Techniques to Manage Small Pupil During Phacoemulsification and IOL Implantation

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In spite of several recent innovations in cataract surgery, patients with small pupils are always challenging. Poor pupil dilation can be observed in cases complicated by pseudoexfoliation syndrome, uveitis, posterior synechiae, trauma or previous intraocular surgery. A significant number of patients who present for phacoemulsification cataract surgery have pupils that do not respond adequately despite several pharmacological attempts with different mydriatic agents. Inadequate pupil dilation can decrease visualization during all stages of the phacoemulsification including capsulorhexis, hydrodissection, lens nucleus fragmentation and IOL insertion. This compromises the surgery and increases the risk for complications.

Pharmacological therapy with the use of nonsteroidal eyedrops or strong mydriatics such as phenylephrine 10% sometimes lead to unwanted ocular and systemic side effects. Intracameral mydriatics is an effective, and safe addition to topical mydriatics in phacoemulsification. In some cases their use can simplify preoperative patients preparation and in certain high-risk groups, may reduce the risk for cardiovascular side effects. Unfortunately, present pharmacological approaches of managing a small pupil during cataract surgery have limitations.

Most surgeons decide to dilate the pupil mechanically at the time of the surgery if pharmacological agents fail. There is no general recommendation or solution to the small pupil problem because the strategies for pupil enlargement greatly depend on surgeon skill and preferences, as well as on intraoperative situation. There are four main dilation methods: the first is the synechiolysis, the second is mechanical stretching, the third is the cutting method and the fourth is the iris retraction. In the first method the surgeon separates the adhesions between the iris, the lens capsule and/or the cornea. The technique of pupillary membranectomy with the forceps presented by R.Osher is also effective in some cases. The second method - mechanical stretching of the pupil was introduced by Miller and Keener. It is usually effective for small pupils with the rigid iris tissue which is usually caused by prior miotic use, pseudoexfoliation, or posterior synechiae. Stretching can be achieved with the spatula, Sinskey hook or special instrument - Beehler pupil dilator. Usually a pair of hooks is introduced through 2 stab incisions in the cornea engage the iris sphincter. After that the hooks are pulled in opposite directions.

This maneuver creates microscopic sphincter tears which enlarge the pupil aperture. The main advantage of this procedure is that it is relatively simple and requires no special instruments.

Mechanical stretching of the pupil usually provides sufficient access to the lens and maintains the pupil diameter intraoperatively. Sometimes iris stretching technique leads to instability of its papillary margin, which can compromise cataract surgery.

In some eyes the stretching technique fails to adequately expand the pupil. The drawback of this technique is that it is creating permanent damage of the iris...
The micro tears of the sphincter muscle are usually clinically asymptomatic but sometimes result in bleeding and pigment dispersion postoperatively. In a study of stretch pupilloplasty by Dinsmore 10, 10% of 50 patients developed an enlarged atonic pupil postoperatively. All patients had a history of injury or inflammatory disease. Partial-thickness iris sphincter cuts made with micro scissors is a common pupil enlargement technique 11. The cutting method is more controlled but requires multiple maneuvers of the scissors inside the anterior chamber which can result in corneal endothelial damage. The disadvantages are the same as those with the stretching method.

Suboptimal pupil dilation in response to the preoperative mydriatic protocols and minimal efficacy of pupil stretching techniques is a usual indication to the intraoperative use of iris hooks or other mechanical pupil dilation devices. For the iris retraction several devices have been introduced in the clinical practice. The main disadvantages of these devices include the bulkiness and rigidity. They are difficult to insert, remove, and manipulate through a small incision.

Graether 12 developed a pupil expander that according to his data is superior to other methods of pupil enlargement, causing less sphincter trauma and fewer cases of permanent pupil size alteration. Pupil dilation technique with the hydrogel ring reported by Siepser 6 has potential benefits but very limited clinical use. The Perfect Pupil device (Milvella) is a disposable polyurethane ring with the 0.24 mm flanged groove throughout the length of the ring and an integrated arm that allows insertion and removal from the anterior chamber at the end of surgery 11.

Retracting the iris tissue rather than cutting it as in a classic sector iridectomy is much simpler and results in a much better postoperative pupil appearance. Mackool 13 was the first one who described a 4-point iris retractor configuration for phacoemulsification. He developed metal iris retractors connected to small blocks of titanium. The latter allows for stabilization of the hooks during the retraction of the iris. This method was enhanced with the introduction of the flexible iris retractor by de Juan and Hickingbotham 14.

Traditionally, 4 evenly spaced retractors are placed through limbal paracentesis 90 degrees apart from one another. The corneal incision is centered on 1 of the 4 sides of the square 15. Some surgeons use iris retractors in a triangular pattern decreasing the number of additional corneal incisions. The use of the iris hooks may lead to the damage of the pupillary margin intraoperatively producing a semi-mydriatic non-reacting pupil postoperatively.

Modification of the original square retractor configuration is described by Oetting and Omphroy 16. The rotation of the square improves lens access in clear corneal phacoemulsification by orienting the phacoemulsification needle along the diagonal. This was called by Dupps and Oetting “diamond configuration” of retractors 17. Advantages of this technique include ease of conversion from phacoemulsification, optimal orientation of the maximum pupil diameter, nucleus expression or intracapsular lens removal, and conservation of iris tissue.

Birhall 18 assessed the effect on pupil shape and circumference of various flexible iris hook positions. He confirmed that malpositioned iris hooks may increase pupil stretching with possible deleterious effects on postoperative pupil function. He recommends using additional fifth hook to create a pentagonal pupil that reduces pupil stretching by 17%.

Masket 19 and Yuguchi and coauthors 20 recommend the pupil not be stretched by the hooks to larger than a 5.0 mm square because overstretching produces irregular atonic pupils postoperatively. Novak 21 suggests the use of hooks with rigid pupils smaller than 3.0 mm (4.0 mm with a hard nucleus) and smaller than 4.0 to 5.0 mm for an inexperienced surgeon. In extremely small and rigid pupils he prefers combining the use of hooks with a radial sphincterotomy.

During engagement of the pupillary edge with the iris hook, it may catch and damage the capsule, leading to an anterior capsule tear that may extend to the periphery. To avoid this problem, a drop of viscoelastic material should be injected between the iris and the capsule before the hook is inserted. The other useful technique is to keep the hook parallel to the iris plane during the insertion and to tilt it slightly posterior right near the pupillary edge to engage the iris plane. The other useful technique is to keep the hook parallel to the iris plane during the insertion and to tilt it slightly posterior right near the pupillary edge to engage the iris plane. The other useful technique is to keep the hook parallel to the iris plane during the insertion and to tilt it slightly posterior right near the pupillary edge to engage the iris plane. The other useful technique is to keep the hook parallel to the iris plane during the insertion and to tilt it slightly posterior right near the pupillary edge to engage the iris plane.
aspiration and chafing from contact with the phacoemulsification needle.

Small degrees of pupil dysfunction are common place after cataract surgery with and without iris manipulation but usually this causes no subjective symptoms. Halpern and coauthors found an incidence of postoperative atonic pupil of 1.1% after phacoemulsification, with pupil diameters ranging from 6.0 to 8.0 mm. Most of the surgical maneuvers for enlarging the pupil and preventing its intraoperative constriction are not safe enough. They can lead to an increased risk of iris sphincter tear, bleeding, iris damage, posterior capsule tears, and loss of the vitreous body.

The postoperative complications can include an atonic pupil of irregular shape with poor cosmetic result, and photophobia. The rate of occurrence of iris prolapse has been reported between 0.3% and 1% in complicated cataract cases. Allan described one of the critical factors of iris prolapse during phaco which relates to fluid velocity. Allan’s model considers the Bernoulli principle as the most important, because when the velocity of fluid passing through the anterior chamber increases, the force exerted on the iris increases by the square of the velocity. The pupil often dilates poorly in atrophic irises, with significantly decreased iris tone unable to withstand the fluidic currents in the anterior chamber and maintain the correct position of the iris. These calculations give us some conclusions. In small pupil, iris tissue is located closer to the zone of the high fluidic currents. Hence it is more likely to be aspirated into the US or I/A handpiece. Decreasing of flow parameters is an important factor in preventing iris damage during phacoemulsification. Central positioning and minimal movements of the handpiece are also important to prevent iris damage. Endocapsular lens nucleus fragmentation is much safer because the areas of the highest fluidics currents are located inside the capsular bag away from the corneal endothelium and iris. Chang and Campbell recently described the intraoperative floppy-iris syndrome (IFIS) associated with systemic administration of the α-1A antagonist tamsulosin (Flomax). The intraoperative diagnostic triad of this symptom is fluttering and billowing of the iris stroma, a tendency for the iris to prolapse through the main and/or side-port incisions, and progressive constriction of the pupil during surgery. Stretching of the pupil is ineffective in IFIS because the iris pupil margin remain elastic and the pupil immediately snaps back to its original size following attempts at stretching it.

Viscomydriasis with high viscosity OVDs such as Healon5 are very useful in small pupil phaco cases. S. Arshinoff described a technique using ophthalmic viscosurgical devices to perform cataract surgery in patients taking tamsulosin. This method uses a combination of the two OVDs. The lower-viscosity dispersive OVD which is highly retentive despite the presence of moderate fluid turbulence, is injected in the periphery of the anterior chamber and covers the endothelial layer and the iris. The viscoadaptive central layer of Healon5, according to S. Arshinoff adds a relatively rigid OVD roof above the surgical space and adds rigidity to the OVD structure to keep the iris from moving and the Viscoat in place. The BSS layer just over the pupillary space and below the viscoadaptive central layer provides working space for the phaco tip. The surgeon is working in the endocapsular space and Healon 5 is not attracted into the phaco tip and the OVD shell structure remains intact throughout the case. This technique gives satisfactory iris stability and permits uneventful surgery.

Cataract surgery in cases of iridoschisis may result in aspiration of iris fibers flowing in the anterior chamber. In these cases, stretching the iris with various instruments or dilating the pupil with iris retractors may not prevent the danger of contact of the phacotip with the iris tissue and aspiration of fibers. Intraoperative iris manipulations may lead to severe postoperative fibrinoid reaction especially in eyes with pseudoexfoliation syndrome, chronic uveitis, glaucoma or diabetes. That is why cataract surgery in the presence of a small pupil remains one of the most difficult and challenging cases.

**Malyugin Ring for Small Pupil Phaco**

To enhance phaco surgery in complicated small-pupil cases we have designed a new device. It is used in cases of pupil miosis refractory to dilation protocols. The device is a square shaped, transitory implant with four circular loops which holds the iris at equidistant points.
It has one-piece design with the curls at each angle of the ring that provides balanced stretching and gentle holding of the iris tissue (Figures 1, 2).

The insertion of the Malyugin ring is carried out through the main incision with injector. The pupil expander is positioned centrally and gently pushed at each angle with the help of a Sinskey hook to trap the iris in the four curls. Once in place, the ring expands the pupillary opening to 6.0 mm. The ring provides stable mydriasis with no trauma to the iris tissue and no need for additional paracenteses. It retracts the iris away from the flow currents and thus helps to prevent its incarceration into the US and I/A hand pieces. As a result of the ring implantation, we obtain a square, 6 mm pupil dilation that allows for safe and comfortable manoeuvres during phacoemulsification.

The ring is usually inserted at the beginning of the phaco procedure through an unenlarged 2.2-2.8 mm clear corneal incision into the pupillary aperture. The surgeon can control the iris without significant changes of his accustomed technique.

Capsulorhexis, hydrodissection, phacoemulsification, and injection of the intraocular lens are performed through the expanded pupil with the device in place. In case of necessity, the ring can be inserted at any stage of the operation.

Cadaver eye study using scanning electronic microscopy showed how much less damage to the pigmented iris tissue was caused by this new instrument than by conventional iris retractors (Figures 3).

**Surgical Technique**

Topical anesthesia is applied using 2% Xylocaine, and paracentesis is done at 12 o’clock. Temporal clear corneal incision is performed using the disposable metal blade. A dispersive ophthalmic viscosurgical device (OVD) is injected in the anterior chamber to stabilize it and protect the corneal endothelium. The ring is introduced into the anterior chamber through the clear corneal phaco incision using a special inserter (Figure 4). The device is placed in the anterior chamber and the
distal scroll engages the iris margin opposite to the incision. The rest of the scroll is then attached to the pupillary margin in a circular manner with a hook, resulting in a pupillary opening approximately 6.0 mm wide (Figure 5). Capsulorhexis is performed using forceps or a bent needle.

Hydrodissection and hydrodelineation are performed with Balanced salt solution until the nucleus can be rotated freely inside the capsular bag (Figure 6). Phacoemulsification is done with the phaco machine using a modified quick-chop technique (Microflow or Kelman US needle; dual linear foot pedal control, 30-35 % of linear US power; 80-100 pps, duty cycle 50 %; vacuum settings at 350 mm Hg; bottle height 95 cm). A deep but short central trench is made in hard nucleus cases. The step-by-step chop in situ and lateral separation technique allows nucleus division with minimal stress on the capsular bag (Figure 7).

Coaxial or bimanual irrigation/aspiration is used to clean residual cortical fibers from the capsular bag (Figure 8). The capsular bag is then filled with the cohesive OVD. In case of necessity posterior capsulorhexis is performed. Foldable intraocular lens (IOL) is inserted with the help of injector (Figure 9).

Then the ring is retracted from the anterior chamber through the clear corneal incision with the same injector device (Figure 10, 11). Aspiration is performed to remove the residual OVD. After viscoelastic removal, clear corneal incision is hydrated with balanced salt solution. At the completion of the case, the pupil constricts spontaneously (Figure 12).

On the first postoperative day, the operated eye usually present with few cells and mild flare in the anterior chamber. The pupillary margin was minimally disturbed or undamaged and the IOL well centered.

We usually treat patients with small pupils after the surgery more aggressively than uncomplicated patients with topical steroids, cycloplegics, and sometimes systemic steroids. Patients receive local antibiotic and steroid treatment for 4-6 weeks.

**Conclusion**

Adequate transpupillary access to the lens is essential for the success of phaco procedures especially in cases with zonular weakness and capsular inadequacy. We believe that our iris retraction technique with the Malyugin Ring has several advantages.

First, the ring is as effective as the other conventional iris hooks. However, compared to other long-in-use iris retractors, it has the advantage of being friendlier with the eye, due to the well-distributed stretching and gentle holding of the delicate iris tissue, and to the easier and less traumatic implantation. It has no sharp or pointed endings that can damage the eye.

Second, equidistant position of the loops that holds the iris tissue ensure correct position of the iris and prevents the effect of overstretching of the pupil observed in incorrect iris hooks position.

Third, the device applies pressure to the sphincter muscle over an area which is wider than in cases of iris hooks. It is particularly useful in patients in which cutting or tearing of the iris tissue should be avoided, especially in the presence of rubeosis, chronic anterior uveitis, or systemic coagulopathy. Iris rim is safely fixed in the loops of the ring and there is no risk of the iris aspiration during phacoemulsification.

Fourth, the ring does not require additional incisions. This instrument is inserted through the one main incision, thus reducing surgical trauma and minimizing the risk of contamination and postoperative inflammatory reaction. In the technique, when the square pupil is formed by the conventional iris retractors the iris can prolapse through the wound. This is particularly true in patients with relatively wide paracenteses and atonic and atrophic irises that seem particularly floppy.

Fifth, ring provides sufficient room for nucleus fragmentation and removal. The device configuration allows the surgeon to work in the deep lens layers below the iris plane and the square shaped pupil formed by the ring. This provides enough space for grooving and cutting the nucleus and increased peripheral visualization during the chopping phase of the procedure.

Sixth, the ring is inserted and removed from the eye with a help of injector thus reducing the risk of contamination and disturbance of the incision architecture and wound integrity.

In summary, different techniques of nucleus disassembly in small-incision cataract surgery require wide and unobstructed view of the anterior portion of the lens as well as the instruments inserted in the anterior
chamber. The other important factor is sufficient manipulability of the instruments which is critical for the successful completion the surgery. A pupil that fails to dilate makes cataract removal more difficult with added risk. The new ring adequately dilates the pupil and prevents iris sphincter damage. It is easy to insert and remove. The ring expands the pupil to 6.0 mm, protects the iris sphincter during surgery, and allows the pupil to return to its normal shape, size, and function after the operation.

Iris ring is an important tool in phacoemulsification surgery. Careful intraoperative manipulation and insertion of the ring with liberal use of OVD can help prevent complications. After the surgery most of our patients had pupils almost indistinguishable from the appearance before surgery with the preserved functional activity. We consider the new device among the most effective methods to increase the size of even very rigid small pupils during phacoemulsification surgery. The use of this method is highly recommended, as it is likely to reduce postoperative abnormalities in pupil size and function.

References