Introduction

Although cataract surgery has been practiced for over 2000 years, modern cataract surgery started with the first intraocular lens (IOL) implantation by Sir Harold Ridley in 1949. At this time classical cataract surgery developed into refractive intraocular lens surgery to correct higher ametropia. This development was only possible because of the improvements of surgical techniques and implants ***(Aufffarth et al., 2001)***.

However, despite new advances in cataract surgery, unsatisfactory visual outcome as a result of a residual refractive error, which is also called refractive surprise, occasionally occurs. Refractive surprise after cataract surgery is an unpleasant and frustrating situation ***(Norrby, 2008)***.

Current methods to overcome refractive surprise are corneal-based surgery (laser refractive surgery) and lens-based procedures (IOL exchange or piggyback IOLs) ***(El Awady et al., 2013)***.

Lens-based procedures were preferable in some situations such as in high degrees of residual spherical errors. Also, lens-based procedures do not alter the anterior corneal surface and do not significantly change the corneal refractive power. The original cataract wound can be reopened soon after the initial surgery. And there is no need for special settings such as those required for laser refractive surgery. New lens based procedures are developed, in which IOL power modification can be done after implantation. New lens based procedures are developed, in which IOL power modification can be done after implantation. They are called modifiable IOLs ***(El Awady at al., 2013)***.

Aim of the Work

To discuss modifiable IOLs as regarding their types, advantages, disadvantages and why they are needed in ophthalmological practice.

Chapter (1)
Current procedures in cataract surgery

Cataract surgery with intraocular lens (IOL) implantation is the most common ophthalmic surgical procedure all over the world ***(Nagy et al., 2009)***.

The first documented treatment of cataract is couching which began around 500 BC, in this procedure the lens was displaced away from the pupil to lay in the vitreous cavity in the back of the eye. The lack of sterilization and the inflammation that would result from the retained lens with its disrupted capsule lead to many complications ***(Bobro, 2009)***.

In 1753 the French physician, Jacques Daviel documented the first series of cataract extractions through a corneal incision to the Royal Academy of Surgery. At that time, the operating microscope had not yet been invented; this made identification and removal of the cortical matter virtually impossible. Later, intracapsular cataract extraction became the standard surgery by the work of Henry Smith in India ***(Tesman et al., 1992)***.

Intracapsular Cataract Extraction (ICCE)

The intra-capsular technique was introduced in 1880. After a large corneal incision, and with the pupil dilated, the lower part of the anterior capsule was grasped by forceps and by a variety of rocking manoeuvres the zonules were weakened and broken from the ciliary muscle (usually without rupture of the capsule). The lens was then delivered upside down. Excess pulling could cause either capsule rupture or vacuum at the vitreous face, which might rupture and cause macular oedema and subsequent retinal detachment ***(Gauldi et al., 2014)***.

Barraquer introduced Zonulysin (i.e. alpha chymotrypsin, a digestive proteolytic enzyme of bovine origin), which could be injected into the posterior chamber for easier and safer lens delivery. Miniature suction devices (Erisophakes) were an alternative method. Krawicz (1963) used a silver rod conducting cold from solid CO_2 in a syringe "cryoextractor" in order to make adhesion to the lens more reliable. This technique was refined by Amoils (1964), who used the cryoprobe which could then be reheated electrically or by warm gas to release the probe if the resulting ice ball also adhered to iris ***(Gauldi et al., 2014)***.

Extracapsular Cataract Extraction (ECCE)

In Extracapsular Cataract Extraction, the lens material is removed, but the back of the lens capsule remains intact. The corneal incision is significantly less intrusive than the intracapsular procedure, yet not as concise as the later-developed phacoemulsification ***(Frey, 2013)***.

The ECCE procedure consists of creating an incision at the limbus, and then the anterior lens capsule is carefully opened through a small circular tear "capsulotomy". The hard nucleus of the lens is then extracted by carefully applying pressure with specific tools. Irrigation/Aspiration is then used by the surgeon in order to remove the soft lens cortex. Viscoelastic material is inserted into the empty lens capsule to maintain its form as the intraocular lens is being implanted, which is then removed after the IOL is successfully placed. The back of the lens capsule remains intact within the eye and assists in firmly supporting the newly placed intraocular lens. The incision is then sealed and protected using stitches ***(Allen et al., 2006)***.

Today, extracapsular cataract extraction is not used as commonly as phacoemulsification, but is helpful when removing extremely advanced cataracts that can be difficult to break up through phaco, or in patients with numerous eye problems that could be worsened by phaco. Visual recovery after ECCE is often longer than phaco, and because the cataract is removed in one singular piece, the incision is much larger, which can cause greater astigmatism and discomfort ***(Allen et al., 2006)***.

Phacoemulsification

In 1967, Kelman published an article describing a totally new approach that would, over the next 25 years, ultimately replaced traditional inpatient cataract surgery with a much less intrusive and more curative procedure that could be performed on an outpatient basis. Kelman called his proce-dure phacoemulsification (*phako* being Greek for 'lens'; *emulsi* for 'milked out') ***(Kecova et al., 2004)***.

In its currently practiced form, phacoemulsification involves making a small, self-sealing incision in the cornea (3 mm in contrast to the traditional larger incision) and then inserting an ultrasonic probe, the vibrations of which (40,000 per second) break and liquefy the cataractous lens without damaging the surrounding tissues. The emulsified fragments of the lens are then removed through the phaco tip ***(Kecova et al., 2004)***.

Surgeons realized that phacoemulsification and IOL implantation lead to exquisite control of the intraocular environment, much more safety in handling complications or challenging cases, rapid postopertaive visual rehabilitation, and a reduction in surgically induced astigmatism. Phacoemulsification ('phaco') has become the standard method of cataract extraction ***(Kanski et al., 2011)***.

Modern phacoemulsification cataract surgery consists of main surgical steps: incisions, continuous curvilinear capsulorhexis (CCC), phacoemulsification, IOL implantation (and centration) and astigmatism correction (toric IOL or limbal relaxing incisions). Each of these steps is critical to the successful outcome of the procedure. Failure of execution of these steps can lead to a less than desirable outcome or serious complications ***(Apple et al., 2011)***.

Manual Small Incision Cataract Surgery (SICS)

While phacoemulsification is by far the most widely used procedure in the developed world, many ophthalmologists use non-phaco small incision surgery in developing countries, which is just as effective when done correctly. This "sutureless non-phaco cataract surgery" has three essential parts to it. The procedure creates a small scleral tunnel, self-sealing, incision that provides low risk for developing astigmatism. However, the incision must also be sufficiently sizable to fit the entire lens nucleus in order to remove it. The nucleus is prepared within the eye for extraction, and then must be delivered extremely carefully so as not to harm the cornea and posterior lens capsule. Manual SICS in comparison to phaco has several advantages, as it requires less resources, can be conducted with virtually any variation of cataract, and involves less training in comparison to Phaco ***(Rozakis et al., 2003)***.

Femtosecond (FS) Laser and Cataract Surgery

The first reported clinical application of the FS lasers for cataract surgery was in 2009. In September 2009, the FDA proved the LenSx (ALCON, California, USA) laser for the creation of anterior capsulotomies prior to cataract surgery. In rapid succession, the application in the creation of corneal incisions and applying the fragmentation of cataracts has also been approved. In 2010, the FDA cleared FS laser systems for cataract surgery ***(Donaldson et al., 2013)***.

FS laser can be used to perform four groups of incisions: capsulotomy, lens fragmentation, astigmatic relaxing incisions, and clear corneal incisions (CCIs, including the cataract incision and paracenteses) ***(Donaldson et al., 2013)***.

Advantages and disadvantages of FS laser-assisted cataract surgery

The ability of FS laser to create incisions at a precise depth and with a desired shape opens the road to cataract incisions and limbal relaxing incisions (LRIs), with a more efficient sealing than conventional clear cornea incisions. Also, use of the FS laser has the potential to revolutionize cataract surgery with the creation of a capsulotomy, or laser-incised capsulorhexis. With the growth of premium IOLs, precisely centered and measured capsulorhexis is essential to achieve optimal visual outcomes especially with the presbyopic correcting intraocular lens (IOLs) and toric IOLs. Moreover, FS lasers have the ability to pretreat, segment or soften the lens to minimize the energy and trauma required for phacoemulsification and removal, and help to speed recovery and achieve better visual outcomes ***(Liu et al., 2015)***.

Apart from the advantages of FS laser mentioned above in the field of cataract surgery. Also, studies have demonstrated that FS laser-assisted cataract surgery causes less corneal edema in the early postoperative period and less trauma to corneal endothelial cells than manual phacoemulsification ***(Abell et al., 2015)***.

Chapter (2)
IOL material and design

The real start of usable IOL technology occurred during World War II. Dr. Harold Ridley, a British ophthalmologist who had cared for many injured pilots during the war, observed that small fragments of cupolas (i.e., Polymethyl methacrylate (PMMA) from crashed planes) that penetrated the globe during the crash did not cause an inflammatory reaction. The material was not rejected by the body and stayed inert in the eye. Ridley recognized that this material could be perfect for artificial lens implantation ***(Apple, 2006)***.

After detailed studies, Sir Harold Ridley implanted the first IOL on November 27, 1947, at Saint Thomas Hospital, in London. He implanted the original PMMA IOL in 750 patients by 1959. In the 1970s; IOL implantation after cataract extraction was considered a standard procedure ***(Apple et al., 2002)***.

IOL Materials

1. PMMA IOLs

Even though the use of nonfoldable PMMA for cataract surgery today plays little role in the United States and Europe mainly because of large wound size, it still plays an important role in countries where extracapsular cataract extraction (ECCE) with manual expression of the nucleus is the technique of choice. PMMA IOLs with a sharp optic edge have been shown to result in relatively low posterior capsular opacification (PCO) rates ***(Shah et al., 2007)***.

Also, PMMA is still used for sulcus-placed IOLs and sulcus-sutured IOLs due to their overall rigidity, which results in good centration and resistance to tilt. Anterior chamber IOLs as well as iris-fixated IOLs are also made of PMMA and known to be very inert concerning the uveal inflammatory reaction ***(Davison et al., 2013)***.

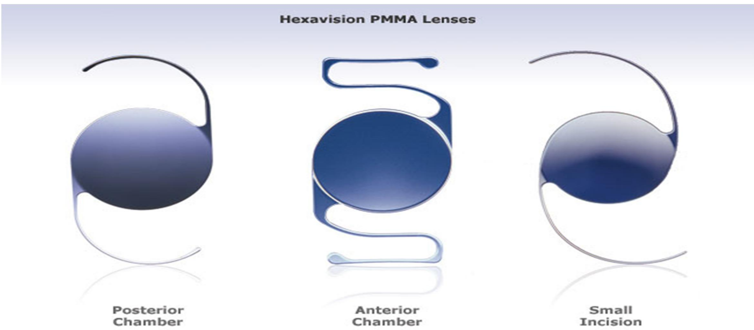

Figure (1): PMMA IOLs ***(www.hexavision-iol.com)***

2. **Foldable IOLs**

Hypdrophilic Acrylic (Hydrogel)

Hydrophilic acrylic is a quite heterogeneous material group and has high water content. These IOLs are cut in the dehydrated state and then hydrated and stored in solution. The water content between IOLs varies widely and can be as high as 38%. A recent Meta analysis on PCO showed that the hydrophilic acrylic IOLs are more prone to develop PCO than hydrophobic acrylic lenses or silicone lenses which may be due to the high water content being more "inviting" to lens epithelial cells (LEC) ingrowth ***(Navaty et al., 2008)***.

Hydrophobic Acrylic

Currently the most commonly used IOL material; these polymers of acrylate are flexible under room temperature. This material has very low water content, a high refractive index, and usually a high haptic memory, which also makes the material usable for the haptics of a monobloc open-loop IOL. This group of materials has been shown to have a good uveal and excellent capsular biocompatibility. The two main groups of this material are AMO Acrylic

(Santa Ana, CA) and Acrysof (Alcon, Fort Worth, TX) ***(Leaming, 2004)***.

One of the disadvantages of this material group is the resultant intralenticular changes. Small water inclusions in the optic material called glistenings can be found in hydrophobic materials, especially with the Acrysof material ***(Werner, 2010)***.

The other disadvantage is dysphotopsias reported with this high refractive index material. The most common type is positive dysphotopsia which included edge glare due to internal reflections at the rectangular edge of the Acrysof IOL under mesopic conditions with a wide pupil. However, with changes in optic geometry, these dysphotopsias have been decreased significantly with newer hydrophobic acrylic models. A smaller proportion of patients reported negative dysphotopsias which are perceived as a scotoma in the temporal peripheral visual field ***(Farbowitz et al., 2005)***.

Silicone

Silicone was the first material available for foldable IOLs. There is a continuous decline in the use of silicone IOLs. While silicone is a very good IOL material, especially concerning its PCO blocking effect, it cannot be used for a