By 2020 the global population of cataract-prone over 60s will number around one billion. By then cataract patients in the west could expect their eyesight to be equivalent to a 20-year-old, after correction with an intraocular lens (IOL). It is also likely that the old joke ‘my arms aren’t long enough to read the paper’ will be defunct, as the replacement lens will also be able to adjust its focal length, or accommodate for near as well as far vision in cataractous eyes – the holy grail in IOL research (see box below).

In just over five decades the implantation of an IOL has developed from being a difficult and hazardous surgical experiment, to the most common and highly-valued long-term medical implant. The potential market for implants is huge – WHO estimated that in 2000 more than 20 million people were blinded by cataracts, most of whom live in India, China and other less economically developed countries, figure 1. In developed nations the removal of a cataract and its replacement with an IOL is the norm, but in some countries a cataract may still be removed using the non-surgical technique of poking the lens with a stick! During the last decade major western lens manufacturers have been moving into the large markets of India and China, usually in collaboration with local manufacturers. Eye care is improving worldwide and the lens implant market is expected to be worth US$2.5 billion by 2005.

What is a cataract?
According to NHS Direct, ‘a cataract is a clouding or whitening of the internal crystalline focusing lens of the eye. This lens is situated behind the coloured iris of the eye and light reaches it through the pupil. The cataract forms as a result of changes in the orderly arrangement of the transparent fibres from which the lens is made. Some degree of loss of lens clarity is present in almost everyone over the age of about 60. Cataract surgery and related interventions have benefits that reach further than simply improving or restoring vision. Improved vision may delay the course of senile dimension in at-risk patients, and specially-designed phakic IOLs show promise in correcting myopia and hyperopia in younger patients.

How does an eye accommodate (focus)?
Accommodation is contraction of the ciliary muscle that relaxes the zonules suspending the eye’s lens. This reduces the stress on the anterior capsular surface, which becomes more convex, increasing the lens power. Loss of the ability to accommodate occurs at about the age of 40 as with ageing the lens thickens and stiffens, to the point where the ciliary muscle’s stress can no longer deflect the lens enough to accommodate.

From solid to folding IOLs
The concept of an artificial lens has been around for hundreds of years, but as with many products, it took developments in materials science to catch up before an impact was made.

A glass lens was tested in Germany in 1795 with disastrous results – the weight of the lens caused it to displace in the eye. There was a long lull in development until the production of a polymeric lens. UK ophthalmologist Harold Ridley observed the biocompatibility of PMMA introduced accidentally into pilots’ eyes during cockpit canopy explosions, and formed an IOL from the material. It was Dutch and American researchers, however, who developed the concept for practical use.

Early implantations of PMMA IOLs after the removal of the existing natural lens were associated with glaucoma, uveitis and posterior dislocations, and acceptance of the IOL was slow. It was not until 1978, when the advantages of placing the lens in the evacuated capsular bag were recognised, (see box, Capsule filling lens developments for the accommodating IOL) that the use of the IOL for the correction of cataracts was adopted widely. Cataractous lenses could also be removed much more quickly by this time, due to Kelman’s phacoemulsification procedure, which uses an ultrasonic ‘drill’ to break up the lens.
Towards the accommodating IOL

The main goals in IOL research at the moment are to reduce the minimum surgical incision from 2.65mm to 1mm, as well as advancing accommodation in some lens designs. There are reports of accommodating IOLs being worn successfully by younger patients, so the challenge is to develop an implant that will do the work of the worn-out ciliary muscles in patients who fall mainly in the over 60s age group.

Accommodation claims have been made for a number of conventional IOLs including HumanOptics’ Akkommodator® 1CU and the AT-45 Crystalens®. In these pseudoaccommodative designs the haptics are strongly engaged with the capsular bag, and hinge or flex, moving the optic forward in response to the capsular relaxation of accommodation. Measured power increases are about 1.3 Dioptre (D), independent of the basic lens power, and it is suggested that recipients learn to accommodate and their vision improves, progressively.

Another lens design, the ThinOptIC®, has been successfully implanted through 1mm incisions. It has a convex anterior surface, a diffractive posterior surface, and is 40 microns thick for all powers. The lens bends under ciliary contraction improving near visual acuity.

The recently-reported SmartIOL®, a thermodynamic IOL introduced by Medennium, is a rod of a hydrophobic acrylic polymer gel that can be customised before insertion through a 1.9mm incision into the evacuated capsular bag. After warming to body temperature, the lens reverts to its premoulded biconvex lens form of about 9.5mm diameter. Medennium claims that the lens accommodates, but computer modelling suggests that the ability of the capsular bag to alter a lenses shape declines sharply with increasing incision diameter. Opinion is divided on this issue. Eye surgeons I Howard Fine MD was quoted in Cataract and Eye Surgery Today as saying, ‘To put the importance of this lens in perspective, if we look at cataract surgery over the last 30 years, there are three major leaps – everything else is an incremental step – Phacoemulsification is one, IOLs are the second, and I believe the SmartLens is the third. There is still a way to go and this lens reaches the market, so time will tell.

None of these lens types appear to have demonstrated a reversible addition of 2D – the introduction and increase necessary to correct presbyopia (long-sightedness) in the over-40s. Filling the lens capsule completely via a 1.9mm incision appears to hold the greatest promise in producing an IOL that will retain accommodation.

In vivo capsule filling lens developments in accommodating IOLs

During the past 40 years, many different types of polymer for in vivo lens formation have been investigated, including silicones, hydrogels, collagen, urethanes and acrylics.

In 1994, Kaseler refilled a rabbit’s capsule with silicone elastomer after extracapsular lens extraction. He encountered two problems – removal of the natural lens through a very small incision in the capsular bag, and leakage of injectable materials. The first problem was largely eliminated by phacoemulsification (ultrasonic break-up of the lens). Using a 1.9mm silicone intracapsular lens implant for myopia and hyperopia, Kaseler reported that the lens was in situ for two weeks in the rabbit capsule.

The recent development of foldable polymer IOLs has opened up the possibility of accommodating IOLs. A number of such devices have been developed and some have been shown to be effective in animal studies.

In 1978 Shearing (US) proposes placement of a glass lens.

In 1984 Shuating (US) proposes placement of an IOL in the evacuated capsular bag.

In 1986 Mazucco (US) patents the foldable IOL.

In 1997 Kelman (UK) invents phakoemulsification ultrasound destruction of a cataract.

The surgery and technology of lens replacement in the human eye has developed rapidly during the past 50 years to the point where the implantation of foldable IOLs for the treatment of cataracts is well established worldwide. New designs of IOL for the treatment of myopia and hyperopia are advancing and are likely to be confirmed within the decade.

Retrieved accommodation in the eyes of non-human primates has been demonstrated using silicone compositions, and the technology of similar injectable systems, able to closely replicate the physical and mechanical characteristics of the young natural lens, is available. So it seems highly probable that ophthalmologists will soon be able to correct not only aphakia but also presbyopia in their older patients.

Further reading


Of particular interest is the recent development of a slow-setting silicone hydrogel lens.”

Acknowledgement

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