Implantation of Multifocal IOLs in the modern cataract and refractive surgeries

Essay

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Eslam Ezzat Atallah

Contents

List of abbreviations

AMO	:	Allergan Medical Optics
D.	:	Diopters
ECCE	:	Extracapsular Cataract Extraction
IOL	:	Intraocular Lenses
IOP	:	Intra-Ocular Pressure
LASIK	:	Laser Assisted in Situ Keratomileusis
MIOL	:	Multifocal intraocular lenses
PCIOLs	:	Posterior Chamber Intraocular Lenses
PCO	:	Posterior Capsular Opacification
Phaco	:	Phacoemulsification
PMMA	:	polymethylmethacrylate
™	:	Trade Mark

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Introduction

The use of multifocal intraocular lenses (MIOLS) is increasing in practice of cataract surgery because of reduction of spectacle dependency and high level of patient satisfaction. Patient who received bilateral MIOLS obtained better corrected near visual acuity , less limitation in visual function , and less spectacle dependency than monofocal IOLS.

MIOLS have been implanted since 1986, with refractive and diffractive designs. Surgically induced astigmatism was a possible complication. Reduced contrast sensitivity, colour vision, increased glare and haloes were common problems of MIOLS. Modern MIOLs can be considered not only for correction of aphakia but also for refractive purposes.

Besides the diffractive type of MIOLs, which produces a second focus for near vision by means of diffraction rings, there is refractive type with 2-7 refractive zones Diffractive MIOLs provide better near visual acuity, increased contrast sensitivity and less glare disability than refractive type

With MIOLs, smaller pupil size is correlated significantly with worse near visual acuity; larger pupil size is correlated significantly with better distance visual acuity but with worse near visual acuity.

Although MIOLs can provide near vision, they may increase higher-order aberrations and negatively influence contrast sensitivity. However, the aspherical MIOLs can reduce aberrations and improve contrast sensitivity as compared with the spherical MIOLs.

When choosing a multifocal intraocular lens, the needs of each patient should be taken into consideration, near visual acuity is significantly better with diffractive type, while distance visual acuity is good with both types but is better with refractive type. New models of MIOLs achieve comfortable distance and near vision.

History of (IOLs) implantation

The concept of IOL implantation following cataract extraction dates back to 1765when *Tadini* an Italian ophthalmologist practicing in Warsaw' conceived the idea of implanting crystal glass balls to correct aphakia ***(Fechner&Fechner, 1979).***

Long after *Tadini*, the modern history of lens implantation began in 1949 with the attempt of *Ridley*, when he inserted a lens made of polymethylmethacrylate (PMMA) ***(Figure 1).*** It was already known that PMMA is well tolerated by the eye, since during World War II pilots with ocular prespex fragments from artificial windshields did not suffer eye troubles ***(Ridley, 1960).***

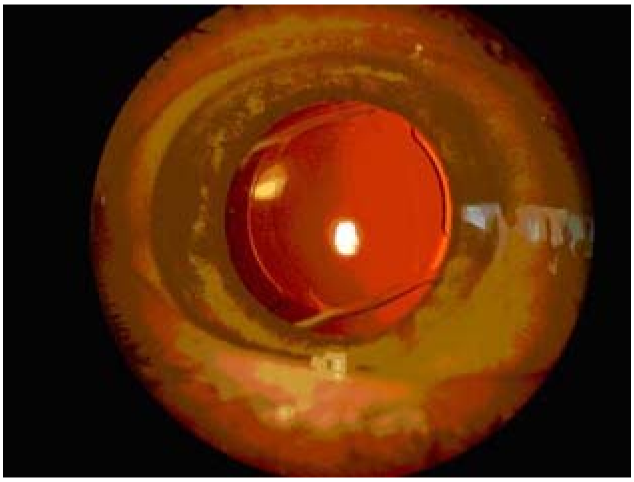

Figure 1:- **Ridley's** posterior chamber lens

(Paleokastritis et al., 2001)

Unsatisfactory results caused by combination of factors including inadequate surgical techniques, poor lens design, heavy lens weight, lack of manufacturing technology, and high incidence of post- operative complications as posterior dislocation in 6% of cases, glaucoma in 10% of cases and intractable uveitis, prevented him from pursuing this goal successfully. However, *Ridley's* remains in ophthalmic history as the first man to implant an IOL to correct aphakia ***(Allarakhia et al., 1987).***

Binkhorst in 1965 designated a lens with two nylon loops to be used with extracapsular cataract extraction (ECCE) ***(figure 2).*** This lens was a modification of his four loop iris supported lens designed in 1957 ***(figure 3).*** Because of the problems with nylon loosing its tensile strength at a rate of 20% per year, *Binkhorst* designed a lens using platinum loops in a clover leaf configuration ***(figure 4)*** with the intention of further increasing the stability of the lens ***(Binkhorst, 1967).***

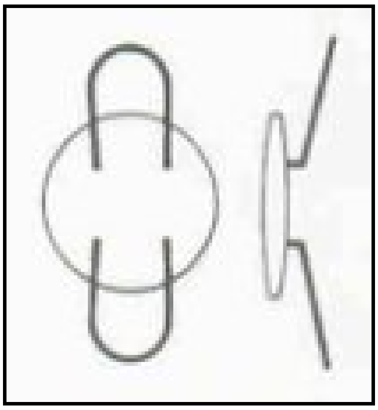

Figure 2:- The two-loop version of the **Binkhorst** lens for extracapsular surgery

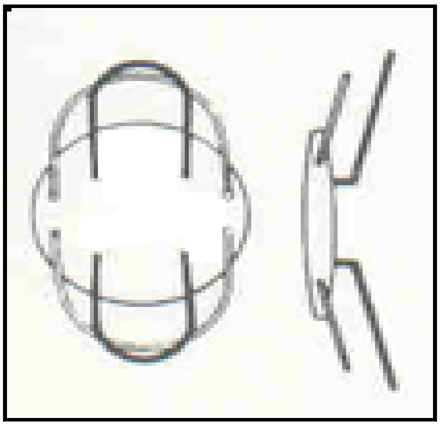

Figure 3:- **The Binkhorst iris clip lens**

In 1975, *Pearce* removed the posterior loops of the iris clip *Binkhorst* IOL, placed it in the posterior chamber, and sutured the superior anterior loop to the iris. Shortly there after, he designated posterior chamber intraocular lenses (PCIOLs) with several bipod and tripod variations. His tripod PCIOL was a rigid IOL with two inferior feet in the bag and a superior foot sutured to the iris. In a later modification of this IOL, *Pearce* extended the superior haptic by 1.5 mm so that the lens could be fixated in the ciliary sulcus without an iris suture ***(Paleokastritis et al., 2001).***

In 1977, Shearing introduced his j-loop posterior chamber lens which consists of an optic with two flexible clear polypropylene, j-shaped loops. ***(Figure 4).*** In the same year, *Simcoe* introduced his c-looped posterior chamber lens. *Kratz* introduced the concept of slightly angling the loops forwards to reduce the incidence of papillary capture ***(Shearing, 1984). (Figure 5).***

Figure 4: - The **Shearing** J-loop PCIOL

(Paleokastritis et al., 2001)

Figure 5: - Long C-shaped haptic, **Simcoe** Style
(Paleokastritis et al., 2001)

Newer technology IOLs with a variety of mechanisms have been tried to allow for far and near vision. Some designs, such as multifocal IOLs, allow simultaneous far and near vision. Some change their power much like the natural human lens (accommodative IOLs) ***(Samalonis, 2000).***

Multifocal intraocular lenses (MIOLs) of different designs have been used for more than 20 years in modern cataract surgery. The first IOLs were either refractive 2-3-zone designs or of diffractive concept. All MIOLs types, regardless of manufacturer, show reduced contrast sensitivity and increased glare for years. Nevertheless, even first-generation MIOLs patients had very good functional results when patient selection, IOL calculation, and surgical techniques were appropriate. ***(Auffarth GU et al, 2008)***

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New developments in this field in recent years such as the multizonal progressive refractive MIOLs, in combination with improved surgical techniques have overcome those initial problems. Therefore, the modern MIOLs can be considered not only for correction of aphakia, but also for refractive purposes ***(Auffarth & Dick, 2001).*** (***Figure 6***).

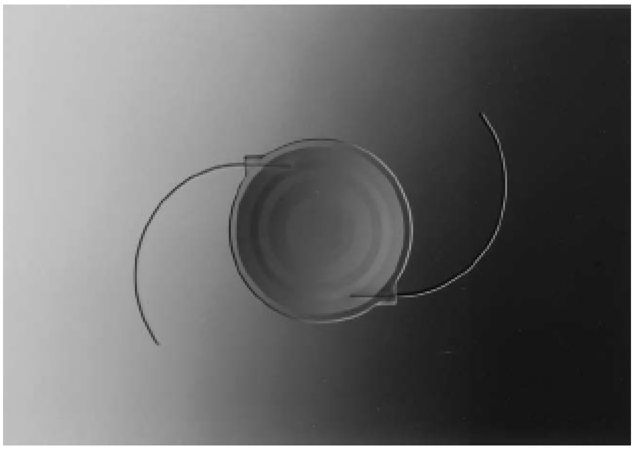

Figure 6:- AMO **Array** multifocal IOL
(Jeffrey H. et al, 2002)

Today's gold standard is foldable, aspherical diffractive or refractive MIOLS. Advancements in technology allow the possibility that MIOLs will be used for aphakia correction as well as presbyopia correction. ***(Auffarth GU et al, 2008)***.

Optics and designs of Multifocal IOLs

Monofocal IOLs can restore optical function of the eye after cataract surgery. The pseudophakic eye is unable to accommodate as the intraocular lens is of a fixed power and this necessitates a separate near addition in the form of glasses ***(Gray and Lyall, 1992).***

Multifocal IOLs was developed to address the loss of accommodation that occurs after cataract extraction. Potential benefits include enhanced near vision and reduced dependence on bifocal or multifocal spectacles ***(Vanderschueren et al., 1991).***

With a multifocal lens, pseudoaccommodative amplitude is increased, but the quality of distance vision is reduced. To get significant benefit at near vision, some of the quality of distant vision should be given up. In most of the multifocal IOLs there is a gain of 2.7D to as high as 4.5D of pseudoaccommodative amplitude. There can be other tradeoffs with multifocal IOLs as reduced contrast sensitivity, halo symptoms and mildly distorted color vision ***(Lipner, 2004).***

A multifocal lens is defined as lens which forms several images for a single object point. Multifocal IOL designs incorporate either **refractive** and/or **diffractive** optical principles to achieve simultaneous distance and near visual acuity. Multifocal IOLs have the ability to function at more than two foci, often with a satisfactory acuity for distant, near and intermediate vision ***(Nordan et al., 1992).***

Both types of multifocal IOLs produce comparable results in terms of distance visual acuity and have an increased depth of focus compared to monofocal IOLs. Several studies have shown that because of a better uncorrected near visual acuity, patients with diffractive or refractive multifocal

IOLs have less dependency on reading glasses than patients with monofocal IOLs. ***(Sibylla R. et al, 2002)***

Diffractive Optics and Designs:

Can be interpreted as the spreading of wavefronts after encountering discontinuities, if the waves are in phase they summate constructively, but if the waves are out of phase, they interfere destructively ***(Percival, 1990).***

Diffractive multifocal IOLs were the first to be evaluated clinically, but they showed significant optical deficiencies that discouraged many ophthalmologists from using them ***(Ellingson, 1990; Jay et al., 1991).***

1- 3M, Microslope Design:-

They are formed by a combination of an anterior spheric refractive surface and multiple posterior diffractive structured surfaces. It uses 20-30 concentric zones to form a diffractive structure. There is difference in height between the zones; the zone step is less than the diameter of a red blood cell. The lens creates two orders of diffraction, 0 and 1 and thus two focal points. The zero order of diffraction allows light to enter unimpeded by diffraction so the normal refractive power of the lens determines the first focal point (distance refractive focus). The first order of diffraction couples the refractive power with diffraction to create the second focal point (near refractive focus). Forty one % of the light is focused at the first focal point, 41% at the second and 18% of the light is focused at higher orders of diffraction. The multifocal performance of this lens is unaffected by decentration, pupil eccentricity, deformation, or pupil size. Distance and near vision is possible if any part of the lens optic is present behind the pupil ***(Gimbel et al., 1991 and Schechter, 1998). (Figure 7 & 8).***

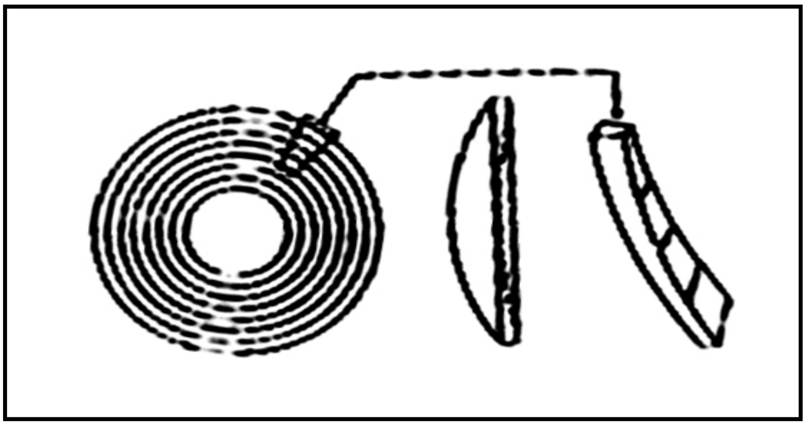

Figure 7:- **3M Morcher** diffractive multifocal IOL ***(Holladay et al., 1990)***

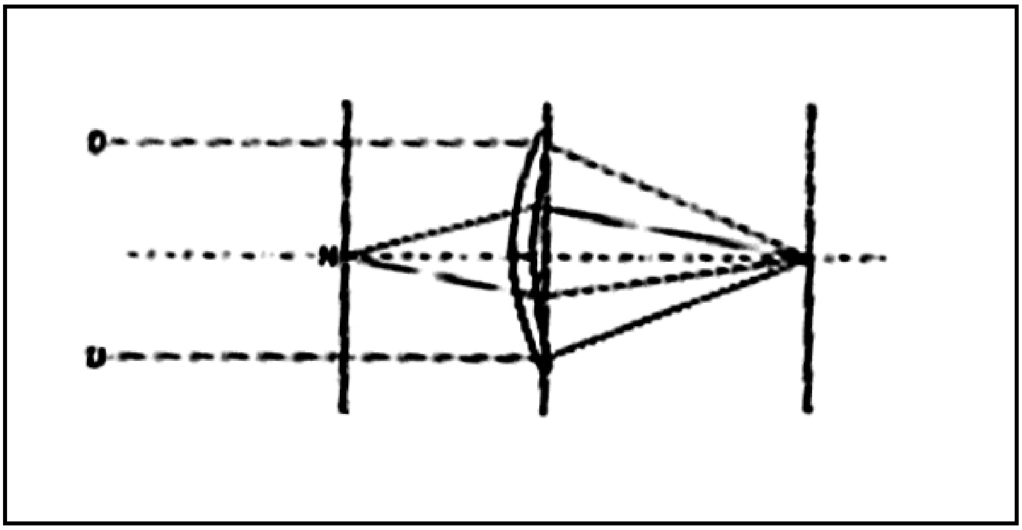

Figure 8:- Ray tracing of **3M** multifocal IOL ***(Duffey et al., 1990)***

The principle of action of diffractive multifocal IOLs is based on the *Fresnel* zone plate ***(Meltzer et al., 1995)*** which is formed of concentric diffractive rings; the spaces between them are adjusted to bring light from infinity to focus ***(Smith and Atchison, 1997).***