Advances in Cataract and IOL Implant Surgery.

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***Abstract**: Refinements in cataract surgery have enabled surgeons to deliver outcomes with high precision and predictability. This review provides a concise update on the surgical techniques of phacoemulsification, available options in phacoemulsification technology and advances in IOL designs. Single plane clear corneal incision has become very popular with the micro-incision phacoemulsification techniques. An incision suspected of incompetence (including side port paracentesis) should be considered for suturing. The micro-incision technique involves two approaches: the bimanual phacoemulsification and the coaxial microincision cataract surgery (CMICS), the difference being in the incision size. The coaxial microincision cataract surgery (CMICS) incision is compatible with the modern IOLs such as aspheric, multifocal and Toric IOLs. For phacoemulsification, longitudinal ultrasound energy when used in the continuous mode has the potential to cause lens repulsion/chatter.The new generation of phacomachines incorporate a hand-piece in which the tip oscillates laterally. The use of this technology clinically translates into less repulsion and good followability of nuclear material. The newer phacoemulsification machines also provide interrupted energy delivery modes for both longitudinal and torsional ultrasound for a more efficient cutting ability and less energy dissipation. Phacomachines improve the intra-operative safety by reducing surge such as with the Intrepid fluid management system. Advances in intraocular lens technology have aimed at improving optic and haptic designs that could reduce the postoperative posterior capsule opacification and improve the visual performance. These are conceptualised to improve the patient's functional visual and quality of life in performing their daily activities. They are presumed to minimize the risk of ocular hazards that occur after removing cataracts and implanting a conventional intraocular lens. All these put together in the management of cataracts can help achieve an optimal post-operative and functional visual outcome.*

INTRODUCTION

The past decade has seen vast improvements in cataract surgery technologies and techniques, with marked improvements in visual outcomes, and notable reduction in post-operative complications. There have been advancements in almost every domain of cataract management: biometry; IOL power calculation; surgical adjuncts; ophthalmic viscosurgical devices (OVD's) and capsule enhancing vital dyes. In this chapter we briefly review the advancements around the surgical management of cataract that have evolved phacoemuslfication into a refractive cataract surgery procedure: surgical techniques, Phacoemulsification technology and IOL technology.

ADVANCES IN SURGICAL TECHNIQUES

Single plane clear corneal incision

Single plane clear corneal incision has become very popular with the micro-incision phacoemulsification techniques. This incision produces less conjunctival hemorrhage and reduces post-operative foreign body sensation. While constructing clear corneal incisions we prefer an internal entry, which is 1.5 mm in length as it provides substantially greater resistance to incision failure. Also the integrity of a self-sealing incision depends to some extent on its length. If the incision is too short, the cataract wound may be susceptible to a postoperative perturbation and wound abnormality. At the close of surgery, we hydrate the stromal incision to enhance wound sealing. Surgeons who use corneal tunnels must pay particular attention to incision details and ensure proper sealing at the close of surgery. Any incision suspected of incompetence (including side port paracentesis) should be considered for suturing. Adopting the clear corneal incision has been instrumental in the development of micro-incision phacoemulsification techniques and thereof the evolution of the refractive cataract surgery.

The "Micro" incision phacoemulsification technique

The micro-incision technique involves two approaches: the bimanual phacoemulsification, conventionally known as Micro-incision cataract surgery (MICS) requires 2 micro incisions each less than 2 mm to accommodate a bare tip without a sleeve for aspiration through one incision and an irrigating instrument through another. The second approach, the coaxial microincision cataract surgery (CMICS) requires an incision of $\leq$ 2.4 mm and accommodates a sleeve over the tip. This allows aspiration and irrigation through the same incision coaxially and allows implantation of an IOL without enlarging it.

Bimanual microincision cataract surgery (MICS)

Some surgeons are hesitant to adopt the bimanual phacoemulsification approach as one either requires to widen the incision to implant an IOL with 6 mm optic, or create a third incision between the two micro incisions to implant an IOL with 6 mm optic, or use an IOL that can be implanted without enlarging it. The IOLs that are designed for implantation through the MICS incision, are yet evolving and do not have a long term proven track record. The use of "premium IOLs" such as multifocal IOLs, aspherical IOLs and spherical IOLs with proven optic and edge design and material such as AcrySof® IOL has shown to improve the visual outcome. These can be implanted through the conventional coaxial incisions as well as microcoaxial incisions. Implantation of these IOLs through micro incisions of bimanual technique still remains an issue. The short and single plane incisions of bimanual micro-incision surgery have also been cited as a cause for endophthalmitis, and persistent wound leak.

The coaxial microincision cataract surgery (CMICS)

The coaxial microincision cataract surgery (CMICS) has quickly grown in popularity among cataract surgeons. It involves performing coaxial phacoemulsification through an incision of 2.2 mm or less. The major advantage of CMICS is that the surgeon does not require investing on new micro-instruments, such as rhexis forceps or irrigating choppers. Since the technique of phacoemulsification i.e. division and fragment removal technique remains similar to the conventional coaxial technique the difference only lying with the incision size, there is no learning curve. The surgeon also does not have to compromise on the quality of the intraocular lens. Established

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monofocal and emerging multifocal and aspheric IOLs can be easily implanted without compromising the width of the micro incision, concluding the surgery with a micro incision in the true sense. With CMICS anterior chamber stability is not compromised and the fluidics in the anterior chamber are maintained by synchronizing the bottle height and aspiration flow rate. The CMICS can be safely done for emulsification of cataracts with a compromised endothelium, in a small pupil, posterior polar cataracts, rock hard nuclear sclerosis, eyes with weak zonules, subluxated cataracts and for any other adverse environment or difficult cataract. The CMICS incision is compatible with the modern IOLs such as aspheric, multifocal and Toric IOLs.

ADVANCES IN PHACOEMULSIFICATION TECHNOLOGY

Torsional Ultrasound - Ozil Technology

This technology is available as the Ozil™ on the Infiniti Vision System, (Alcon Laboratories, Texas, USA)

How does it differ?

The OZILTorsional technology incorporates a new handpiece capable of creating rotatory ultrasound movements of the phaco needle at 32 kilohertz (KHz). The tip oscillates laterally 5.5º degrees (2.75º on each side).This translates in approximately 90 microns of stroke at the cutting edge. However, at incision stroke is approximately ½ of it, i.e. 40 microns.

These torsional movements create a side-to-side motion at the tip[1], which allows emulsification on both excursions, with reduced repulsion of fragments in contrast to longitudinal phacoemulsification. Clinically this translates into a more efficient cutting ability, and less energy and heat dissipation. Energy and aspiration work in harmony with OZil because the lens substance is not pushed away. That means clinicians can use lower aspiration flow rates and lower bottle height. The benefit of being able to use lower fluid parameters is that there is a reduced chance of attracting the posterior capsule to the phaco probe. In addition less fluid turbulence within the anterior chamber offers better endothelial protection. This harmony confers the dual advantages of increased efficiency and intra-operative safety.

The Ozil technology can be effectively utilised with CMICS and works favourably even in compromised environments such as dense cataracts, eyes with a small pupil and floppy iris.

TRANSVERSAL ULTRASOUND – THE ELLIPSE TECHNOLOGY

The Ellipse technology in the Signature Phacoemulsifier recently introduced by AMO, USA also provides the ability to simultaneously blend longitudinal and transversal modes, both optimized with proven WhiteStar Technology.

The blended longitudinal and transversal modes provide constant emulsification designed to reduce clogging of the phaco tip. It also affords efficient cutting that does not require changes in technique and allows the use of a straight or curved phaco tip,

Enhanced Fluid Management Systems

The newer phacoemulsification machines have improved fluid management systems that help reduce surge and improve surgical performance. The intrepid FMS in the Infiniti Vision System has provided additional fluidic efficiency and safety during optimal and especially during difficult phacoemulsification procedures.

A dual-linear phacoemulsification platform available on the Millenium and the Stellaris Vision Enhancement System, (Bausch & Lomb, USA) separates phaco and vacuum, allowing cataract surgeons to maximize their control over the procedure.

Staar Surgical's Cruise Control device is also a good adjunct to bimanual microincisional phaco. This disposable, inexpensive flow restricting device can dramatically reduce post-occlusion surge, which otherwise limits the ability to use higher vacuum levels with bimanual microincisional phaco. The Cruise Control device can be quickly attached to the aspiration tubing of any phaco machine.

Interrupted Ultrasound Energy Delivery

Longitudinal ultrasound energy when used in the continuous mode has the potential to cause lens repulsion/chatter and wound site thermal injury. To overcome these the new generation of phacoemulsifiers provide interrupted energy delivery modulations such as the Pulse mode in the Sovereign, White Star ICE technology, (AMO, USA) and Signature with CASE (AMO, USA) and the Hyperpulse and linear MicroBurst modes (Infiniti Vision System, Alcon). The hyperpulse on the Infiniti system allows one to choose from the different permutations and combinations of the duty cycle and pulse frequency. All these interrupted energy delivery systems allow for intermittent delivery of energy which allows the fluidics to work between the pulses. Thereby the thermal safety profile during phacoemulsification is improved. The duration of the ultrasound energy delivery and the frequency of delivery of ultrasound energy can be modulated, depending from machine to machine.

ADVANCES IN IOL TECHNOLOGY

IOL material and design

It has been recognised by the industry that the hydrophobic acrylic material has a tacky surface quality that promotes good stability of the IOL in both, the anteroposterior direction as well in terms of rotation. It generates fibronectin and other natural tissue adhesives that stabilize this implant to the capsular bag. The premium IOLs from Alcon, AMO, and Zeiss are being designed on the hydrophobic platform. An IOL with a sharp posterior edge all along its 360 degree circumference has, in addition to the material, been recognised as a cause for the low incidence of the posterior capsule opacification. The Currently, single-piece hydrophobic acrylic IOL (Acrysof, Alcon, Tecnis, AMO) are popularly used hydrophobic acrylic IOLs.

Blue light filtering IOL

Removing the protective crystalline lens and replacing it with a clear (UV-blocking) intraocular lens (IOL) allows a greater amount of blue and violet light to enter the eye more so than that allowed by the normal adult crystalline lens. Blue light has been implicated for the development of age-related macular degeneration (ARMD). The recent EUREYE, 89 although showing no overall association between blue-light exposure and neovascular or early ARMD, identified a subgroup of patients with low antioxidant levels in whom an association between bluelight exposure and neovascular ARMD was seen. Development of the Blue light filtering IOLs was to specifically reduce transmission of short-wavelength visible light to protect the retina from possible light-induced damage and to reduce cyanopsia. The Blue light filtering IOL (AcrySof Natural, Alcon Laboratories, USA) and the blue light filtering IOL from Hoya is a yellow tinted intraocular lens that has a blue light filtering chromophore that filters light in a manner that approximates the human crystalline lens in the 400-475 nm blue light wavelength range addition to the standard ultraviolet (UV) light filtering, it reduces transmittance of blue light wavelengths from 71% at 400 nm to 22% at 475 nm.

Benefits that have been suggested include protection against retinal damage due to blue light, with a possible role in preventing the development or exacerbation of age-related macular degeneration (ARMD); improvement in contrast sensitivity and reduced glare under photopic and mesopic conditions; and reduction in disturbance of blue color vision. Several potential disadvantages may become evident if short-wavelength light transmission is reduced (or allowed in excess, as in the case of cyanopsia with UV-blocking IOLs). Potential side effects of a reduction in blue-light transmission include color-vision disturbance, decreased scotopic sensitivity (which can lead to poorer performance in dim lighting conditions), and sleep-wake timing disruption. In view of the number of clinical studies that show no color-vision abnormalities, color-vision disturbance does not appear to be a significant problem with this type of IOL. The implantation of AcrySof Natural intraocular lens did not worsen the pre-existing severity of colour defect in congenital partial red-green colour defective individuals. Also although there is a theoretical argument that these IOLs may decrease scotopic sensitivity, there is no clinical evidence to date. Studies to date have also failed to show a detrimental effect of blue light-filtering IOLs on photopic and mesopic contrast sensitivity in normal eyes, and have found improved photopic contrast sensitivity in eyes of diabetic patients. It has also been reported that there is improved photopic and mesopic vision at middle spatial frequencies with these IOLs, with a reduction in the effect of central glare. While it is still debated if blue light filtering IOLs theoretically provide better photoprotection but worse photoreception than conventional UV only blocking IOLs, Violet blocking IOLs have offered similar UV-blue photoprotection but better scotopic and melanopsin photoreception than blue blocking IOLs in laboratory studies.

Aspheric IOL

The aspheric IOL improves the quality of vision especially by reducing the spherical aberrations, improving contrast sensitivity or retinal image quality under mesopic conditions. The optical quality of the eye is determined by the combination of corneal and lens aberrations. The cornea has positive spherical aberrations that change little with age. When the eye ages, there is a shift in the spherical aberrations of the lens towards more positive values. This change combined with the positive spherical aberrations of the cornea degrades the optical quality of vision. After cataract extraction if a IOL with a standard spherical lens design is implanted it can lead to a reduction in vision quality due to spherical aberration (SA).Therefore to improve the optical quality, an Aspheric IOL with negative spherical aberrations is needed to compensate for the positive spherical aberrations of the cornea.

It has been observed clinically that IOLs such as the Tecnis (model Z9000, AMO, USA) with an aspherical anterior surface result in less loss of contrast sensitivity than IOLs with a spherical surface by compensating for the spherical aberration of the cornea. This aspheric IOL has a -0.28 spherical aberration that compensates the total amount of the ocular spherical aberration. Clinical observations have suggested not compensating fully the spherical aberrations of the eye as some moderated residual SA may improve the depth of field and consequently better performance for near tasks.

Another aspheric IOL which has a less negative spherical aberration (-0.17) than the Technis IOL is the AcrySof IQ (model SN60WF, Alcon Laboratories,Inc.). It has a modified posterior surface to create a more equi-biconvex optic meant for improving contrast sensitivity. The AcrySof Natural single piece IOL is the platform for AcrySof IQ IOL and filters blue light with its proprietary blue light filtering chromophore. The AcrySof IQ shares the basic design features of the AcrySof Natural including a 6 mm optic, 13 mm overall length and Stable Force® Modified-L haptics. The surface modification reduces the central IOL thickness by 9% for 20 diopter lens. Another aspherical IOL from Bausch and Lomb, USA, is the SofPort®. It is designed to be aberration free with uniform center-to-edge power for optical performance that is unaffected by pupil size or location of the optic. In other words, this IOL has zero asphericity.

Studies have been reported which demonstrated significantly higher contrast sensitivity with aspheric IOLs compared to the spherical IOLs at all spatial frequencies during mesopic testing in illumination conditions with and without glare. The authors routinely use the aspherical AcrySof IQ IOL.

Toric IOL

Good unaided distance visual acuity following cataract surgery and intraocular lens (IOL) implantation is now a goal that every patient expects. Central to this is the need to reduce post-operative astigmatism. Surgically induced astigmatism has been reduced by the micro-incision phacoemulsification techniques. However the percentage of individuals with corneal pre-existing astigmatism exceeding values that cannot be reduced by changing the incision site. In our unpublished data 74.7% patients had clinically significant astigmatism (greater than 0.5 D. Out of these, majority i.e. about 74.9% (887/1184) cases had an astigmatic error of 0.5-1.5 D. To correct regular corneal astigmatism, Toric IOLs have proved to be very precise and effective. Several varieties of the Toric IOL are now available: The STAAR **Toric IOL** (STAAR Surgical Company, Monrovia, CA) is a single-piece silicone foldable lens.

Rayner T-*flex*® Toric IOL (573T and 623T) is a hydrophilic acrylic IOL with the torus (cylinder) implemented on the anterior surface of the optic and the Amon-Apple Enhanced Square Edge on the posterior surface. The HumanOptics AG (Erlangen, Germany), has a three-piece, foldable toric IOL, the MicroSil Toric IOL. This IOL, type MS 6116 TU, has PMMA haptics in a z-design, and silicone optic. The Acri.LISA Toric 466 TD is a toric IOL (Acri.Tec) with multifocality. This lens model, is made of hydrophilic acrylate with a hydrophobic surface, and has a biconvex diffractive multifocal lens, with a diffractive aspheric back surface and an aspheric toric front surface.

The Acrysof Toric lens which is composed of an acrylic polymer that has UV and blue-light absorbers has demonstrated very good stability post-operatively with a low percentage of individuals requiring IOL repositioning. (chang) The AcrySof Toric IOL has demonstrated good rotational stability. This IOL has also demonstrated good post-operative uncorrected distance visual outcome and has reliably and reproducibly reduced the pre-existing refractive error following its implantation. (bauer njc, jcrs 2009, mendicute 2009). In a study conducted by the authors to evaluate the visual outcomes and residual refractive error following the AcrySof Toric IOL in eyes with pre-existing astigmatism, they concluded that BCVA in all eyes was 6/12 or better with 99% achieving 6/9 or better. The residual refractive astigmatism was within $\pm$ 0.25 D in 68% eyes, within $\pm$ 0.5D in 83%, within $\pm$ 0.75D in 97 % and within $\pm$ 1.0D in 100% eyes. The refractive astigmatism showed excellent stability between follow-up examinations with 94% cases remaining unchanged. A change of 0.25 D was seen in 4% and only 1% changed by 0.5 D.

Multifocal IOL

To expand the functional vision beyond just distance vision, multifocal IOLs with multiple foci have been approved by the FDA. These multifocal IOLs with two primary focal points provide the ability to see distance and near simultaneously. Multifocal IOLs that are available use either multizone refractive optics (ReZoom, Abbott Medical Optic, USA), full optic diffractive optics (Technis, Abbott Medical Optic, USA and the Acri.Lisa, AcriTec AG, Germany) or a combination of both with hybrid optics (Restor, Alcon Laboratories, USA).

The amount of near addition that can be incorporated into a multifocal

IOL is different for every IOL. A refractive multifocal lens such as the Rezoom (Advanced Medical Optics, Inc.) has 3.50D at the IOL plane, and about 2.85 D on the spectacle plane. Full optic diffractive lens such as the Tecnis Multifocal has a 4.00D on the IOL plane, an amount that is equivalent to 3.00D at the spectacle plane. The apodized diffractive IOL such as the Restor multifocal has a add of 4.00 diopters equivalent to approximately 3.20 diopters at the spectacle plane. These diffractive IOLs provide a superior near focus to that of refractive multifocal lenses. Recently it has been recognised that an aspheric platform can improve the visual quality by decreasing unwanted visual phenomenon associated with multifocal IOLs and increases the range of focus. This improves the intermediate vision. The three aspheric designs available are AcrySof ReSTOR SN6AD3, Acri.Lisa 366D, and Tecnis ZM900. In a laboratory study the AcrySof ReSTOR SN6AD3 aspheric IOL followed by The Acri.Lisa IOL have showed superior optical properties.

The aspheric apodized diffractive Restor multifocal IOL has a lower add of 3.00 diopters equivalent to approximately 2.40 diopters at the spectacle plane. The authors implant this IOL when considering implantation of a multifocal IOL. In the authors experience the percentage of patients who achieved 20/20 vision at all three distances with this multifocal IOL was higher than the percentage of patients who received the spherical AcrySof IQ ReSTOR +4.0 D multifocal IOL.

Accommodating IOL

Another approach to achieve simultaneous distance and near vision is to implant a monofocal IOL with a flexible haptic design that uses the eye's natural accommodative ability, the accommodative IOL. The Crystalens IOL (Bausch and Lomb, USA) has been approved by the FDA. These monofocal accommodative IOLs are generally associated with fewer photic disturbances but might not provide improved functional near and intermediate vision. The Synchrony Dual Optic Accomodating IOL (Visiogen, Irvine, CA, USA) silicone bag-filling IOL works on the Helmholtz theory of accommodation. It consists of two optics suspended at an optimal distance from each other. Following the Helmholtz theory of accommodation, relaxation of the circular cilairy muscles increases zonular tension; the two optics move closer together , decreasing optical power. Contraction of the circular ciliary muscles produces the opposite effect. (Presented by Dr. David Chang, in the symposium at 22nd APACRS Annual Meeting June 2009)

Bag-in-the Lens IOL

A major postoperative deterrant to optimal visual outcome as well the second largest burden to the eyecare economics after cataract surgery, is the treatment for posterior capsule opacification. Recently, a new concept of introducing the "Bag-in-the-lens" has been introduced. Here, equally sized anterior and posterior capsulorhexes are created. These anterior and posterior capsular leaflets are then inserted into the grooves of a specially designed IOL. Although technically demanding, this technology promises to provide clear visual axes and eliminate PCO. However, longterm outcomes need to be evaluated.

Technological improvements have made it possible to customise IOL implantation to some extent. However for optimal visual outcomes it is crucial to refine the surgical technique, understand the nuances of technology and the needs of our patients before choosing to opt for a premium IOL Technology.

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