The Evolution of Cataract Surgery: The Most Common Eye Procedure in Older Adults

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Cataract surgery is the most common refractive surgical procedure performed on aging individuals. Major advancements in surgical and lens technology have led to enormous increases in surgical volume because of the improved safety profile and outcomes. Current research holds the potential for restoring full vision, including accommodation, without the need for glasses in the near future.

Key words: *cataract, lens, refractive, vision, phacoemulsification*

Introduction

Good-quality vision is one of our most prized possessions. Surveys have shown that sight is the sense that people most fear losing.[1,2] Vision problems are common among older adults, with a slightly higher prevalence in women than in men (Figure 1). The bulk of the correctable visual problems is secondary to refractive errors, problems with focusing images sharply on the retina, which can be corrected with glasses or contact lenses. Cataracts—the clouding of the lens—is, however, becoming an increasing problem. Between 1994 and 2003, the proportion of older adults who self-reported the presence of cataracts rose from 14% to 20% in the Canadian community health survey.[3] It is speculated that a greater awareness of treatment possibilities, resulting in a higher demand for surgery, may be a reason for this rise. The removal of a cataract followed by the implantation of an intraocular lens is the principal refractive surgical procedure performed in older adults. Cataracts are a major public health issue, especially in developing countries, since they are responsible for 47.8% of the world's total blindness.[4]

Annual direct health care costs for vision loss in Canada in 2006 were estimated to be $2.9 billion.[5] Correction of refractive errors accounted for $190.5 million, while cataract surgery represented the single largest cause sector—estimated at $513.4 million. This large cost is directly related to the frequency of the procedure. In 2002, the rate for cataract surgery was approximately 8,000 cases per million persons in Canada,[6] midway between the reported rate in the United States (7,000 per million) and Australia (9,000 per million).[7] Cataract surgery is relatively inexpensive compared with other surgical interventions. The cost per quality-of-life years gained ranges from $2,023 to $2,727 in the United States, depending on whether the first or second eye is being studied.[8] This compares very favourably with other procedures (e.g., hip arthroplasty at $2,279, knee arthroplasty at $6,535, implantable defibrillator at $21,804, in U.S. dollars).[9] The cost-effectiveness of the procedure is further increased when considering the indirect benefits that have been attributed to cataract surgery, such as reduced rates of automobile accidents[10] and hip fractures[11] among individuals who had visually significant cataracts.

History of Cataract Surgery

Cataract surgery is one of the oldest surgical procedures known, first documented in the fifth century BC.[12] In ancient times, cataracts were treated with a technique called couching, which could only be performed when the lens had become completely opaque, rigid, and heavy to the point that the supporting zonules had become fragile. The eye would then be struck with a blunt object with sufficient force to cause the zonules to break so that the lens would dislocate into the vitreous cavity, restoring limited but completely unfocused vision. Centuries later, the technique was modified so that a sharp fine instrument was inserted into the eye to break the zonules to cause the dislocation.

The first reported surgical removal of a cataract from the eye occurred in Paris in 1748.[13] The advent of topical anesthesia made this procedure more practical. The early techniques involved removing the entire opaque lens in one piece using an incision that went halfway around the circumference of the cornea. It was critical that the lens remained intact as it was being removed, so surgery was restricted to so-called ripe lenses: cataracts so hardened that they would not break into pieces as they were being removed. This limited the surgery to only the most advanced cataracts. Since fine sutures did not exist at that time, patients were kept immobilized with sandbags around their head while the wound healed. Consequently, the early literature reporting cataract surgery routinely documented the mortality rate (secondary to pulmonary emboli).

The improvements in cataract surgery and the corresponding results over the past few decades have been nothing short of astounding (Table 1). The first major advance was the development of techniques allowing the removal of the lens while leaving the lens capsule behind.[14] The intact capsule acted as a barrier preventing lens material from falling into the vitreous cavity. This allowed less advanced cataracts to be removed since any residual fragments could be removed at the time of surgery with aspiration and would not be retained in the vitreous, where they would incite inflammation. This change also resulted in the reduction of the wound down to approximately a quarter of a corneal circumference. The introduction of fine sutures around this time greatly enhanced the safety and quality of results.

The most significant change marked by the modern era was the introduction of phacoemulsification surgery in 1967 by Dr. Charles Kelman.[15] In this technique, ultrasonography is used to break the lens into minute fragments that can be aspirated. A combined ultrasonographic, irrigation, and aspiration hand piece allows the removal of any lens through a small incision. This revolutionized the performance of surgery, leading to smaller and smaller wounds. Today, routine wounds are <3 mm long, and 1 mm wounds are on the horizon.

As the evolution of surgical techniques progressed, the advancement in lens replacement technology was equally dramatic (Table 2). Originally, no intraocular lens implants were used following cataract surgery, and patients had to rely on "Coke bottle"–thick hyperopic glasses. These were associated with a variety of unpopular optical aberrations. Intraocular lenses evolved secondary to the pioneering work of Howard Ridley, a British ophthalmologist.[16] He recognized that the penetration of shattered fragments from airplane windshields into the eyes of World War II fighter pilots when their planes had been hit did not always lead to damage. He created the first artificial lens from this material, leading to the creation of an entire industry.

Table 1: Major Advancements in Cataract Surgery

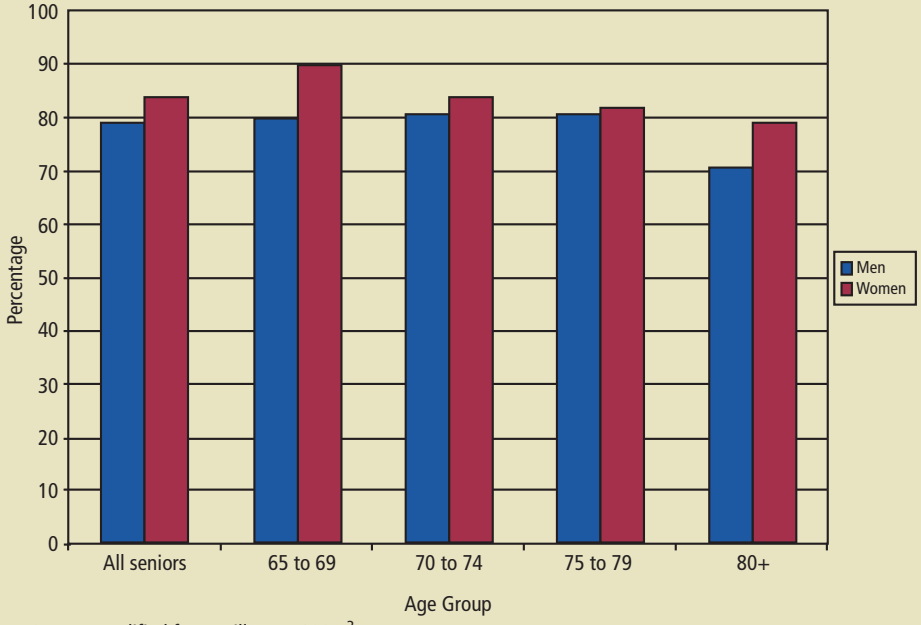
Surgical Technique	Major Feature
Intracapsular cataract extraction	Large incision, required "ripe" lens
↓	
Extracapsular cataract extraction	Slightly smaller incision and vitreous not disturbed
↓	
Phacoemulsification	Smaller incision resulting in faster healing and much less induced astigmatism

Table 2: Advancements in Intraocular Lens Technology

Lens	Advantages
Rigid PMMA	Eliminated need for extremely thick hyperopic glasses
Foldable (acrylic or silicone)	Allowed for smaller incision surgery with faster healing
Aspheric or toric	Eliminates higher order visual aberrations, producing better vision
Multifocal	Provides distance and near vision but sometimes with aberrations
Accommodating*	Provides distance and near vision without aberrations

PMMA = polymethyl methacrylate.
*Lenses that can restore full accommodation are not yet available.

Figure 1: Percentage of Older Adults with Vision Problems

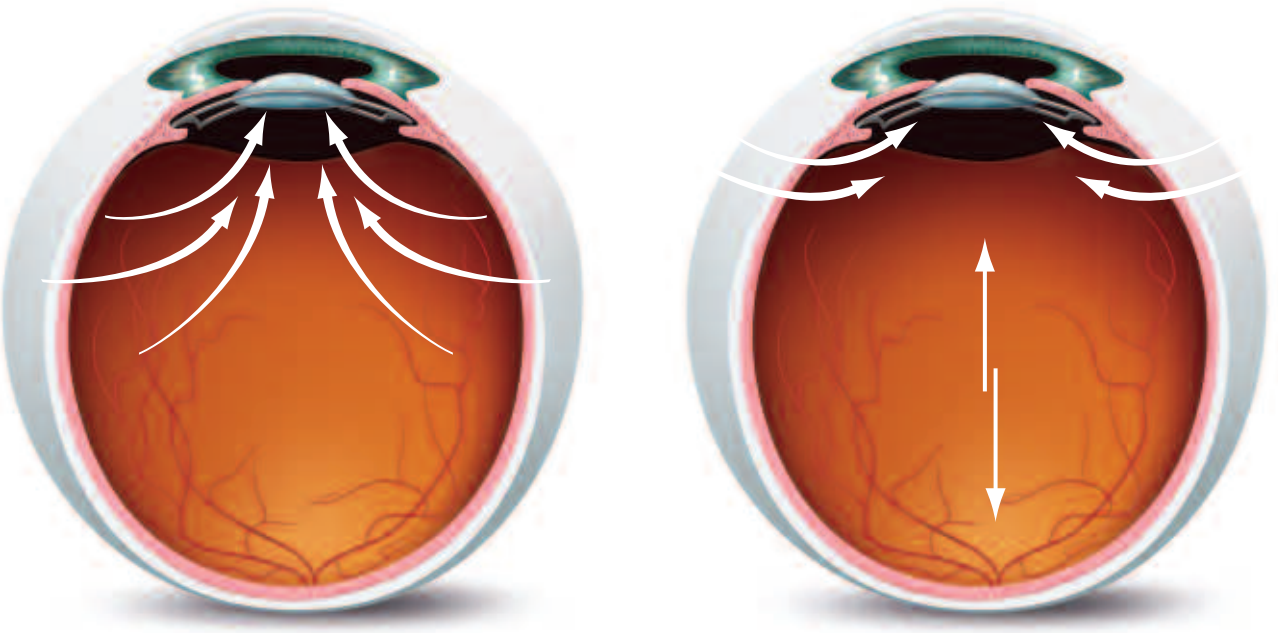


Source: Modified from Millar WJ, 2004.[3]

Figure 2:
Accommodating Lens Implant

Research and Development

The majority of the lenses currently implanted in North America are monofocal with a power chosen to restore good distance vision. A variety of new lens technologies are being developed that use moving monofocal lenses that attempt to restore natural accommodation by harnessing the shift in lens location when the ciliary muscles constrict. This promising technology is now available, but these early versions result in only a limited degree of accommodation so that people still rely on reading glasses for prolonged reading or seeing fine print.



Action

The two forces activated during accommodation are vitreous movement and ciliary muscle swelling. Both of these forces can move the optic forward and/or backward during accommodation.

Source: Some material for this figure came from the advertising website at: http://www.lenstec.com/lenstec/tf_accom_process.html

The evolution of smaller surgical incisions was matched by the development of new lens implants created out of different materials (such as acrylic and silicone) that could be folded to allow the lens to be inserted through a tiny wound. At the present time, commercially available lenses can be inserted through wounds a little over 2 mm.

Lenses are manufactured in a variety of different optical powers. Prior to surgery, patients undergo a series of measurements determining the optical length of their eye and the focusing power of their cornea to determine what will be the optimal intraocular lens power for them. The majority of the lenses currently implanted in North America are monofocal with a power chosen to restore good distance vision. This usually still leaves the patient dependent on glasses for reading.

A recent advance has been the creation of aspheric lens technology that not only corrects the patient's focal length but also corrects some optical aberrations that naturally occur in the cornea due to aging.[17] The prime goal for lens developers in recent years has been to create a lens that will restore quality distance and near vision without the need for glasses. The initial attempts involved the creation of multifocal lenses that have concentric rings of different optical strengths so that light from different distances is focused on the retina. These complex lenses are associated with some optical aberrations that are not always tolerated. This has led to limited adoption of these lenses in North America.

A variety of new lens technologies are being developed that use moving monofocal lenses that attempt to restore natural accommodation by harnessing the shift in lens location when the ciliary muscles constrict (Figure 2).[18] This promising technology is now available, but these early versions result in only a limited degree of accommodation so that people still rely on reading glasses for prolonged reading or seeing fine print.

As these basic lens technologies have given us the ability to correct hyperopia or myopia, treatments have developed to also deal with preoperative astigmatism (irregularity of curvature of the cornea). A popular approach uses limbal relaxing incisions[19]; this approach involves making almost complete-thickness cuts through the peripheral cornea at the appropriate location to neutralize the astigmatism. As excimer laser technology has improved, some surgeons have elected to use this procedure to correct residual astigmatism as well as any residual hyperopia or myopia that remains following the cataract surgery.[20] This is the principal use of this laser technology among older adults since this technology is primarily aimed at young patients seeking to eliminate myopia. Finally, new intraocular lens implants are now available that can correct not only myopia or hyperopia but also a variable degree of astigmatism.[21] These lenses come with a variety of astigmatic powers. When they are implanted, the surgeon simply lines up the surface markings of the new lens with the previously measured steep access of the patient's astigmatism to neutralize it.

Key Points

- The prevalence of cataracts is increasing.
- Cataracts are a major public health issue, especially in developing countries, since they are responsible for 47.8% of the world's total blindness.
- Technical advances in surgical technique have resulted in safer, more rapid surgery that is very cost effective.
- New lens technology allows correction of a variety of optical aberrations that previously could not be corrected with an intraocular lens such as astigmatism.
- Future lens implants will likely be able to accommodate so that people may not need glasses after cataract surgery, even for reading.

Conclusion

Cataract surgery is the principal refractive surgical procedure performed in older adults. Technological advances have allowed for improved surgery through smaller incisions, resulting in better outcomes. Improvements in lens implants provide better visual outcomes than were previously possible. Lenses that will also accommodate, eliminating the need for reading glasses, will likely be available in the future.

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