Indications for Conversion

While phacoemulsification is considered the gold standard of cataract extraction in the developed world, certain intraoperative situations may necessitate cataract removal by alternative manual methods. Indications for conversion to manual cataract extraction may include very dense nucleus requiring prolonged phacoemulsification, posterior extension of capsulorhexis, posterior capsular tear, zonular loss, shallow anterior chamber, miosis, corneal thermal burn, or equipment malfunction [1]. In the developed world, the traditional practice under such circumstances has been to convert to extracapsular cataract extraction (ECCE). Over the past decade, however, the successful implementation of MSICS for high quality, low-cost cataract surgery in the developing world has generated increasing interest in its use even in developed settings when phacoemulsification may be unsafe or unavailable.

ECCE Versus MSICS

Conventional ECCE and MSICS are both extracapsular methods of cataract extraction. These techniques are differentiated by the size and location of the main wound and by the need for wound suturing. ECCE was introduced in the early 1980s, with

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the development of microsurgical instrumentation. In ECCE, a clear corneal wound approximately 12 mm in length is constructed, allowing expression of the nucleus and aspiration of cortical material, leaving an intact posterior capsular bag. A posterior chamber intraocular lens is then placed in the bag and the large corneal wound is sutured [2, 3]. As microsurgical technology advanced, this procedure was eventually replaced by phacoemulsification – the breakdown of lens material using an ultrasonic probe through a much smaller incision [4, 5]. Although no longer routinely utilized as a primary procedure for standard cataract extraction, ECCE remains one possible means for addressing lenses not suitable for phacoemulsification.

Manual small incision cataract surgery was first described by Blumenthal as an intermediate step for surgeons wishing to convert from ECCE to small incision sutureless phacoemulsification [6]. In 2000, Ruit described a manual sutureless small incision technique specifically designed to provide low-cost, high-quality surgery in the developing world [7]. These and similar techniques, as described in previous chapters, have become widely popularized throughout the developing world as cost-effective solutions to the increasing backlog of global cataract blindness. Growing experience – largely from high-volume centers in India and Nepal – suggests that manual small incision cataract surgery (MSICS) offers several advantages over ECCE and in fact delivers visual outcomes and safety profiles nearly identical to those for phacoemulsification at only a fraction of the cost [8–13].

Three randomized controlled trials comparing outcomes for planned ECCE and MSICS cases all showed better uncorrected visual acuity in the MSICS group at 6 weeks follow-up [8–10]. This was associated with less surgically induced astigmatism (SIA) in the MSICS group compared to ECCE [10]. Aravind Eye Hospital retrospectively compared complication rates for phacoemulsification, ECCE, and MSICS over a 12-month period, for surgeons of varying skill levels. Of the nearly 80,000 cases reviewed, 53,603 cases were MSICS, 20,438 were phacoemulsification, and 5,736 were ECCE. For all surgeon skill levels, ECCE had the highest complication rates while MSICS had the lowest. This effect may have been amplified by the fact that MSICS is the manual procedure of choice at Aravind while ECCE tends to be reserved for cases deemed too risky for either of the small incision techniques [11]. Other reported advantages of MSICS over ECCE include smaller self-sealing wounds, shorter operative time, shorter overall postoperative recovery, and lower overall cost [14, 15]. While no randomized controlled studies have directly compared ECCE and MSICS in the setting of unplanned conversion from phacoemulsification, because the advantages of MSICS arise primarily from its self-sealing sclerocorneal wound – a constant factor in both planned and unplanned settings – many if not all of these advantages may apply in both situations.

Additional Anesthesia

For nearly a century, retrobulbar anesthesia was the anesthetic of choice for cataract surgery. Although this technique provides excellent anesthesia and akinesia, it has also been associated with several sight-threatening and even life-threatening complications [16]. Over the past several decades, the need for safer, less invasive anesthesia techniques has been recognized. Peribulbar anesthesia, first described in the 1980s, was shown to be equally effective and safer than retrobulbar anesthesia and subsequently became widely utilized [17, 18]. Sub-Tenon's anesthesia, introduced in the 1990s, has also been shown to be safe and effective for ECCE, phacoemulsification, and MSICS [19–21]. As surgical techniques have continued to advance, with ever-smaller wound sizes, more and more surgeons are adopting topical anesthesia techniques with or without supplemental peribulbar, subconjunctival, sub-Tenon's, or intracameral anesthesia. Patient satisfaction with topical anesthesia for phacoemulsification has been comparable to that for retro- or peribulbar injection [22–26].

Conversion from phacoemulsification to MSICS may or may not require supplemental anesthesia. Clearly, if phacoemulsification was initiated under retrobulbar or peribulbar anesthesia, then no additional anesthesia is needed before converting to MSICS. While there are no studies comparing various anesthesia techniques specifically in the setting of conversion from phaco to unplanned MSICS, a number of studies evaluating various anesthesia techniques for planned ECCE and MSICS offer valuable, transmittable insights. In 2005, Parkar and colleagues analyzed safety and efficacy outcomes in a randomized comparison of peribulbar and sub-Tenon's anesthesia for patients undergoing MSICS. They found no significant difference in pain during or after surgery, no difference in intraoperative or postoperative complications, and no difference in visual acuity between the two groups. In fact, administration of sub-Tenon's anesthesia (after instillation of an anesthetic drop) was found to be more comfortable for patients compared to peribulbar injection [21].

In 2009, Gupta reported the successful use of topical 2 % lignocaine gel with intracameral 2 % lignocaine for MSICS with 91 % of patients reporting mild to no pain [26]. This study, though promising, was controversial as intracameral lignocaine has been shown to cause transient endothelial cell toxicity in animal models. In 2012, Mithal et al. conducted a prospective interventional series evaluating patient comfort undergoing MSICS with topical lignocaine gel only. They found that of 128 patients, 95 % reported mild to no pain. Reported advantages of topical anesthesia included decreased patient anxiety, immediate visual recovery, full motility, and no risk of retrobulbar complications [27]. While early reports from experienced MSICS surgeons are promising, further studies will help to better establish the safety and efficacy of topical anesthesia alone for planned MSICS.

In the setting of unplanned conversion from phaco to MSICS, the reliability of topical anesthesia alone (as performed for routine phacoemulsification) is less certain as the added surgical time and need for a sclerocorneal tunnel will likely require more robust, targeted anesthesia to ensure patient comfort and safety. Accordingly, if the possibility of conversion to MSICS is anticipated before starting the case, we recommend using retrobulbar, peribulbar, or sub-Tenon's anesthesia, with peribulbar or sub-Tenon's preferred due to their comparable efficacy and better safety profiles.

If, however, conversion to MSICS is unexpected and only topical anesthetic was used initially, we suggest supplementation with either subconjunctival 2 % lignocaine with epinephrine (at the site where the sclerocorneal tunnel will be created) or sub-Tenon's block (may be done in any quadrant, but inferonasal is preferred).

Sub-Tenon's block is performed by incising conjunctiva and tenon's down to bare sclera, bluntly dissecting posteriorly (careful to avoid muscle insertions) and then injecting standard block solution posterior to the equator in the sub-Tenon's space using a curved or angled cannula [28]. Transconjunctival peribulbar block (*without* epinephrine) may also be performed intraoperatively (transcutaneous injection becomes more cumbersome once the patient has been draped), though this may be more uncomfortable for the patient.

Incision

As has been described in earlier chapters, the success of MSICS hinges on proper wound construction. When converting from phacoemulsification to MSICS, care must be taken to ensure that wound site, dimensions, architecture, and stability are optimized. As opposed to planned MSICS, where the surgeon may position the sclerocorneal wound to neutralize preexisting astigmatism, when converting from phacoemulsification, site selection will depend primarily on the position of the initial phaco wound. In order to ensure integrity and stability of the sclerocorneal wound, the main phaco wound should be sutured closed then completely avoided. As the sclerocorneal wound should be about 4 clock hours wide at the limbus, the surgeon will need to position this wound approximately 90° away from the main phaco incision in order to avoid it. Usually this will mean if the surgeon initiated phacoemulsification temporally, then MSICS will be performed superiorly and vice versa. While this may result in suboptimal astigmatic effect (assuming the initial phaco wound was positioned to minimize astigmatism), wound integrity – of paramount importance – will be maintained. The ability to dictate sclerocorneal wound position (and its subsequent astigmatic effect) may be one argument to err on the side of planned MSICS, rather than phaco with possible conversion, if the likelihood of conversion is felt to be high.

Capsule Opening

An adequate capsular opening is another vital component of successful conversion from phacoemulsification to MSICS. Continuous curvilinear capsulorhexis (CCC) is the standard capsular opening for phacoemulsification. When feasible, this is also the preferred method for MSICS, as maintaining an intact capsular rim makes the remaining steps easier and safer. While the capsulorhexis size required for successful MSICS will vary depending on the size of the nucleus, a rule of thumb is 5.5 mm or larger. If the initial capsulorhexis size is inadequate, it should be enlarged. In experienced hands, one option is to nick the existing capsular rim with a cystotome and then using this capsular tag to initiate a second capsulorhexis [29] thus widening the capsular opening while maintaining a stable, continuous anterior capsular rim (Fig. 1a). Another option is to use intraocular scissors or a cystotome to create three to five radial relaxing incisions around the capsulorhexis rim (Fig. 1b). Lastly, a can-opener technique may be employed, using cystotome or bent 26-gauge needle to make many small, connecting tears in the capsule (Fig. 1c). The advantages of this technique are that it can be performed when visibility is poor, it can be

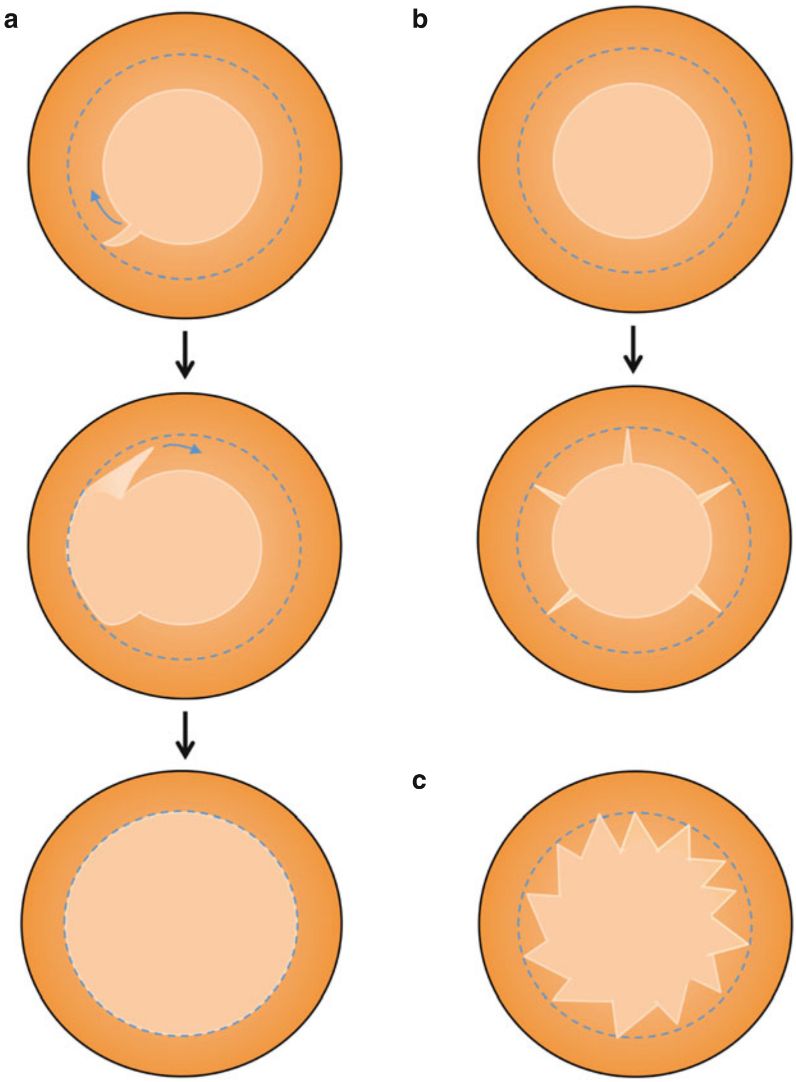

Fig. 1 (**a**–**c**) Techniques for enlarging the capsulorrhexis when converting from phacoemulsification to MSICS. (**a**) Nick the capsulorrhexis edge to create a new flap, then tear this flap 360 degrees; (**b**) Create a series of relaxing incisions in the capsular bag; (**c**) Employ can-opener technique

performed quickly, and it is less technically challenging than CCC. Disadvantages include higher risk of anterior capsular tear with posterior extension, higher risk of intraocular lens (IOL) decentration, and higher PCO rates [30, 31].

Prolapsing Lens with Loose Zonules or Torn Capsule

When zonular compromise or capsular tear is suspected, steps should be taken to facilitate nuclear delivery while minimizing stress on these structures. If nuclear delivery is hindered by a small pupil, then the pupil should be enlarged. This can be accomplished with bimanual pupillary stretching, iris hooks, or relaxing sphincterotomies. If the capsular opening is too small, this too should be enlarged, as described above. The scleral tunnel should also be widened as needed to minimize resistance to nuclear prolapse [29, 32]. In cases of known or suspected posterior capsular tear, cortex removal should be performed with low irrigation, under the cover of viscoelastic, to avoid extension of the tear. In cases of mild to moderate zonular instability, placement of a capsular tension ring (CTR) can be considered, provided that the capsular bag is intact. If zonular dehiscence is more extensive (4 clock hours or more), a scleral-fixated capsular tension segment (CTS) or modified capsular tension ring (MCTR) is indicated [33]. In these cases, attempts should not be made to dial the nucleus out of the bag as this may result in total dislocation of the lens to the posterior pole. Lenses with severe zonular dehiscence are most safely addressed by a vitreoretinal surgeon via a pars plana approach. Where retina support is unavailable, intracapsular extraction with ACIOL or secondary placement of an iris or scleral-fixated IOL is an option.

Alternative nucleus delivery techniques may also employed to reduce stress on weak zonules or a compromised capsule. Venkatesh described a bimanual prolapse technique using a Sinskey hook and a cyclodialysis spatula. The Sinskey hook is placed through the scleral tunnel and used to gently displace the nucleus toward 6 o'clock. Once the superior pole of the nucleus is visualized, the cyclodialysis spatula is positioned beneath the nucleus via the side port incision. Employing the spatula as a fulcrum, the Sinskey hook is used to dial the nucleus out of the capsular bag. This method allows rotational forces to be absorbed by the cyclodialysis spatula, minimizing stress on the capsule and zonules [29]. Variations of this method have been described using different instruments. Fry described a similar technique known as phaco sandwich, utilizing an irrigating vectis for his supporting instrument rather than a cyclodialysis spatula [34].

Anterior Vitrectomy

The prolapse of vitreous into the anterior chamber requires careful management to avoid potentially devastating consequences. Incarceration of vitreous in the anterior chamber can result in vitreoretinal traction and subsequent cystoid macular edema or retinal detachment. Vitreous in the surgical wound can result in wound leak and endophthalmitis. Automated, high-speed vitrectomy is the procedure of choice in these settings. Manual cellulose sponge vitrectomy, once regarded as viable option in the absence of an automated vitrector, has fallen out of favor due to the retinal traction induced each time the sponge is lifted for cutting of the vitreous [35]. In the setting of conversion from phacoemulsification to MSICS, an automated vitrector is usually available and should be used. Dilute Kenalog (10:1) injected into the anterior chamber is useful to highlight vitreous, thereby facilitating its removal. A secondary benefit is the anti-inflammatory effect of Kenalog, which in theory may reduce the risk of postoperative cystoid macular edema [36]. After thorough automated vitrectomy (preferably confirmed with Kenalog staining), cellulose sponges may be used to extract any remaining vitreous from the external wound, since its adhesions to the retina have been cut [37]. Theoretically, this may help reduce the risk of wound leak and endophthalmitis.

IOL Choice

Worldwide, the rigid 3-piece polymethyl methacrylate (PMMA) intraocular lens is the most commonly used IOL for MSICS. The advantages of PMMA include low cost, good biocompatibility, and relatively low incidence of dysphotopsias. The three-piece design allows for safe, stable implantation in either the capsular bag or ciliary sulcus, depending on the surgical scenario. These IOLs range from 5.00 to 6.5 mm in diameter, with the 6.0 mm size being most commonly used. This optic size is usually well-accommodated by the external incision of the scleral tunnel which is typically 6.5 to 7.0 mm in length. Smaller diameter IOLs (5.0–5.5 mm) may produce more dysphotopsias under scotopic conditions, due to exposure of the optic edge when the pupil is more dilated [38].

When performing phacoemulsification, most surgeons use a foldable, single-piece acrylic or silicone IOL to allow for insertion through a small incision. These single-piece IOLs can also be used when converting from phacoemulsification to MSICS, as long as the posterior capsule remains intact and the lens-zonule complex is sufficiently stable. In the case of a torn posterior capsule, however, generally a 3-piece IOL should be placed in the ciliary sulcus. An exception would be in the case of a stable round hole, without vitreous loss. In this case, placement of a single-piece IOL in the capsular bag can be considered. A single-piece IOL should never be placed in the ciliary sulcus as this can lead to iris chafing and subsequent uveitis-glaucoma-hyphema (UGH) syndrome [39]. If zonular instability is detected, placement of a capsular tension ring (CTR) should be considered prior to IOL placement in either the bag or sulcus [33].

When sulcus IOL placement is needed, it is important to adjust the lens power calculation to account for the relatively anterior position of the sulcus compared to the capsular bag. Failure to account for this change in effective lens position will result in myopic surprise. Several studies have shown that the power of the sulcus-based IOL should be between 0.5 D and 1.0 D less than the power calculated for in-the-bag placement [40, 41].

References

1. Mercieca K, Brahma AK, Patton N, McKee HD. Intraoperative conversion from phacoemulsification to manual extracapsular cataract extraction. J Cataract Refract Surg. 2011;37(4):787–8.
2. Apple DJ, Solomon KD, Tetz MR, Assia EI, Holland EY, Legler UF, et al. Posterior capsule opacification. Surv Ophthalmol. 1992;37(2):73–116.
3. Duane T. Textbook of ophthalmology. Philadelphia: Lippincott-Raven; 1986. p. 25.
4. Norregaard JC, Bernth-Petersen P, Bellan L, Alonso J, Black C, Dunn E, et al. Intraoperative clinical practice and risk of early complications after cataract extraction in the United States, Canada, Denmark, and Spain. Ophthalmology. 1999;106(1):42–8.
5. Mehta KR, Mehta C. Teaching standards in phacoemulsification. How realistic are they?. Symposium on phacoemulsification VI ophthalmological congress of SAARC countries; 20 Nov 1999; Kathmandu; 1999.
6. Blumenthal M, Ashkenazi I, Assia E, Cahane M. Small-incision manual extracapsular cataract extraction using selective hydrodissection. Ophthalmic Surg. 1992;23(10):699–701.
7. Ruit S, Paudyal G, Gurung R, Tabin G, Moran D, Brian G. An innovation in developing world cataract surgery: sutureless extracapsular cataract extraction with intraocular lens implantation. Clin Experiment Ophthalmol. 2000;28(4):274–9.
8. Gogate PM, Deshpande M, Wormald RP, Deshpande R, Kulkarni SR. Extracapsular cataract surgery compared with manual small incision cataract surgery in community eye care setting in western India: a randomised controlled trial. Br J Ophthalmol. 2003;87(6):667–72.
9. George R, Rupauliha P, Sripriya AV, Rajesh PS, Vahan PV, Praveen S. Comparison of endothelial cell loss and surgically induced astigmatism following conventional extracapsular cataract surgery, manual small-incision surgery and phacoemulsification. Ophthalmic Epidemiol. 2005;12(5):293–7.
10. Gurung A, Karki DB, Shrestha S, Rijal AP. Visual outcome of conventional extracapsular cataract extraction with posterior chamber intraocular lens implantation versus manual small-incision cataract surgery. Nepal J Ophthalmol. 2009;1(1):13–9.
11. Haripriya A, Chang DF, Reena M, Shekhar M. Complication rates of phacoemulsification and manual small-incision cataract surgery at Aravind Eye Hospital. J Cataract Refract Surg. 2012;38(8):1360–9.
12. Venkatesh R, Tan CS, Sengupta S, Ravindran RD, Krishnan KT, Chang DF. Phacoemulsification versus manual small-incision cataract surgery for white cataract. J Cataract Refract Surg. 2010;36(11):1849–54.
13. Ruit S, Tabin G, Chang D, Bajracharya L, Kline DC, Richheimer W, et al. A prospective randomized clinical trial of phacoemulsification vs manual sutureless small-incision extracapsular cataract surgery in Nepal. Am J Ophthalmol. 2007;143(1):32–8.
14. Tabin G, Chen M, Espandar L. Cataract surgery for the developing world. Curr Opin Ophthalmol. 2008;19(1):55–9.
15. Gogate PM, Kulkarni SR, Krishnaiah S, Deshpande RD, Joshi SA, Palimkar A, et al. Safety and efficacy of phacoemulsification compared with manual small-incision cataract surgery by a randomized controlled clinical trial: six-week results. Ophthalmology. 2005;112(5):869–74.
16. Garg A. Anesthesia in cataract surgery. In: Garg A, Fry L, Tabin G, Pandey S, Gutierrez-Carmona F, editor. Clinical practice in small incision cataract surgery. New Delhi: Jaypee Brothers Medical Publishers Ltd; 2004.
17. Davis 2nd DB. Retrobulbar and facial nerve block? No; peribulbar? Yes. Ophthalmic Surg. 1985;16(9):604.
18. Davis 2nd DB, Mandel MR. Posterior peribulbar anesthesia: an alternative to retrobulbar anesthesia. J Cataract Refract Surg. 1986;12(2):182–4.
19. Briggs MC, Beck SA, Esakowitz L. Subtenons versus peribulbar anesthesia for cataract. Eye. 1997;11:611–43.

20. Davis DB, Mandel MR, Nileson PJ, Alerod CW. Evaluation of local anesthesia technique for small incision cataract surgery. J Cataract Refract Surg. 1998;24:1136–44.
21. Parkar T, Gogate P, Deshpande M, Adenwala A, Maske A, Verappa K. Comparison of subtenon anaesthesia with peribulbar anaesthesia for manual small incision cataract surgery. Indian J Ophthalmol. 2005;53(4):255–9.
22. Nielse PJ. A prospective evaluation of anxiety and pain with topical anesthesia or retrobulbar anesthesia for small incision cataract surgery. Eur J Implant Ref Surg. 1995;7:6–10.
23. Maclean H, Burton T, Murray A. Patient comfort during cataract surgery with modified topical and peribulbar anesthesia. J Cataract Refract Surg. 1997;23(2):277–83.
24. Zehetmayer M, Radax U, Skorpik C, Menapace R, Schemper M, Weghaupt H, et al. Topical versus peribulbar anesthesia in clear corneal cataract surgery. J Cataract Refract Surg. 1996;22(4):480–4.
25. Johnston RL, Whitefield LA, Giralt J, Harrun S, Akerele T, Bryan SJ, et al. Topical versus peribulbar anesthesia, without sedation, for clear corneal phacoemulsification. J Cataract Refract Surg. 1998;24(3):407–10.
26. Gupta SK, Kumar A, Kumar D, Agarwal S. Manual small incision cataract surgery under topical anesthesia with intracameral lignocaine: study on pain evaluation and surgical outcome. Indian J Ophthalmol. 2009;57(1):3–7.
27. Mithal C, Agarwal P, Mithal N. Outcomes of manual small incision cataract surgery under topical anesthesia with lignocaine 2% jelly. Nepal J Ophthalmol. 2012;4(1):114–8.
28. Stevens JD. A new local anesthesia technique for cataract extraction by one quadrant sub-Tenon's infiltration. Br J Ophthalmol. 1992;76(11):670–4.
29. Venkatesh R, Veena K, Ravindran RD. Capsulotomy and hydroprocedures for nucleus prolapse in manual small incision cataract surgery. Indian J Ophthalmol. 2009;57(1):15–8.
30. Gimbel HV, Neuhann T. Development, advantages, and methods of the continuous circular capsulorhexis technique. J Cataract Refract Surg. 1990;16(1):31–7.
31. Gimbel H. Capsulorhexis. In: Colvard M, editor. Achieving excellence in cataract surgery. Self-published in Encino, California; 2009. p. 19–25.
32. Gutierrez-Carmona FJ. Complications and their avoidance in manual small incision cataract surgery. In: Garg A, Fry L, Tabin G, Pandey S, Gutierrez-Carmona F, editors. Clinical practice in small incision cataract surgery. New Delhi: Jaypee Bothers Medical Publishers; 2004. p. 499–502.
33. Weber CH, Cionni RJ. All about capsular tension rings. Curr Opin Ophthalmol. 2015;26(1):10–5.
34. Fry L. The phacosandwich technique. In: Rozakis GW, Anis AY, editors. Cataract surgery: alternative small incision techniques. Indian Edition ed. Thorofare, NJ: SLACK Publishers; 1995. p. 71–110.
35. Charles S. Posterior dislocation of lens material during cataract surgery. In: Garg A, Fry L, Tabin G, Pandey S, Gutierrez-Carmona F, editors. Clinical practice in small incision cataract surgery. New Delhi: Jaypee Brothers Medical Publishers; 2004. p. 542–6.
36. Kasbekar S, Prasad S, Kumar BV. Clinical outcomes of triamcinolone-assisted anterior vitrectomy after phacoemulsification complicated by posterior capsule rupture. J Cataract Refract Surg. 2013;39(3):414–8.
37. Chiu CS. 2013 update on the management of posterior capsular rupture during cataract surgery. Curr Opin Ophthalmol. 2014;25(1):26–34.
38. Ellis MF. Sharp-edged intraocular lens design as a cause of permanent glare. J Cataract Refract Surg. 2001;27(7):1061–4.
39. Kirk KR, Werner L, Jaber R, Strenk S, Strenk L, Mamalis N. Pathologic assessment of complications with asymmetric or sulcus fixation of square-edged hydrophobic acrylic intraocular lenses. Ophthalmology. 2012;119(5):907–13.
40. Suto C, Hori S, Fukuyama E, Akura J. Adjusting intraocular lens power for sulcus fixation. J Cataract Refract Surg. 2003;29(10):1913–7.
41. Osher RH. Adjusting intraocular lens power for sulcus fixation. J Cataract Refract Surg. 2004;30(10):2031.

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