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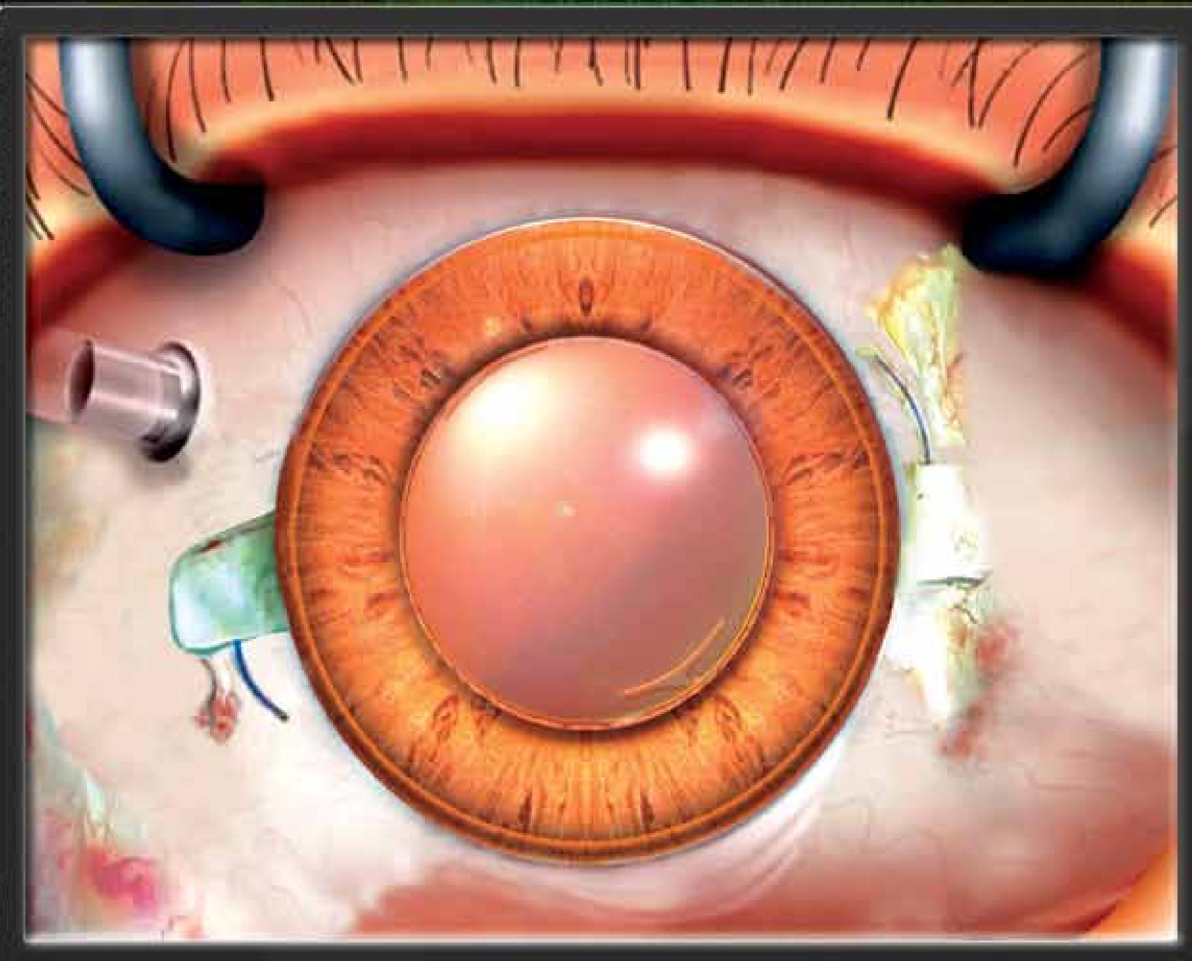
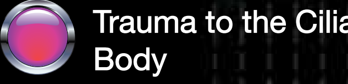


Handshake Technique in Foldable Glued IOL

An Update on the Management of Dry Eye



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Handshake Technique in Foldable Glued IOL

Amar Agarwal, MD, MS, FRCS, FRCO
Soosan Jacob, MD, MS, FRCS, DNB

The use of foldable IOL in glued IOL surgery has made possible many more advantages for this surgery. It gives all the advantages of small self sealing incisions. Intraoperative advantages include having a well formed globe throughout all the steps of surgery, absence of iris prolapse during IOL insertion, decreased surgical time as there is no need to suture the corneo-scleral section. The risks associated with a large section such as expulsive hemorrhage, are also reduced. Decreased incidence of postoperative complications associated with larger wounds (such as postoperative wound leak, shallow AC, etc.) as well as decreased astigmatism associated with a large wound, are other advantages.

The foldable glued IOL also has all the other advantages that have already been previously described with the glued IOL. Trans-scleral fixation utilized in the glued IOL technique per se makes it very stable. Faster surgery and the ability to ensure good intraoperative centration are other advantages of this technique.

The advantages that the glued IOL has over sutured scleral fixated IOL are numerous. All suture related problems such as suture degradation, slippage, loosening, knot exposure and extrusion are avoided. It is much more easier to get good intraoperative centering of the IOL as the degree of tuck of the haptics into the tunnel can be adjusted to obtain good centration unlike in sutured SFIOL where tying down of the first knot determines the centration of the IOL. Also, as in glued IOL, the haptics themselves are externalized and fixated into the scleral tunnel, it is much more stable with lesser chances of pseudophakodonesis/ endophthalmodonesis unlike a sutured SFIOL which is hung like a hammock from the sclera wall with two sutures. Less endophthalmodonesis would in turn lead to a decreased incidence of posterior segment complications such as cystoid macular edema or retinal detachment. The externalized haptics tend to rub less against the ciliary body than a sutured SFIOL in which the haptic lies curved within the eye. Potential to cause uveitis- glaucoma- hyphema (UGH) syndrome is also therefore less.

Technique

Any three piece foldable IOL can be used for this technique. All the steps here remain the same except the technique of IOL insertion into the AC. Once the infusion cannula/ AC maintainer has been fixed and the flaps and sclerotomies made, a 2.8 mm keratome is used to make a corneal incision. This may be enlarged very slightly so as to allow easy insertion. A side port may also be made to allow the surgeon easier maneuverability and as a future access point if required. The three piece foldable IOL is loaded into the injector and the injector tip is introduced into the AC. At the same time, a 23 G MST forceps is introduced through the sclerotomy under the scleral flap. It is preferable to have a pushing type injector though a screwing type injector may also be used with the assistant gently screwing it as the surgeon holds the injector with one hand and the MST forceps with the other hand. It is also advisable to have the injector tip within the mouth of the incision and not use wound assisted injection of the IOL which can lead to a sudden, uncontrolled entry of the IOL into the eye and a consequent IOL drop.

As the IOL is being injected into the AC, the tip of the haptic is caught with the MST forceps and exteriorized while injection is continued very gently **(Figures 1 and 2)**. The injector is then slowly

Eye Research Centre & Dr. Agarwal's Group of Eye Hospitals Chennai, India

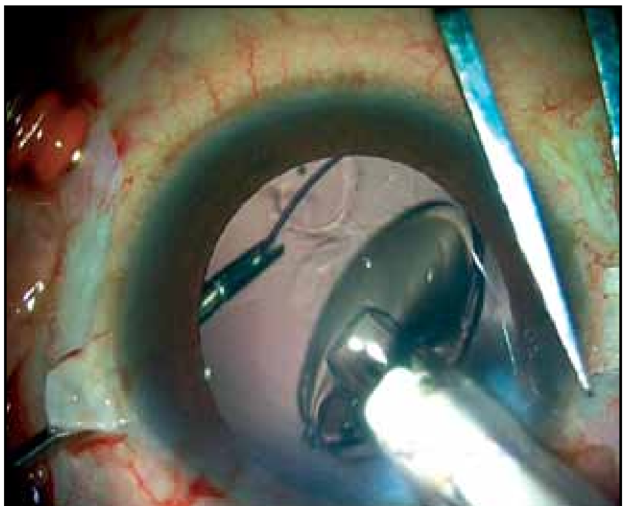

Figure 1: Leading haptic of the foldable IOL is grasped at its tip by the 23 gauge MST forceps introduced through the sclerotomy.

withdrawn so that the second haptic is left trailing outside the wound. The first haptic is then held by an assistant while the surgeon flexes the second haptic into the AC into the jaws of an MST forceps introduced through the second sclerotomy **(Figure 3)**. This haptic is also thus externalized out **(Figure 4)**. A bent 26 gauge needle is then used to create a tunnel in the direction of the exteriorized haptics at the edge of the scleral flap. Vitrectomy is then used to clear up the scleral bed in case that any vitreous has prolapsed out. Both haptics are then tucked intra-sclerally. Centration of the IOL is checked for and if not well centered, the degree of tuck of the individual haptics is adjusted till the lens

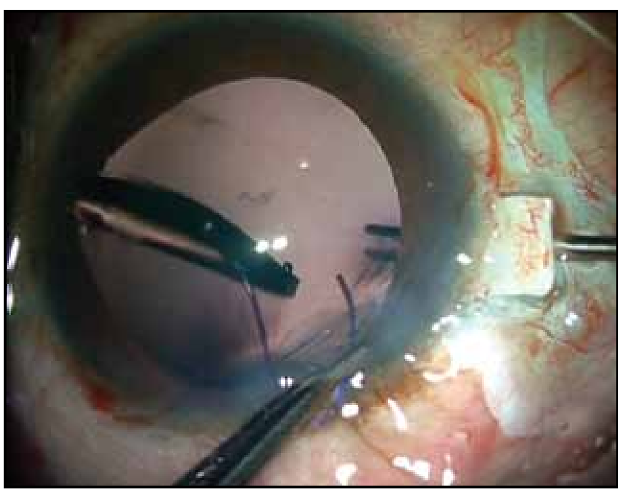

Figure 3: The first haptic is held by an assistant while the surgeon flexes the second haptic into the AC into the jaws of an MST forceps introduced through the second sclerotomy .

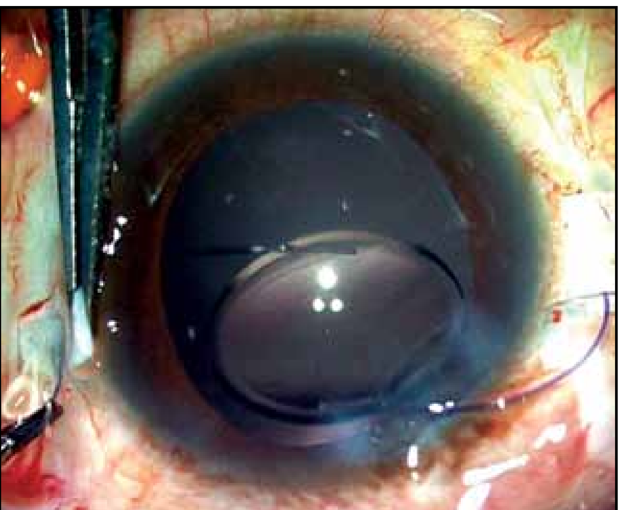

Figure 2: The leading haptic is exteriorized through the sclerotomy.

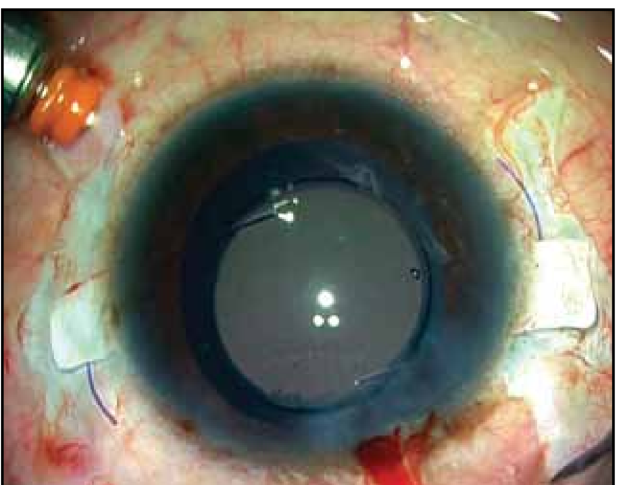

Figure 4: Both haptics are externalized and then tucked into scleral tunnels made at the edge of the scleral flaps.

becomes well centered. The scleral bed is then dried and fibrin glue applied. The scleral flaps are then glued down. Fibrin glue is then also used to seal the mainport and the sideport by applying over the incisions. The conjunctiva is also closed with fibrin glue.

Handshake Technique For Foldable Glued IOL

The exteriorization of the haptics is a key step in the glued IOL. Since the surgeon is maneuvering with both hands simultaneously, one hand injecting the IOL while the other grasps and exteriorizes the haptics, he/she needs to be familiar with the

handshake technique as a means of transferring the haptic from one hand to the other. If one of the haptics is not caught or if it gets released accidentally after grasping it, the situation can be easily resolved using this technique **(Figure 5)**. It utilizes two MST forceps, one of which holds one haptic. Depending on ease of access, the other MST forceps is introduced through the opposite sclerotomy or through the side-port. The first hand then transfers the haptic into the second MST forceps such that the first hand now becomes free **(Figure 6)**. It is essential to hold the haptic at its tip before exteriorizing it so that it doesn't snag on the sclerotomy while being brought out. For this reason, this handshake transfer of the haptic between the two MST forceps is continued till the tip of the haptic is caught by the forceps on the side to which the haptic is to be exteriorized. This technique thus allows easy intraocular maneuvering of the entire haptic or IOL within a closed globe system.

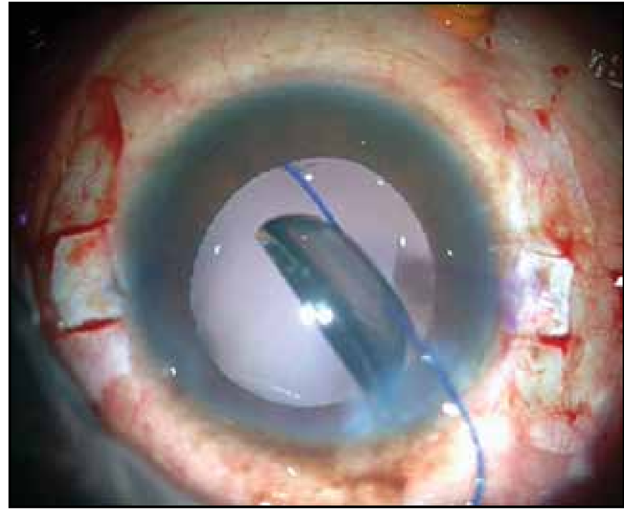

Figure 5: Another case showing the leading haptic lying free within the vitreous cavity.

Glued Multifocal IOL

A multifocal IOL can also be implanted in eyes with no/absent capsule using this technique. It is extremely easy with this technique to ensure centration of the IOL by adjusting the degree of tuck of the individual haptics

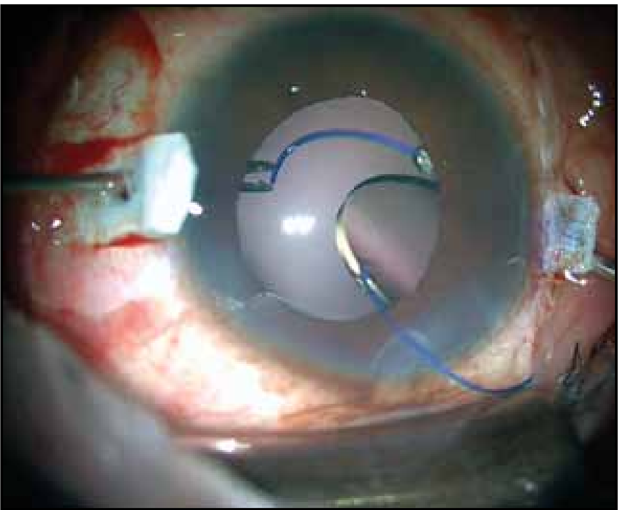

Figure 6: The handshake technique is used to bimanually transfer the haptic between the two hands till it is caught at the tip and is then externalized.

into the scleral pocket. This therefore enables a well centered multifocal IOL even in such compromised eyes. More importantly, it is also possible to center the multifocal IOL taking into consideration the angle kappa of the patient. This can allow centration of the IOL on the visual axis as opposed to being centered on the pupil.

Conclusions

The foldable glued IOL technique and the handshake technique have further refined the glued IOL procedure by the use of smaller incisions, better intraocular maneuverability, easier surgery, better postoperative visual acuity and fewer postoperative complications.

An Update on the Management of Dry Eye

James P. McCulley, MD, FACS, FRC Ophth

Dry eye (keratoconjunctivitis sicca) is an ocular condition that affects millions of Americans of varying ages, sexes, and overall physical health. For many decades, dry eye disease was thought to be limited to ocular surface dryness due to a decrease in the aqueous phase of the tear film.[1] Advances in the understanding of dry eye disease, reported in 1995, included the discovery that the etiology of this condition is multifactorial and involves[2] distinct components: tear evaporation and insufficient tear production.[2] In 2007, the International Dry Eye WorkShop's (DEWS) subcommittee for Definition and Classification expanded the definition of dry eye disease, beyond tear deficiency and evaporation, to include tear film degradation and potential damage to the ocular surface. The subcommittee also recognized the contributions to the disease process of hyperosmolarity of the tear film and inflammation of the ocular surface **(Figure 1)**.[3]

The moisture of the ocular surface is maintained by the tear film, which is comprised of 3 dynamic and interactive layers: an aqueous layer (secreted by the lacrimal glands), a mucous layer (produced by conjunctival goblet cells and by corneal and conjunctival epithelial cells), and a lipid layer (secreted primarily by the meibomian glands).[4,5] The stability of the tear film, which must be maintained between thousands of blinking events that occur each day, and the interaction of the tear film with the corneal surface are important in maintaining ocular surface integrity and quality of vision.[1,6] A perturbation of any component of the tear film that alters tear volume, composition, distribution, and/or clearance can lead to dry eye disease.[1,5]

The National Eye Institute (NEI)/Industry Dry Eye Workshop and, later, the DEWS subcommittee for Definition and Classification categorized dry eye disease, based on etiology, into aqueous tear-deficient dry eye (ADDE) and evaporative dry eye (EDE).[2,3] ADDE results primarily from a decrease in tear production (ie, hyposecretory dry eye) by the main and accessory lacrimal glands, while EDE (ie, hyperevaporative dry eye) is proposed to be the result of a defective tear film lipid layer— either lipid insufficiency and/or poor lipid spreading due to abnormal composition— resulting in excessive evaporation of the aqueous tear film and decreased tear film stability.[2,7] Of importance, though, it has been reported that up to 40% of patients with EDE can also have ADDE (ie, combined mechanism dry eye disease).[8]

Figure 1: Aqueous Tear-Deficiency Dry Eye (ADDE).

ADDE is most frequently encountered in clinical practice. In particular, we have observed that ADDE occurs in 25% to 50% of patients who have chronic blepharitis.[9] Separately, the most common cause of EDE is either posterior blepharitis or meibomian gland dysfunction (MGD), the latter of which may be classified as either hypersecretory (easily expressed glands and excessive meibum and foam along the lid margin) or obstructive (plugged or opaque gland orifices and high

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rate of gland dropout).[10,11] While the role of MGD in hyperevaporation and EDE is well established, it is currently unclear as to whether MGD and the associated tear hyperevaporation rate play important mechanistic roles in ADDE as well.

James P. McCulley was the first to associate meibomian lipid abnormalities with dry eye and ocular surface disease.[12] William Mathers was the first to recognize that a hyperevaporative rate was involved in the association between obstructive MGD and EDE. Specifically, compared with normal patients, Mathers and others have reported a significantly greater rate of tear evaporation in patients with obstructive MGD; increases in the rates of tear evaporation among these patients have been shown to be proportional to the severity of meibomian gland obstruction.[10,13,14,15] In one of our early studies of tear evaporation, the tear characteristics and meibomian gland dropout (by meibography) among 18 patients with dry eye (as evidenced by ocular surface drying) were compared with those of 11 control patients.[16] In this study, no differences in absolute tear evaporation rates were observed between patient groups. Relative to the control patients, however, we found that all patients with dry eye (regardless of whether they had slit-lamp manifestations of MGD) had lower tear volumes and flow, poorer Schirmer's test results, and more frequent incidences of meibomian gland dropout. In a subsequent study, we found a positive trend between evaporative rate and total aqueous tear loss in dry eye patients (with or without MGD) when compared with control patients.[17] This suggests that, regardless of whether or not patients with dry eye also have MGD, the patients universally experience significant losses in the absolute amount of aqueous tears via evaporation.

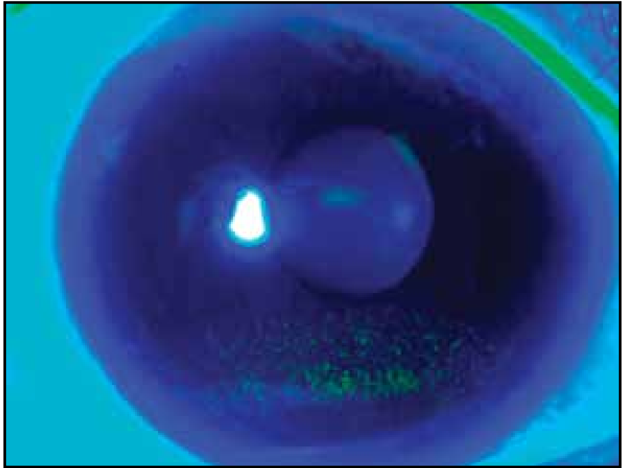

Figure 2: Corneal fluorescein staining in dry eye.

The most often practiced, first approach to the management of dry eye (ie, initial clinical treatment of a patient who has symptoms consistent with ocular surface drying, vital staining, a history of fluctuations in vision, and no signs of significant inflammation) is the use of a topical ocular preparation that provides lubrication and prevents evaporation **(Figure 2)**. For patients with dry eye disease associated with MGD, in particular, it is crucial to select an artificial tear product that contains both polymer and lipid components to simultaneously protect the ocular surface and replenish tear film lipids. Systane® Balance Lubricant Eye Drops (Alcon Laboratories, Inc., Fort Worth, TX), the latest hydroxypropyl-guar gellable lubricant eye drop, contains micro-emulsions of oils (LipiTech™ System) designed to minimize the evaporative loss of tears from the ocular surface **(Figure 3)**. Systane Balance also contains 2 demulcents, mineral oil, and a polar phospholipid surfactant (dimyristoylphosphatidylglycerol). Polar lipids in the tear film are proposed to act as surfactants that help spread the nonpolar lipids over the aqueous component of the tear film, thus creating a barrier between the 2 layers, and providing supportive structure for the nonpolar lipid phase, which creates a seal that decreases evaporation from the tear film.[18,19] In a recently conducted study (unpublished data), we found that the instillation of a single drop of Systane Balance in the eyes of patients with ADDE significantly decreases tear evaporation rates at 30 and 60 minutes after instillation. Given the continued action of Systane Balance for the duration of the current study, we plan to conduct further studies to include later assessments at 4 and 6 hours after instillation.

Any perturbations in normal physiology are almost guaranteed to result in inflammation. In the studies described above, although the degree of inflammation in the patients' eyes was not recognized by slit-lamp evaluations, we can assume that there was some underlying inflammatory process that contributed to the ocular surface drying and associated vital staining of the epithelium. Thus, a second approach to the management of dry eye disease, complementary to the use of lubricant eye drops as previously mentioned, involves the dietary supplementation of anti-inflammatory omega-3 fatty acids. Several studies have established an association between the dietary intake of omega-3 supplements and changes to the meibomian gland oils, thus suggesting positive implications for the management of dry eye disease.[20,21,22] Recently, we conducted a pilot, prospective, randomized, double-masked, vehicle-controlled,

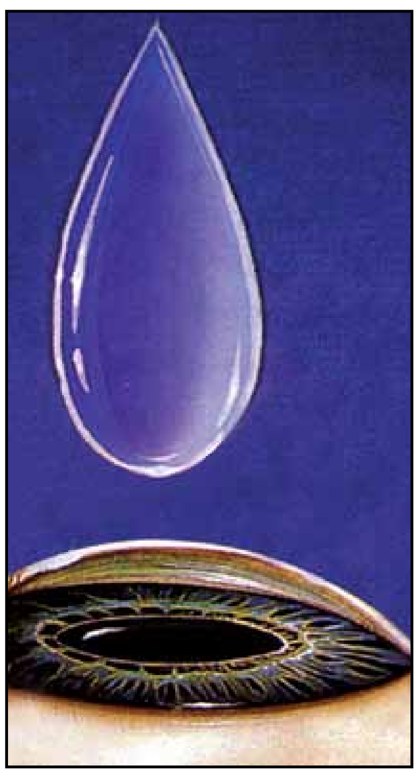

Figure 3: Lubricant frequent use for successful management of dry eye. *(Art from Jaypee-Highlights Medical Publishers)*

90 day study in which patients with dry eye, who presented with or without MGD, received either a daily dose of an omega-3 fatty acid supplement (n=21) or a vehicle (n=15).[23] The supplement contained 450 mg of eicosapentaenoic acid, 300 mg of docosahexaenoic acid, and 1000 mg of flaxseed oil (TheraTears® Nutrition; Advanced Vision Research, Woburn, MA). At the end of the study, more patients in the omega-3 supplement group with symptoms became asymptomatic compared with patients in the vehicle group. Although no differences were observed at the end of the study between treatment groups in meibum lipid composition, greater improvements among patients in the supplement group relative to patients in the vehicle group were observed in Schirmer's test scores, mean tear flow rates, and mean tear volumes.

For patients who present with a more serious manifestation of dry eye, including ocular surface drying accompanied with significant eyelid inflammation, the current treatment approach should include the short-term (1-2 weeks) use of a steroid-antibiotic combination in order to rapidly bring the inflammatory process under control. Based on the preceding discussion, following management of the associated inflammation, the best treatment approach then consists of the co-administration of lubricating, topical ocular drops and oral doses of omega-3 dietary supplements.

The strategies and therapeutic approaches outlined herein for the management of dry eye disease, including the prevention of evaporative tear loss, increases in lubrication, protection of the ocular surface, and inhibition of inflammation, address one or more etiopathological components of the disease. These approaches, therefore, represent the ideal management of dry eye in all patients, regardless of disease causation and/or type. In addition to this initial approach to dry eye management, there are other therapeutic modalities available for the more severe or unresponsive dry eye patients.

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Trauma to the Ciliary Body

Zhizhong Ma, M.D.

The usual management in open anterior segment trauma is:

- Suture the sclero-corneal wound.
- Control the natural course of wound healing.
- Treat complications.

What occurs after conventional sclero-corneal wound repair?

Surgical reparation of the wound is required to prevent the formation of leucomas and synechiae as well as shallow or flat anterior chamber, which may potentially induce secondary glaucoma.

The resulting limbal scar may drag and deform the pupil and even be connected to lens material and vitreous, eventually inducing traction retinal detachment and proliferative vitreo-retinopathy behind the wound.

What is neglected, what is not properly timed and what is not done in the management of this condition?

The inner aspect of the wound is usually neglected. A mass of tissue formed by the blood clot with incarcerated vitreous, uveal tissue and lens material, as well as fibroblast cells migrated from the scleral surface will eventually become the origin of the proliferating tissue[1] leading to proliferative vitreo-retinopathy (PVR). Traumatic PVR is associated with traction retinal detachment as well as the changes occurring in the inner aspect of the wound, resulting in poor visual outcome in involved eyes.

Follow-up after initial repair of the wound usually misses an adequate timing of removal of the wound fibrotic material. Traumatic PVR may be secondary to an improper management of the inner aspect of the wound and non-optimal timing.

Complications of ciliary body damage following ocular traumatism

The progression of ciliary body damage, as occurs in anterior segment injury is not acceptable. Both conditions differ in the following aspects:

- The ciliary body is located behind the anterior sclera preventing routine examinations.
- The ciliary ring is a border region between the anterior and posterior segments.
- The evaluation and treatment of the ciliary body is difficult in the usual clinical setting for both anterior and posterior segment surgeons.

However, the anterior sclera is an exposed location that is vulnerable to trauma. For this reason, ciliary body injuries could be considered as a "no man land" in ophthalmic surgery, meaning a deserted region that is not well understood and that might be better explored.

The following cases illustrate examples of complications of ciliary body trauma.

Case 1: Sclero-corneal laceration **(Figure 1)**. The ciliary processes have been replaced by fibrotic tissue in the damaged area (black arrow), which tend to affect the neighboring ciliary processes and form a fibrotic membrane along the ciliary ring (white arrow). At the inner aspect of the wound, a clot formed by blood remnants, fibrotic tissue, vitreous and lens material can be observed.

Professor of Ophthalmology, Chairman Department of Ophthalmology, Peking University Third Hospital, Beijing, China

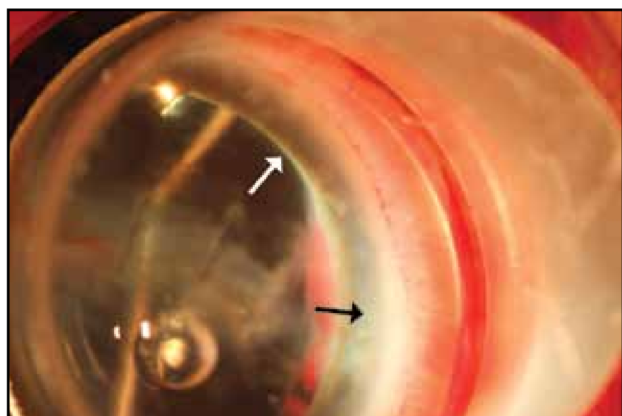

Figure 1: Case 1 shows that ciliary processes at the wound-involved region have disappeared and have been replaced by fibrotic tissue (Black arrow). A fibrotic membrane appears along the ciliary ring (White arrow).

Case 2: The ciliary body was detached from the sclera in a ruptured globe. The ciliary processes became atrophic and pigment epithelium layer was exfoliated (white arrow) eventually causing ocular hypotony.

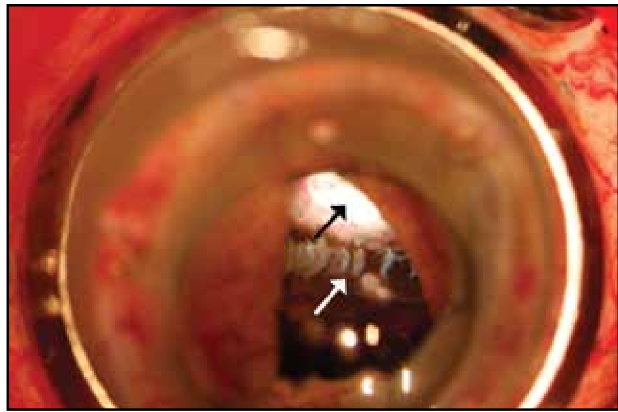

Figure 2: Ruptured globe complicated with ciliary body dialysis. Ciliary processes became extremely thin and pigment epithelium layer was exfoliated (White arrow).

Case 3: A ruptured globe 60 days after injury. The whole retina is affected by a severe PVR forming a closed funnel and the damaged ciliary ring shows a fibrotic membrane (A: black arrow). Damaged ciliary processes (B: black arrow) with an attached blood clot. The ciliary ring is covered by a membrane (B: white arrow) connected to remnants of lens material (B: pink arrow).

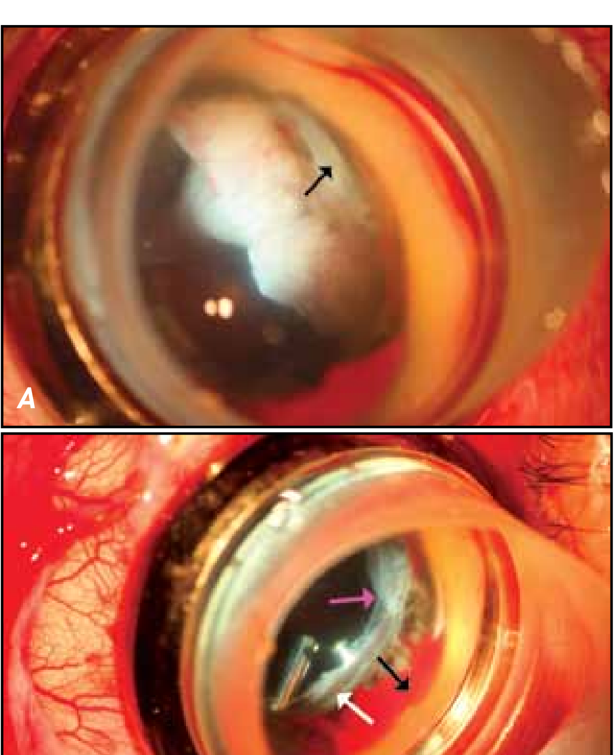

Figure 3: Ruptured globe 60 days after injury. A: The whole retina is contracted into a closed funnel and a fibrotic membrane formed over the damaged ciliary ring (Black arrow). B: Damaged ciliary processes (Black arrow), ciliary membrane (White arrow) and remnants of lens material (Pink arrow) can be observed on the opposite site of the wound.

Case 4: Split ciliary body (black arrow) and iris root. Some parts of the outer layer of the split ciliary body are detached and the sclera is exposed (white arrow). Ciliary body detachment permitted aqueous entrance into the suprachoroidal space resulting in extremely low intraocular pressure.

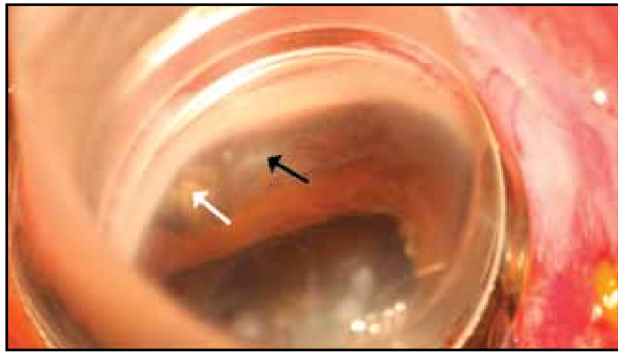

Figure 4: Ruptured globe with split ciliary body (Black arrow) combined with ciliary dialysis in case 4. Part of the outer layer of the split ciliary body is detached exposing the bare sclera (White arrow).

Management of complications in ciliary body damage

Full understanding the characteristics and long-term outcome as well as a careful pre operative evaluation are required for the treatment of these complications. The natural history of ciliary body healing is similar to that of the anterior and posterior segment. Complications associated with the wound healing process are responsible for the devastating outcome of injured eyes, which was neglected by previous usual management. Thus, prevention and treatment of these complications should be emphasized.

Timing management of ciliary body trauma after initial wound repair

Previous ideas for the management of open anterior segment trauma should be left aside. A surgical procedure should be carried on soon after the initial wound repair instead of waiting passively for the arrival of long-term complications. According to our experience in cases similar to those shown above, surgical intervention according to clinical evaluation should be performed before proliferative membrane are well established. There is no direct evidence in the literature regarding the exact timing of continuous procedure. According to Meitz and Heimann's[2] observations, it seems that traumatic PVR could be observed two weeks after injury. In our opinion, continuous treatment should be implemented no later than three weeks after the initial trauma.

Considerations on Surgical Procedures

We recommend a three-port pars plana vitrectomy (TPPV). TPPV offers the following advantages:

1. The target tissue can be reached more easily via pars plana.
2. TPPV permits a thorough examination and surgical management of the ciliary body with the aid of intraocular illumination and scleral indentation.
3. Closed operative setting with stable intraocular pressure control guarantees better visualization and facilitates safe and proper manipulation.
4. TPPV permits manipulation of the anterior and posterior segment when required.
5. A wide armamentarium of instruments is available. For instance, intraocular laser is frequently used. Bimanual technique is usually required.
6. Vitreo-retinal surgeons should be experienced with this technique

Principle and techniques

As previously discussed, the origin for proliferation is within the wound. Hence the emphasis of surgical management should be focused on the wound itself. The clot of tissue formed in the inner aspect of the wound should be fully debrided and the surrounding tissues should be disconnected from the wound to create a free area in both sides and posterior. Disorganized tissues, such as incarcerated iris and retina, should be structurally reconstructed. Lens material, blood clot and vitreous hemorrhage should be completely removed.

Loose ciliary membranes can be peeled off with the aid of forceps while established membranes need bimanual manipulation to avoid damage of ciliary processes. In this scenario, direct observation of the ciliary processes created by scleral indentation is very helpful.

Split or dialyzed ciliary body can be sutured. TPPV under prism lens visualization and stable intraocular pressure with constant infusion facilitates this manipulation..

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Choosing the Best Modalities for Treatment of Keratoconus

Islam M. Hamdi FRCS (Glasg), PhD

Classic schools in ophthalmology manage two modalities in the treatment of keratoconus: hard contact lenses and keratoplasty. Now, after the introduction of new methods like Intrastromal Corneal Ring Segments (ICRS), Corneal Collagen Cross Linking (CXL) and Phakic IOLs (PIOL), what would be the rational of utilizing/combining these modalities, in order to get the best out of each?

By definition, keratoconus is a PROGRESSIVE ECTATIC disease. So, we have to deal with these two situations:

- Improve vision (not correctable by standard methods).
- Treat the progression of the disease.

Contact lenses per se, were never proved to stop the progression. At the same time, keratoplasty is a radical form of therapy.

Optical Correction

In a case of keratoconus, where the cornea bulges forward in an unplanned manner, error of refraction would constitute a sphere, a cylinder and, the most important of all, a variable amount of irregularity. The latter is now known as high order aberrations. Keratoconus cases would then fall into a category known as "highly aberrated eyes", characterized by irregular astigmatism. In this category, all subjective methods of assessment, naming: manual skiascopy, autorefractometry and aberrometry, do not precisely evaluate the patient's actual refraction. We learned by time that, the actual spectacle prescription the patient will get, will depend mostly on trial and error of different powers on the trial frame. This is usually not related to the objective reports. This phenomenon could be explained that, ultimately, the patient is looking through the visual axis, which intersects the cornea at an immeasurable point and all these instruments give values that are not necessarily appreciated by the fovea.

Spectacles will only be able to correct sphere and regular astigmatism, remains the irregularity.

Soft contact lenses, even in toric forms, have very limited role in optical correction, as they conform to take the shape of the irregular cornea.

Hard contact lenses are an excellent optical solution, acting by cancelling the irregular anterior corneal surface, optically. However, there are some facts limiting the role of hard lenses. First, they do not stop the disease. Hence, the need of an additional modality to achieve this goal. In this case, CXL is valuable and shall be discussed in details. Second, being hard decreases the tolerability for such lenses. A big sector of keratoconus patient is already allergic. Even those who are not, will mostly find it less practical.

Phakic IOLs are a tool to correct high errors of refraction, without involving the cornea. Their safety, stability and efficacy are true virtues for such a method. A point in favor of PIOLs with keratoconus is the wide capaci-

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ty of the anterior chamber, after the forward movement of the cornea. On the other hand, the case should be proved to be stable, either after cross CXL, ICRS, graft or via serial topographies. Nevertheless, in the last situation, the patient should be warned about the possibility of progression, especially if he/she is still below 40 years of age. Still, the high order aberrations will be far from corrected. And, again, the proper subjective correction for the patient should be the one to consider.

Treating the Cornea

Corneal Collagen Cross-Linking

CXL was proved to achieve its goal. That goal was to stop the disease. It also gained much popularity for other reasons, like its simplicity and easy adoption for non cornea specialists. It' s still wise to highlight some issues to refine the practice with CXL.

The most important of all is the safety. Many protocols concerning dose and duration of UVA irradiation were developed. Nevertheless, they all agree on the lowest values for corneal pachymetry. That was found to be 400 microns. The reason behind that, is to maintain a sufficient optical protection by the riboflavin and keep penetrating rays level below the threshold of intraocular structures damage. The structures concerned are: corneal endothelium (decompensation), iris tissues (iritis), lens (cataract) and retina (photo toxicity). Corneas with keratoconus are usually thin. Pachymetry should always be considered for the suitability to CXL after subtracting epithelial values (50-70 microns). Moreover, a procedure with corneal exposure for almost 1 hour will progressively dehydrate the stroma and make it thinner. That's why, continuous measurement of pachymetry (thinnest point) and judicious uses of hypotonic riboflavin solution are essential with CXL.

Results of CXL are the second issue. All studies that tackled the CXL, agreed that it halts progression, at least on the short and medium terms. However, visual and topographic changes are a very debatable topic. The reason behind that is that, a successful CXL procedure is naturally accompanied by haze and stromal scarring. Biomechanically, corneal scars were always known to be accompanied by a hyperopic shift as a result of shortening and scar tissue contraction. However, this "improvement", if any, is not predictable or measurable. That's why, the patient should only be promised of stability with CXL, rather than improvement. That gets us back to the optical condition of the patient. If the patient does not have a satisfactory optical solution, he/she will mostly not appreciate the value of CXL. This includes acceptable spectacle correction (and future phakic IOL implantation) or hard contact lens.

Intrastromal Corneal Ring Segments

The history of ICRS goes back to almost 2 decades, initially indicated to treat myopia. With the rise of easier, other more predictable alternatives (excimer laser), refractive surgeons gradually gave up the use of ICRS for refractive correction. Then, observations also demonstrated some significant effect on the "irregular" keratoconus. That was quite earlier than the advent of CXL. Still, ICRS did not get the popularity of the latter. Although, literature is full of studies demonstrating the success of ICRS, there are actually many reasons for this slow adoption of such a tool. The least of them is the technical difficulty and the most is the poor knowledge of their function. Another non scientific reason is that, the investment in this method is not equal to other ophthalmic devices. The major producers of different ICRS prototypes have smaller budget to spend on research & development. ICRS did not capture the interest of major ophthalmic companies, either. This is, in my opinion, one of the most leading factors that slowed down their propagation. We can summarize the role of ICRS and the reasons behind their smaller popularity will be discussed in the next few lines.

Similar to any other procedure, there are three stages that should be mastered in order to get the maximum benefit out of which. Any user (surgeon) should be fully aware of these stages in order to reach this success. Any imperfection, at any step will lead to a poor result. These steps are:

- Case and ring selection.
- Proper implantation.
- Postoperative management.

To begin with, it is really essential to note that ICRS different designs behave differently and each of the previous considerations should not be generalized on ICRS as one category. I personally would like to stratify ICRS according to their optical zones (OZ) diameters into: large - intermediate - small OZ ICRS **(Figure 1)**.

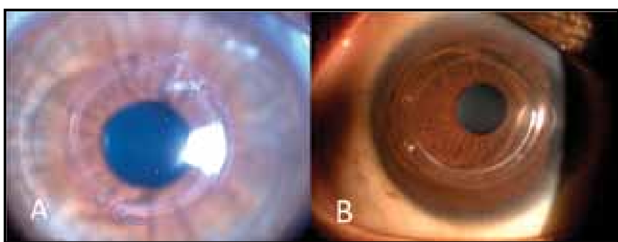

Figure 1: Examples for Intrastromal Corneal Ring Segments (ICRS): (A) Small OZ, Ferrara ring, (B) Large OZ, Intacs.

Concerning case selection, the actual spectrum of cases that might benefit from ICRS is wide (some of GI until GIII, A-K classification). Very mild cases with low K readings (<48.0D steep meridian) AND low irregularity (astigmatism on topography <1.5D) will mostly not benefit for example from ICRS. Severe cases as well do not benefit. By severe cases, we mean high Ks (>55-60D on steep meridian), scarred, degenerative and complicated cases. Cases of ambiguous topography and severe PMD, will mostly not benefit as well. Sometimes, the cornea condition is very suitable for ICRS, but with a wide difference between the 2 eyes. In a unilateral case, a form of suppression or even amblyopia can be found after a long standing duration. Even with full success of ICRS, such cases are not usually satisfied due to the difference between the treated and the normal eyes. One has either to shift to a hard contact lens, or to warn the patient about this point before taking any further step.
By ring selection we mean "the monogram". This is specifically a very debatable issue. Since ICRS started as a vision correction, refraction was always considered in the choice of number and thickness of segments to be used. This is almost a universal agreement between manufacturers.

In my opinion, this is not entirely true. The first reason is that, treating keratoconus is treating primarily the irregularity. This doesn't mean targeting spectacle independence. Another very important reason not to depend on refraction is the lack of accurate measurement of refraction for such cases. This factor was explained earlier, in details, with the optical correction section.

Let's take for example a case of keratoconus **(Figure 2A)**. Axial map shows a steep meridian sim K value of 50.83 and the flattest 48.28. On the other hand, the OPD map (optical path difference map) shows an error of refraction, poorly evaluated (in yellow) as -9.5 DS and -1.5DC for refraction. Spherical equivalent would be -10.25 D. Choice of segments based on refraction would imply using the thickest ones available (regardless the design). In this example, the segments chosen were following the topographic values, which, in this case, were much lower. After the surgery **(Figure 2B)**, axial map showed acceptable K values. The OPD map could, more successfully, evaluate refraction as -1.0 DS and -2.25 DC. If we insisted to go for the first choice, the resultant topography would be distorted and the quality of vision would be the lowest. This applies by far, to all current designs.

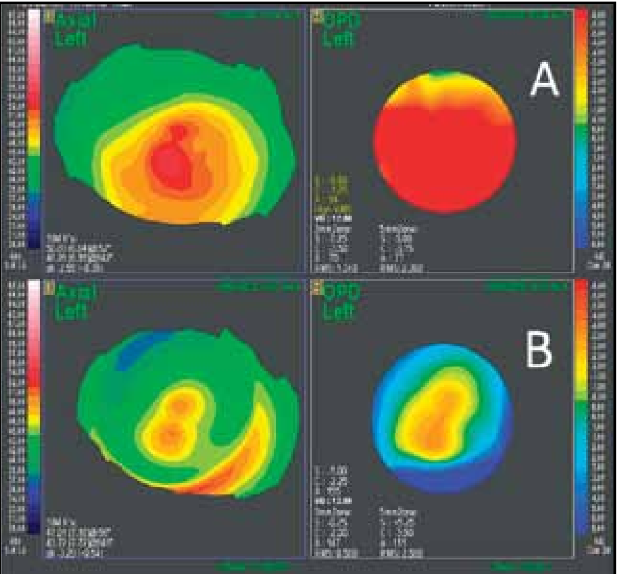

Figure 2A-B: 2- A case implanted with ICRS, based on the topographic values. (A) Preop.: showing poor refraction values (B) Postop.: showing the desired improvement.

To conclude this point, a topography oriented nomogram is more likely to improve cases rather than considering refraction.

After choosing the proper case and the proper segment. It is important to implant the ICRS properly. The surgical skills required to master ICRS implantation are not too demanding. The only issue is that, they are not linked to similar ophthalmic procedures as in cataract extraction for example. The skills in that field are cumulative, while in ICRS it is totally unrelated. After a dozen of cases, an average ICRS procedure should take 10-15 minutes. On the other hand, it is crucial for the segments to be implanted properly, to obtain the desired effect.

Different designs of ICRS center the rings differently. Small OZ rings, center either on the pupil or on the visual axis. Whereas, large OZ rings take the geometric center as reference. However, they all agree on the deepest plane possible for implantation. Another important note in the procedure is to respect the ring marking. If that is not achieved, an elliptical OZ is formed rather than a circular one, with an unexpected result. Also a higher risk of melting over the segment and possible extrusion might ensue.

The biggest advantage of the use of femto-second laser in the ICRS implantation is the repeatability of the results. Not only a fast procedure is made, but it also limits the variability of results between different surgeons.

After case and segment selection, and a successful ICRS procedure, remains the proper postoperative handling of the case. Keratoconus patients are usually young with high expectations. The success of ICRS is obtained not before 3-6 months. As mentioned earlier, the success means the ability to see WITH glasses, not to get rid out of them. All that should be clarified before the procedure and stressed upon after the procedure. A large sector of patient satisfaction is pre and post operative patient education.

The surgery doesn't require more than a short term antibiotics - steroid therapy. Longer than that, a viscous form of artificial tear drops is necessary. There is no pathology to explain a dry eye syndrome in ICRS implantation. We need however, to fill out the minute irregularity left in between the newly implanted segment and the remaining of the old cone. A marked difference was found in practice after the use of these drops, even a long duration after the surgery. They contribute markedly in the proper assessment of the condition and the improvement of quality of vision, by smoothening the anterior corneal surface.

Keratoplasty

Replacing the cornea is the ultimate solution for a severely damaged one. Keratoplasty remains the practice of longest track among the other alternatives. Results of transplantation are variable among different doctors. The financial cost is high with a life time necessity for care.

The most ideal technique is the deep lamellar one. There have been many methods to reach near or at the Descemet's membrane level. Maintaining that layer, improves the chance of graft survival and provides visual results similar to the penetrating one. In case of Descemet's rupture, it is advised to wait at least 6 months to avoid rejection. Then, the lamellar technique is almost not possible and the penetrating one is preferred **(Figure 3)**.

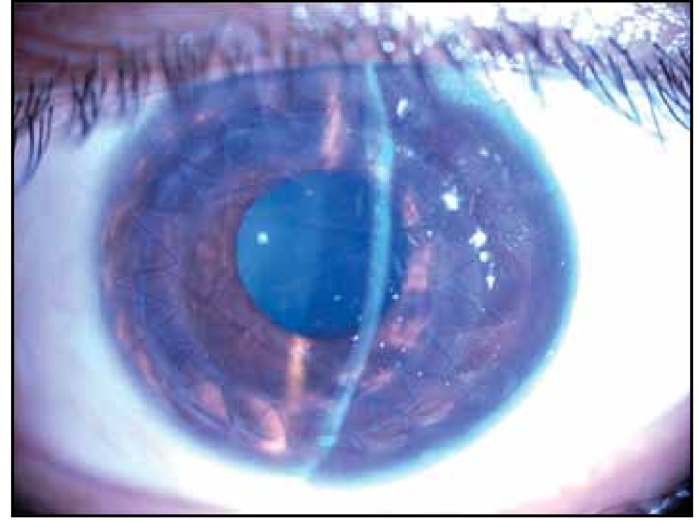

Figure 3: Deep Anterior Lamellar Keratoplasty (DALK), indicated for keratoconus 1 week postop.

Mixing Procedures

As already mentioned, keratoconus cases are complex ones. The mixing between different procedures might refine the results. This is more a very subjective issue among surgeons and depends upon own preferences and outcomes. To provide the patient with the best available care, time is needed. The patient has to be aware that final stability might take up to several months or even years.

CXL was tried, successfully, in several studies together with surface laser ablation (PRK). It is not necessary to correct the whole error. The benefit of excimer laser is to smoothen the surface of the cone with a topography guided technique. The role of CXL will be to prevent further progression. Any remaining error could be corrected by spectacles with a better quality of vision. If this technique is chosen, the most important is to leave at least 400 microns before CXL. Other protocols advise not to remove more than 50 microns with PRK.

Some authorities advise to combine CXL with ICRS. The cone will benefit from stability of CXL and visual improvement of ICRS. This opinion is not supported by others who believe that ICRS stops or limits to a greater extent the cone progression, specially the smaller OZ rings. Another issue is that, if we do combine them, raise some questions: should we perform them separately or simultaneously? And if separately, which one first and what is the interval between both? We can present our modest points of view in the following:

CXL improves stability because it "freezes" the cone. It will prevent progression, but will resist the correction of ICRS. By this principle, it is expected to intervene with the normal results of ICRS nomogram and the results will be bizarre. So, implant the ICRS first and allow them at least 6 months to act, then perform CXL to freeze it on the new position. CXL can be postponed or even completely abandoned, waiting for the detection of progression, if any.

Correction of residual error after arresting progression and improvement of vision will vary according to the original choice.

Excimer laser ablation can be satisfactory when used after keratoplasty and as a conjunction prior to CXL as explained earlier.

Again, PIOL is a good option after any method, providing that refraction is stable and other conditions in the anterior segments permit.

A unique method is currently being adopted to correct high regular astigmatism after keratoplasty. That's the Astigmatic Keratotomy using Femtosecond laser. Early trials by many surgeons including Dr. David Huang (Portland, Oregon) and the author of this article, are being made trying to reach a proper nomogram to validate this method. Preliminary results show acceptable efficacy and predictability, as well as excellent safety and stability.

From what was presented, we can conclude that the variability in treating options for keratoconus offer a larger spectrum for surgeons to utilize. It is essential though, to master some of them, or better, all of them, to provide our patients a better chance of therapy.

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Assessment of Corneal Optical Quality for Premium IOLs with Pentacam

Naoyuki Maeda, MD

With the new advancements in cataract surgery, the safety and the efficacy of the procedures utilized have been more and more remarkable than ever. As a result, the indication of cataract surgery has been expanding, and the expectations of cataract patients to the post-surgical results have been raised.

The introduction of premium intraocular lenses (IOLs) or new technology IOLs such as multi-focal IOLs, toric IOLs, and aspherical IOLs enabled us to modify the optical property of the eye post-operatively with the tailor-made fashion. Although the choice of IOLs except for the power was not so critical from the patient's point of view in the days when only the spherical IOLs were available, the post-operative satisfaction of the patients can be currently altered not only by the IOL power but also by the optical characteristics of the IOL.

Therefore, it is important for cataract surgeons to understand the life style of each patient, the ocular pathology, and the optical quality of the eye before surgery.
In this article, the assessment of corneal optical quality with Pentacam for the selection of premium IOLs will be introduced as the example and the importance of the screening procedure with the corneal topographer before cataract surgery.

Corneal Topography for Selecting Premium IOLs

At clinics where new technology IOLs are available, surgeons have to select one particular IOL from at least four kinds of IOLs for each patient. It will be necessary to evaluate the optical quality of the cornea during the pre-operative evaluation because suboptimal optics of the cornea or post-operative refractive error may spoil the premium IOL implantation.

We have been proposing four steps in the interpretation of corneal topography before performing cataract surgery as shown in **Table 1**.

The Pentacam HR (OCULUS, Germany) is one of the instruments categorized as slit scanning corneal topographer or Scheimpflug-based corneal topographer. We had a chance to develop a program with which the four steps of the screening procedure were easily performed.

Similar to the manual keratometer, it is very important for the interpretation of the topographic data to confirm the reproducibility of the data. Especial attention should be paid to very elder patients, patients with narrow palpebral fissure, or patients with poor fixation during measurement. If QS (quality specification) in the map is indicated with red color, the data should not be used. In doubt, the measurements should be repeated at least twice for each eye until reproducible topographic maps are obtained.

Figures 1, 2, 3 are the examples of the output. This program consists with 3 topographic maps, one Scheimpflug image, and one data box. The upper left is the axial power map using anterior surface data with keratometric refractive index (1.3375). This map is used to

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Table 1: Four Steps in the Interpretation of Corneal Topography.

Step 1: Evaluation of corneal irregular astigmatism	Check the irregular astigmatism with the refractive power map qualitatively, and with total HOA quantitatively. The current cut-off value of less than 0.3 µm (RMS, 4mm) for multifocal IOLs, and more than 0.5µm (RMS, 4mm) for the informed consent about significant irregular astigmatism is important.
Step 2: Detection of abnormal corneal shape	Check the abnormal corneal shape with the axial power map qualitatively, and with sagittal front-back ratio quantitatively. Determine whether to select the routine method or special method for IOL power calculation.
Step 3: Evaluation of corneal spherical aberration	Check the corneal spherical aberration. The tentative cut-off value of 0.1µm (RMS, 6mm) or higher for aspherical IOL and less than 0.1µm (RMS, 6mm) for spherical IOL.
Step 4: Evaluation of corneal cylinder	Compare the magnitude and axis of cylinder between K readings and wavefront. Consider surgical correction of regular astigmatism depending on the magnitude and axis.

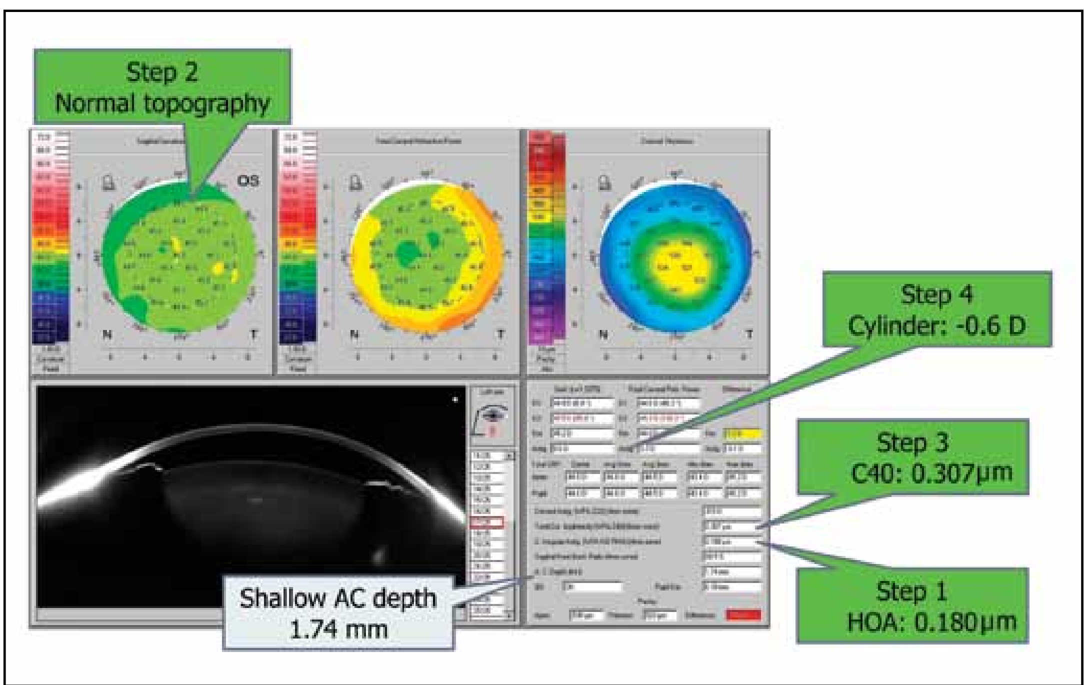

Figure 1: Normal cornea with shallow anterior chamber:
Total HOA (0.180 µm), spherical aberration (0.307 µm), front-back ratio (80.5 %), and cylinder (-0.5 D) are within normal ranges. Either multifocal aspherical IOL or monofocal aspherical IOL is fine in terms of optical quality of the cornea although anterior chamber is shallow (1.74mm).

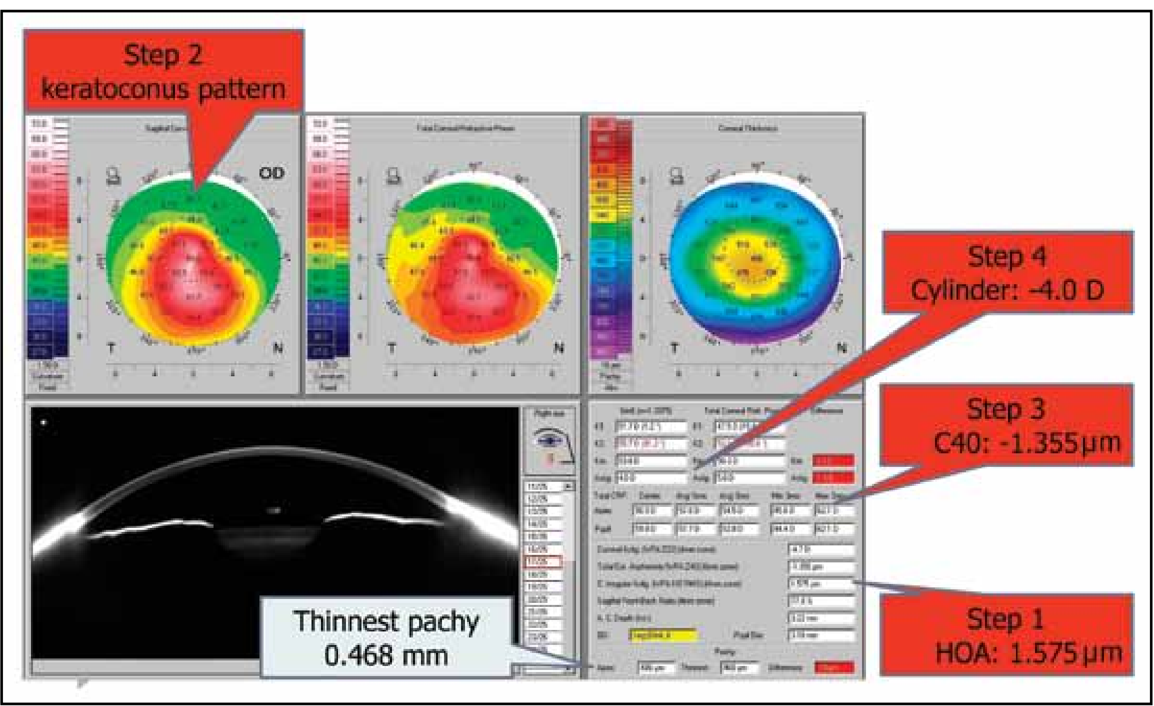

Figure 2: Moderate keratoconus:
Total HOA (1.575 μm) is high and spherical aberration (-1.355 μm) is too low. Conventional spherical IOL is recommended with the informed consent for the effects of corneal irregular astigmatism on quality of vision.

diagnose the abnormality in corneal shape. The upper center is the map of the total corneal refractive power. The total corneal refractive power (n=1.376 for cornea, n=1.336 for aqueous) is calculated from anterior and posterior refractive powers of the cornea and used for IOL power calculation for the patients with corneal shape abnormality such as post-LASIK, post-PTK, and post-keratoplasty. The upper right is the corneal pachymetric map. This map can be used to check the thickness at the main incision and at the side ports. The Scheimpflug image can be used to show the cataract to the patients and also to check the anterior chamber depth. The data box shows topographic indices including total corneal refractive power, corneal irregular astigmatism (total higher-order aberration), corneal spherical aberration, and corneal cylinder. In addition, simulated K readings, anterior chamber depth, pupil diameter, corneal thickness and others are available.

Step 1: Evaluation of Corneal Irregular Astigmatism

Even if there were no problems for performing cataract surgery in patients with mild pterygium, subclinical keratoconus, or mild corneal scar, irregular astigmatism due to these corneal diseases might affect the quality of vision of the eye after surgery.[1] When cataract surgeries were only performed in the cataract patients with advanced visual loss, surgeons might not need to pay attention to such mild irregular astigmatism because of the remarkable improvement in their visual acuity. However, mild irregular astigmatism can be the cause of

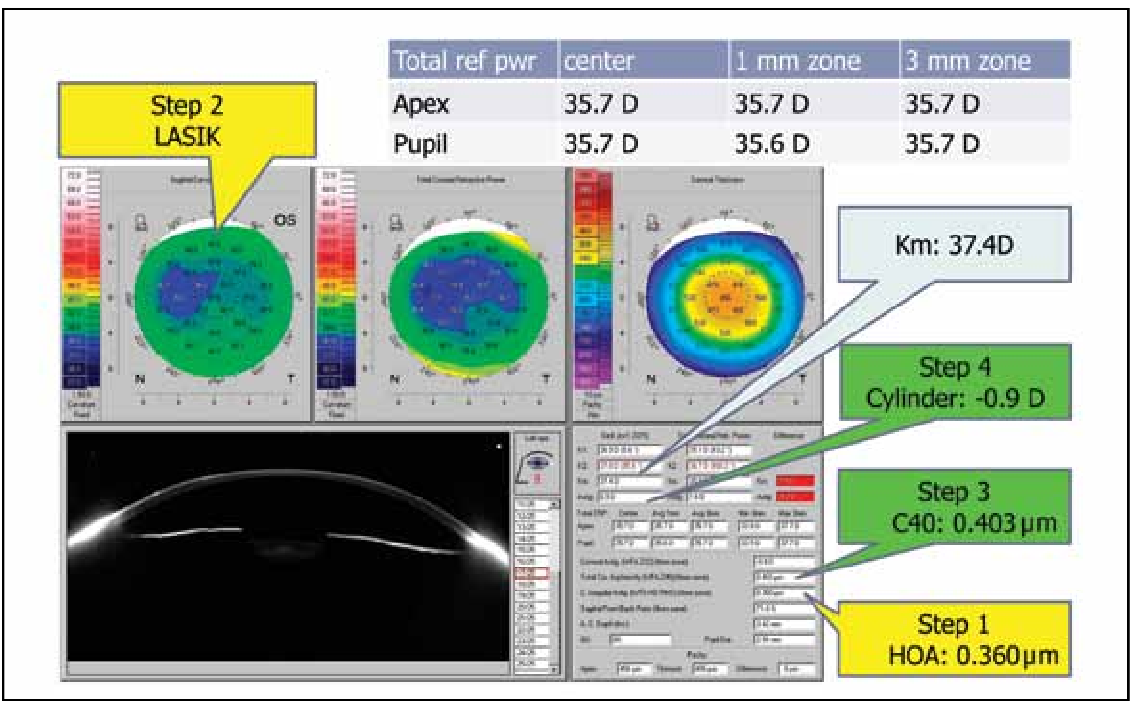

Figure 3. Post-LASIK:
Total HOA (0.360 µm) shows mild irregular astigmatism and spherical aberration (0.403 µm) is relatively high but within normal range. Monofocal aspherical IOL is recommended with the aid of special IOL formulas for post-LASIK.

the dissatisfaction of the patients when post-operative visual acuity or contrast sensitivity was not improved as expected due to the irregular astigmatism in the patients with relatively mild cataract and in the patients with the premium IOL.

Pre-operative evaluation of corneal irregular astigmatism and the informed consent about the effects of corneal irregular astigmatism on quality of vision will be useful for avoiding the claims after surgery even for the candidates of conventional IOLs.

As show in the improvements of results following multi-focal IOLs by the aspherical design, mild increase of HOAs can be the cause of suboptimal results with the multifocal IOLs.

Currently, we set the cut-off value in total higher-order aberrations for 4mm diameter to 0.3 µm for mild irregular astigmatism, 0.5 µm for moderate irregular astigmatism.

Step 2: Detection of Abnormal Corneal Shape

After many years, Laser in Situ Keratomileusis (LASIK) has become popular and established a position in the correction of refractive errors. As the results, avoiding post-operative refractive errors following cataract surgery in the post-LASIK patients have been a subject of discussion. Although these patients are generally interested in the good uncorrected visual acuity following cataract surgery, it is well-known that the hyperopic shi-

ft in post-operative refraction is frequently seen with the conventional power calculation.

For preventing the post-operative errors in such patients, it is important to review the topographic map so as not to overlook the abnormal corneal shape. In the case of post-LASIK patients, special methods should be considered for the calculating IOL power,[2] and the total corneal refractive power can be used in the no history methods.

Step 3: Evaluation of Corneal Spherical Aberration

Aspherical IOLs are widely applied for correcting the average corneal spherical aberration.[3] However, the wide range of variation in corneal spherical aberration exists even in the normal population. In addition, higher positive spherical aberration in myopic LASIK[4] and lower negative spherical aberration in hyperopic LASIK and keratoconus are reported. It will be reasonable to measure the corneal spherical aberration while choosing aspherical IOL or spherical IOL. We set the cut-off value to 0.1 µm or higher for aspherical IOL at this moment.

Step 4: Evaluation of Corneal Cylinder

Toric IOL is effective to obtain good uncorrected visual acuity in patients with regular corneal astigmatism. However, implantation of a toric IOL for patients with severe irregular corneal astigmatism is considered as a contraindication. Therefore, it is critical to evaluate not only corneal regular astigmatism with manual keratometer but also corneal total higher-order aberration with corneal topographer. Also the comparisons of magnitude and axis of regular astigmatism between manual keratometer and wavefront derived value may be helpful to confirm the reproducibility of data.

Summary

As the optical quality of the cornea in candidates of cataract surgery is not always in good condition, it seems to be rational for cataract surgeons to screen the corneal topography in order to select the premium IOLs with the tailor-made fashion for optimizing the optical quality of the eye following cataract surgery. All the cut-off values written above are tentative, and the accumulations of the results and the verification of the usefulness will be necessary to establish the topographic screening system before cataract surgery.

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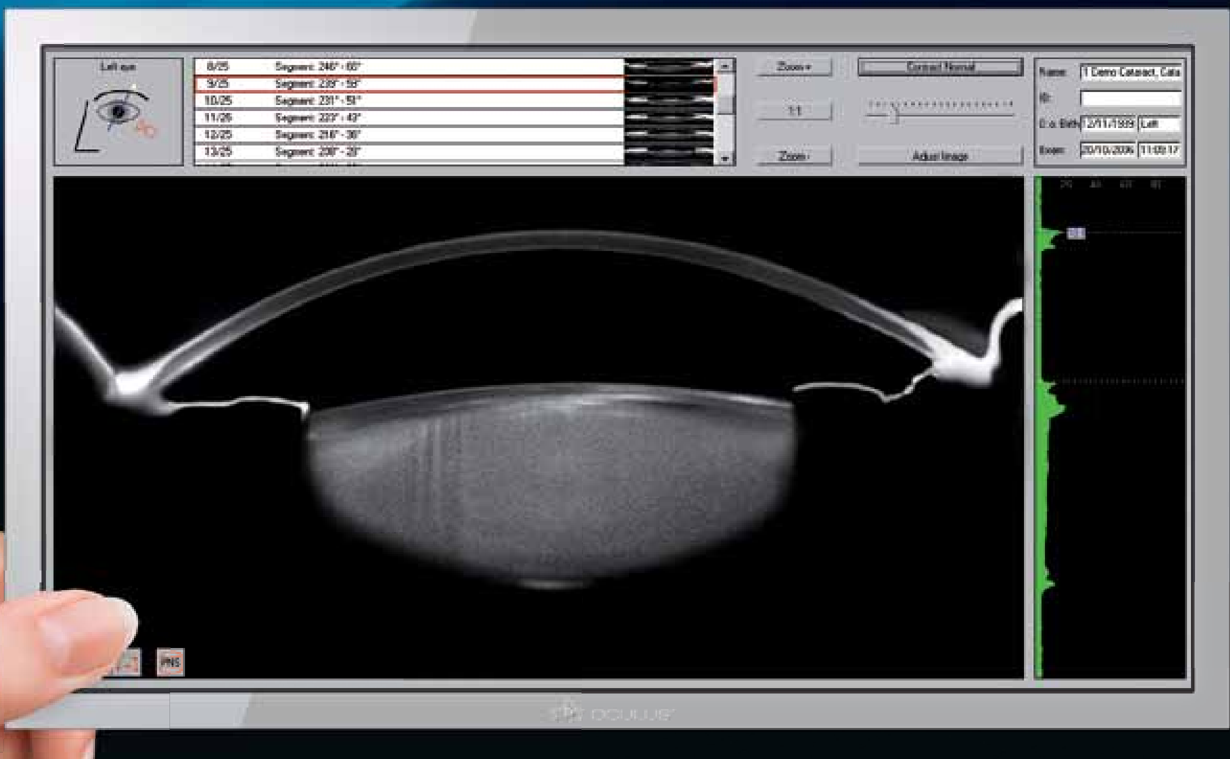

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