Vision Restoration

Cataract Surgery and Surgical Correction of Myopia, Hyperopia, and Presbyopia

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KEYWORDS

• Cataract • Refractive surgery • Refractive error • Myopia • Presbyopia
• Astigmatism • Phacoemulsification • LASIK

KEY POINTS

- The decision to remove the cataract rests mainly with the patient and planning for surgery is a combined effort between the patient, ophthalmologist, and primary care physician.
- More often than not, cataract surgery is also a refractive procedure with the potential of making the patient less spectacle-dependent for near, intermediate, and distance vision.
- Intraocular lens implants and surgical approaches continue to advance to allow each patient an individualized operative approach.
- Phacoemulsification remains the most common approach for cataract surgery around the world, with femtosecond laser–assisted cataract surgery emerging as a popular adjunct to phacoemulsification over the past decade.
- Refractive procedures, such as LASIK, SMILE, and PRK, are indicated for patients with refractive error in otherwise healthy eyes.

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INTRODUCTION

Advances in vision restoration procedures have developed over the past decade and have redefined what is considered possible for patients with refractive errors.[1] With

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cataract surgery being the most commonly performed surgical procedure in the United States and refractive surgery developing at a rapid pace, patient expectations for near perfect vision are unprecedented. Procedures, such as laser in situ keratomileusis (LASIK), photorefractive keratectomy (PRK), and small incision lenticule excision (SMILE), are continuously being improved to widen the eligibility criteria for patients. Correction of presbyopia, notoriously difficult to achieve, is now closer to realization than was considered possible.

Refractive surgical procedures entail altering the refractive components of the eye (the cornea and/or lens) to decrease or eliminate dependence on glasses and contact lenses. Corneal-based procedures are geared toward reshaping the surface of the cornea in patients with refractive errors (ametropia), and this is done by laser removal of corneal tissue from the surface (PRK), under a corneal flap (LASIK) or more recently, laser removal of corneal tissue through a corneal pocket (SMILE). These refractive procedures are indicated in healthy eyes without comorbid conditions. Lens-based procedures replace the natural crystalline lens with an artificial intraocular lens (IOL) implant. These procedures are indicated in patients with cataracts that diminish vision or make it difficult to visualize the retina. Another indication for lens removal is to prevent a particular type of glaucoma related to thickening of the lens. Less commonly, lens removal with an IOL implant is performed in the absence of a cataract for the sole purpose of reducing or eliminating the need for glasses. This is called a clear lens extraction. The type of procedure selected depends on the cause and degree of refractive error, patient's age, postoperative refractive target, type of cataract, and surgeon's experience.

CATARACT

Introduction

A cataract is defined as the opacification of a crystalline lens that over time can cause visual impairment in form of blurry vision, halos and glare around light, difficulty reading small print, and eventually blindness. Cataracts are classified as being age-related, secondary to systemic disease (ie, diabetes mellitus), secondary to primary ocular disease (uveitis, acute angle closure), traumatic, and congenital.

It is currently estimated that of the global population with moderate to severe vision impairment, 57.1 million cases are caused by cataract.[2] With an estimated 3.3 million procedures performed annually, cataract surgery is one of the most common procedures done in the United states. These projections are expected to increase to 4.4 million in 2030 as the US population continues to increase.[1]

Causes and Associated Conditions

The development of cataracts occurs over time as part of the natural aging process of the lens. The crystalline protein that makes up more than 90% of the lens anatomy denatures and degrades with age, leading to a gradual opacification of the lens. Most patients do not develop visually significant cataracts until they are "very elderly," which is greater than or equal to 85 years old as defined by the World Health Organization and National Institute of aging.[3] The process is accelerated in patients with systemic conditions, such as diabetes, because of the high concentration of glucose in the aqueous humor diffusing into the lens. The glucose becomes metabolized into sorbitol and then results in osmotic overhydration, which leads to the development of opacities. Other systemic diseases that may result in cataract formation include myotonic dystrophy, atopic dermatitis, and neurofibromatosis type 2. Cataracts may also develop secondary to a primary ocular disease, including chronic anterior uveitis

(secondary to prolonged inflammation and topical steroids the lens is exposed to), acute angle closure glaucoma (secondary to focal infarcts on the lens epithelium), high degrees of myopia (>-6 diopters), and congenital conditions (eg, hereditary retinal dystrophies).

Traumatic cataracts, as the name suggests, arise secondary to various forms of trauma and is the most common cause of unilateral cataracts in younger patients. Causes include penetrating, blunt, and radioactive trauma. In addition, these types of cataracts tend to be more challenging than the typical age-related cataracts because of a denser lens and weakened zonules, therefore increasing the risk for posterior dislocation of the lens intraoperatively.

Indications for Surgery and Preoperative Evaluation

The most important factor to consider when assessing the suitability of a patient for cataract surgery is the impact of the cataract on the patient's ability to perform essential activities of daily living, such as driving, reading, and work involving near vision. Deciding when to remove the cataract rests mainly with the patient and their specific needs. In some cases, cataract surgery may be medically indicated when the cataract is adversely affecting the health of the eye, such as lens-induced glaucoma (phacolytic glaucoma).

Preoperative planning is a combined effort between the ophthalmologist and primary care physician. Because this is an elective procedure in most cases, a general medical history should be taken and the patient should be optimized with respect to their medical comorbidities (eg, diabetes, hypertension). This is more important if the patient requires general anesthesia, and preoperative assessment should be done as per local guidelines. In most cases, the procedure is done under monitored intravenous sedation with topical anesthetic and in some cases a local block is administered (retrobulbar, peribulbar, subconjunctival/subtenon). General anesthesia is considered in cases where the patient is uncooperative or experiencing severe anxiety surrounding the procedure.

It is also important to make note of the medications that the patient is taking at the time of referral/consultation. Relevant medications include systemic α-blockers (eg, tamsulosin), which can lead to intraoperative floppy iris syndrome, the triad of iris billowing, pupil constriction, and iris prolapse. Intraoperative floppy iris syndrome may make the procedure more difficult and necessitate the need for iris retractors. The literature suggests that in patients who have a history of systemic α-blockers use, discontinuation preoperatively has little to no effect in mitigating intraoperative floppy iris syndrome; however, it is still important for the surgeon to be aware before the procedure to adequately prepare for the surgery.[4] With respect to anticoagulant and antiplatelet therapy, management should be as per local protocols. Although most surgeons do not stop these medications preoperatively, the international normalized ratio should be within therapeutic range 24 hours before surgery in otherwise stable patients. When possible, some surgeons do prefer to stop aspirin a week to 10 days before surgery. Cataract surgery is considered a low-risk operation for bleeding. Modifying certain surgical details (eg, the use of topical anesthesia rather than retrobulbar block or the use of intraoperative mydriatic rather than iris retractors) is done to further reduce bleeding risk in this group of patients.

In terms of the ophthalmic preoperative assessment, biometry plays an essential role in the planning of a successful procedure with satisfactory visual and refractive outcomes. Keratometry and biometry, defined next, are needed to calculate the IOL power for the patient.

- *Keratometry*: Done to determine the anterior corneal surface curvature. This is defined as diopters or millimeters of radius of curvature. This is assessed by a keratometer or by corneal topography.
- *Optical coherence biometry*: Measures the axial length (the total length of the eye) through a noncontact method that uses two coaxial partially coherent low-energy laser beams to procedure an interference pattern.
- *IOL power calculation*: Various formulae exists that are used to calculate the required IOL power needed to achieve the desired refractive outcome.

Intraocular Lens Options

The first IOL was implanted in 1949, and their use in cataract surgery has become standard since the 1970s.[5] With advances in cataract surgery, such as the introduction of phacoemulsification allowing for smaller corneal incisions, shorter postoperative recovery periods, and more pliable IOLs, a myriad of options now exist tailored to the visual goals of the patient. The choice of IOL is determined by the patient's visual preferences, type and degree of astigmatism, and refractive error.

- Monofocal IOLs
  - These are by far the most common option for IOL implants in cataract surgery. Monofocal IOLs are geared toward improving the patient's uncorrected visual acuity at a single focal point (near, intermediate, or distance vision). This option still requires the use of glasses postoperatively either for distance or near, or sometimes both. A common scenario is a patient who has cataracts and opts for a monofocal lens in both eyes to correct them for distance vision without glasses. The patient would then require glasses to wear for near activities. The exception is for patients with planned "monovision" where one eye is targeted for distance and the other eye for near. This allows for less dependence on glasses postoperatively, but may not be tolerated by all patients and requires careful patient selection (**Fig. 1**A).
- Multifocal and extended depth of focus IOLs
  - Unlike monofocal IOLs, multifocal and extended depth of focus IOLs offer the benefit of potential spectacle independence. In multifocal lenses, the expanded range of vision is because of the added magnification in different zones or rings of the lens allowing the patient to see at near, intermediate, and distance. In extended depth of focus lenses, there is a single elongated focal point to enhance the depth of focus. The drawbacks of multifocal and extended depth of focus lenses include the increased likelihood of glare and haloes especially at night (**Fig. 1**B).
- Toric IOLs
  - Toric IOLs are considered in patients with astigmatism in addition to a cataract. The toric IOL is suitable for patients with astigmatism because of the lens having different powers in different meridians allowing for the surgeon to adjust the orientation of the IOL based on the patient's degree of astigmatism.
  - Toric IOLs have to a large extent decreased the need for limbal-relaxing incisions intraoperatively. These are small incisions made at opposite ends of the cornea at the junction between the cornea and sclera (the limbus), to alter the curvature of the cornea making it more spherical in shape. This is done in cases of low to moderate astigmatism, and is sometimes performed with a femtosecond laser instead of toric IOL placement.
  - Patients may require further refractive surgery (eg, LASIK, PRK) after toric IOL placement in the event of residual astigmatism (**Fig. 2**).

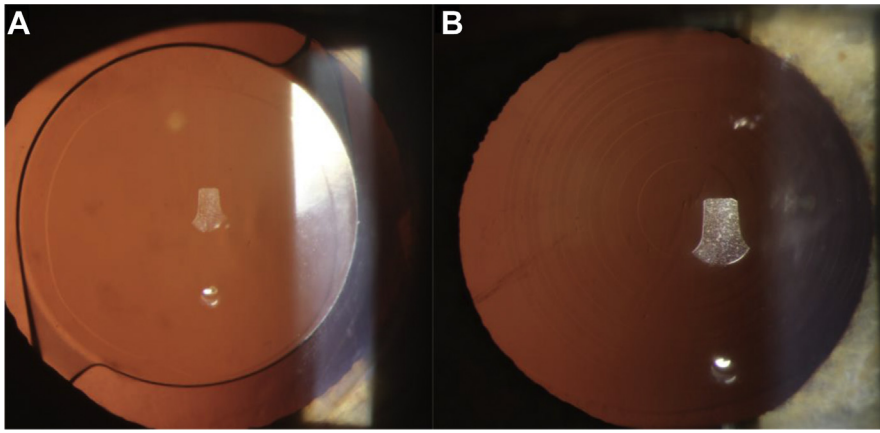

Fig. 1. (*A*) Monofocal IOL. (*B*) Multifocal IOL.

- Accommodative IOLs
  - Like the multifocal IOLs, the accommodative IOL offers the option of spectacle independence. This IOL is unique in design compared with other alternatives by virtue of its aspheric shape and flexible haptics. As the name suggests, the flexible haptics allow for accommodation whereby they slightly move the IOL forward when using near vision. The trade-off, however, is in a reduced level of magnification compared with a multifocal IOL. Studies have shown multifocal IOLs to be superior to accommodative IOLs with respect to near vision.[6,7]

SURGICAL TECHNIQUES

Cataract surgery has evolved significantly over the past two millennia, from its ancient and crude predecessor "couching" in the fifth century, to the more sophisticated techniques of today.[8] The first recorded cataract removal was performed in Paris in 1748.[9,10] Since its invention in 1967, phacoemulsification has become the most popular cataract removal technique in the developed world.[5] Since its Food and Drug

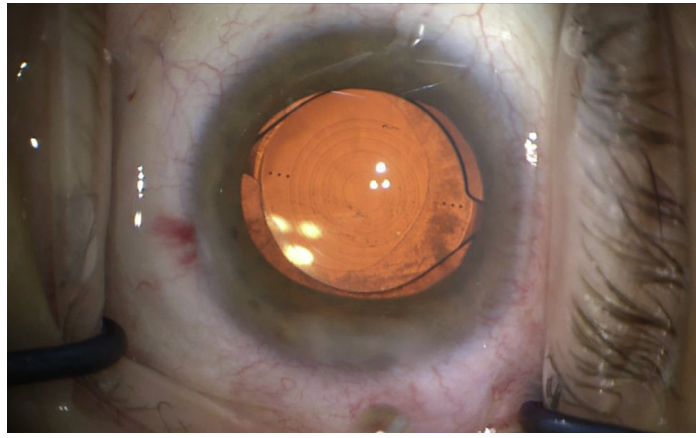

Fig. 2. Toric IOL.

Administration approval in 2010, femtosecond laser–assisted cataract surgery has been gaining popularity as an adjunct to phacoemulsification, especially for patients with astigmatism. The preferred choice of technique depends on surgeon discretion and opinions differ among surgeons regarding the safety, complication rate, and cost-effectiveness of the two options. Ultimately, the patient's preferences, refractive goal, choice of IOLs, whether the patient has astigmatism, and the density of the cataract figure into the decision about which technique is best for the patient.

Phacoemulsification

The traditional approach, phacoemulsification, is the most commonly performed cataract surgery worldwide and is performed by the breakdown of the crystalline lens into small enough fragments, by ultrasound energy, which are aspirated out of the anterior chamber through a phacoemulsification tip handpiece.

Surgical steps

1. Topical proparacaine or tetracaine drops are applied followed by povidone-iodine 5% into the conjunctival sac. Ophthalmic lidocaine gel then is instilled onto the ocular surface. Eyelids and eyelashes are cleaned thoroughly. Antiseptic is left in place to have its affect for 3 minutes followed by an eye rinse with sterile saline.
   * Consider retrobulbar or peribulbar injection, intravenous sedation or general anesthesia if there is concern over patient's ability to cooperate during procedure.
2. A side port incision is made approximately 60° left of main incision (**Fig. 3**).
3. Viscoelastic is injected into the anterior chamber (Video 1).

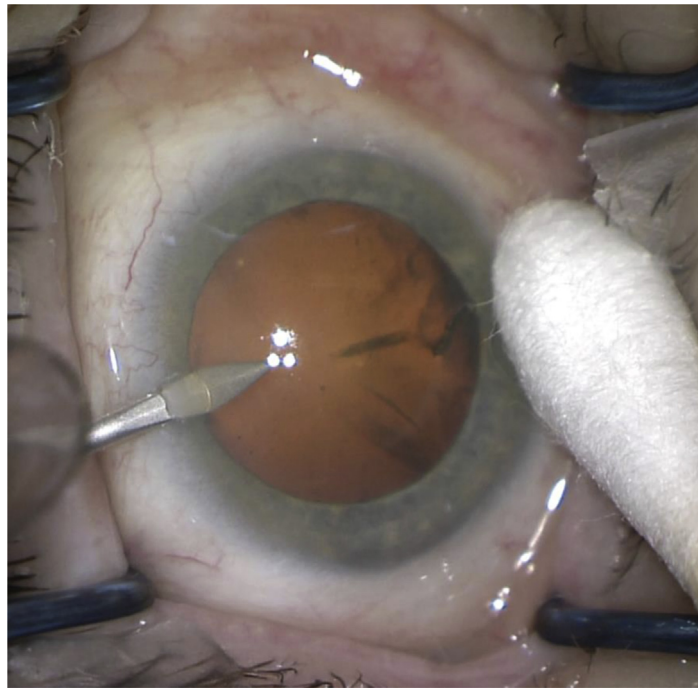

Fig. 3. Side port incision.

4. A main corneal or perilimbal incision is made with a keratome.
5. A continuous curvilinear capsulorhexis is performed, whereby a tear is created in the capsule and then guided in a continuous and curvilinear fashion around the anterior surface of the lens capsule (Video 2).
6. Nuclear disassembly is performed by first undergoing hydrodissection and hydrodelineation, the process of separating the nucleus and cortex of the lens from the capsule. This allows for manipulation of the nucleus for disassembly with the phacoemulsification handpiece (Video 3).
7. Aspiration of lens cortex is done carefully via vacuum (Video 4). This step is essential to mitigate postoperative inflammation and allow for optimal centration of IOL implant. Extra care must be taken when aspirating; it should be done slowly so as to monitor for any wrinkles in posterior capsule, which may indicate engagement of the posterior capsule.
8. IOL implantation is initiated by filling of the capsular bag with viscoelastic, followed by the introduction of a loaded injector cartridge with the IOL slowly injected and unrolled inside the capsular bag (Video 5). When using a toric IOL it is important to carefully observe while rotating the IOL to ensure that the haptics are within the capsular bag and that the optic is correctly aligned. Once the surgeon is satisfied with the positioning of the IOL, the viscoelastic should be aspirated to reduce the risk of postoperative rise in intraocular pressure.
9. Incisions are closed by hydrosealing (stromal saline injection). In some cases, the incisions may be closed by suturing. The surgeon may adopt several prophylactic measures to prevent postoperative endophthalmitis, such as intracameral, subconjunctival, or topical antibiotics with or without the use of steroids.

Femtosecond Laser–Assisted Cataract Surgery

The use of femtosecond laser technology in cataract surgery has steadily gained popularity over the past decade. The femtosecond laser is able to perform four of the steps related to cataract surgery: (1) the corneal incisions (main incision and side ports), (2) incisions into the peripheral cornea to reduce astigmatism, (3) the capsulorhexis, and (4) the initial fragmentation of the crystalline lens. The remainder of the procedure is continued manually, which includes the phacoemulsification of the lens and aspiration of lens cortex.

The advantages to this approach include better circularity and centration of the capsulorhexis to allow for more precise positioning of the IOL and reduced expenditure of ultrasonic energy when removing lens fragments. It often is offered to patients with astigmatism.

Disadvantages to this approach include the higher out-of-pocket costs to the patient compared with standard phacoemulsification, the steep learning curve, longer total operating times, and perceived difficulty with certain complex cases (eg, small pupils).

How Much Will it Cost?

Because cataract surgery is a medically necessary procedure, most of the costs associated with cataract surgery are covered by health insurance. The standard cost includes removal of the cataract, standard monofocal IOL, and may cover either a set of prescription glasses or contact lenses after the procedure. Decreasing dependence on glasses or contact lenses is not considered a medical necessity and therefore, the addition of premium IOLs to reduce such dependence and the addition of femtosecond laser technology to treat astigmatism are typically services not covered by insurance.

Complications

Cataract surgery, like any operative procedure, comes with risks of infection and bleeding. The main ones specific to ocular surgery to be aware of include the following:

- *Endophthalmitis*: This is defined as an acute (within 4 weeks of surgery) or chronic (>4 weeks after surgery) inflammation of the internal content (tissue or fluid) of the eye secondary to an infection. Symptoms include pain, redness, and vision loss, with inflammatory signs of conjunctival injection, and/or hypopyon. Sometimes the source of infection is hard to identify with complete certainty but it is thought to be from the resident flora of conjunctiva and eyelids. Possible risk factors include posterior lens capsule rupture during surgery, prolonged procedure time, and delay in receiving postoperative antibiotics. Evidence has shown that administering intracameral antibiotics into the anterior chamber at the end of the procedure may reduce the risk of endophthalmitis.[11] However, the use of intracameral antibiotics is still controversial in the United States and has not been universally adopted. Thankfully, this is a rare complication with an incidence around 0.1% in contemporary literature.[12,13]
- *Posterior capsular opacification*: With a varied incidence in the literature of 5% to 50%, this is the most common delayed onset finding of an otherwise uncomplicated cataract surgery.[14–16] Posterior capsular opacification is also referred to as an "after cataract" and occurs because of the proliferation and migration of lens epithelial cells. It is universally seen in children after cataract surgery. Posterior capsular opacification is straightforward to treat in the clinic setting. This is done by performing a posterior capsulotomy with a neodymium:yttrium-aluminum-garnet laser (**Fig. 4**).

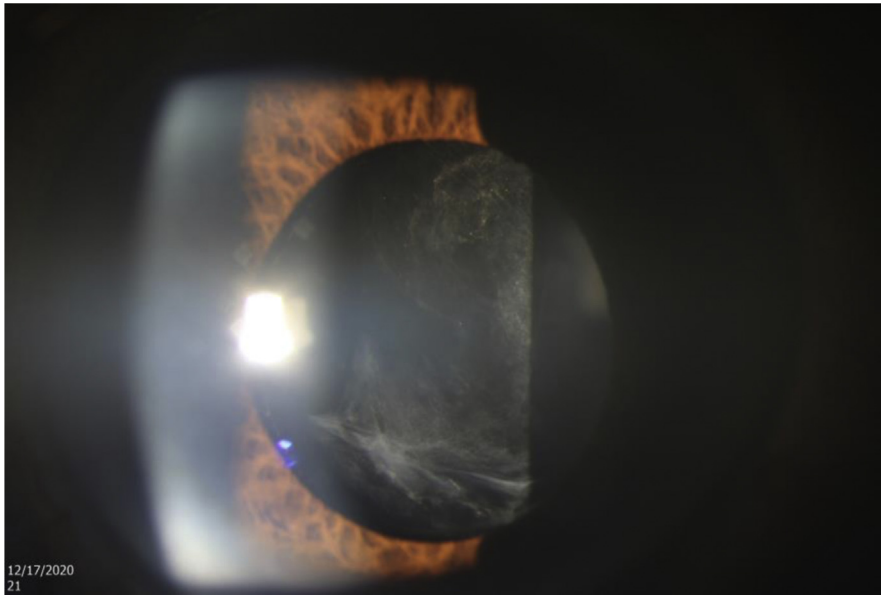

Fig. 4. Posterior capsular opacification.

Refractive Procedures

Although cataract surgery is a form of refractive surgery, other options exists for patients with otherwise healthy eyes that do not have an opacified lens obscuring vision. These options include LASIK, SMILE, and PRK. These procedures improve the patient's vision by reshaping the surface of the eye, the cornea, by either an excimer laser, a femtosecond laser, or both depending on the procedure chosen. LASIK is the most common of the previously mentioned procedures and is defined by its superb visual outcomes, quick postoperative recovery periods, and minimal risk of complications.

DISCUSSION

Future Directions

The continuing advances in IOL technologies in the form of EDF IOLs, low-add multifocals, trifocals, and adjustable IOL technology do not seem to be slowing down. The current market penetration of presbyopic IOLs is around 8%, and with surgeons becoming more confident they can achieve a patient's desired refractive outcome and the continual improvement of technology, that figure will only rise. In addition, fewer patients may require corneal refractive surgery as surgeons achieve improved refractive outcomes with cataract refractive surgery. Furthermore, the holy grail that is the correction of presbyopia may be closer to reality than a dream with advancements in IOL technology and development of drugs allowing for true restoration of accommodation.

SUMMARY

Vision restoration procedures continue to advance at a rapid pace with exceptional outcomes. It is important to remember that cataract surgery is a form of refractive surgery. Many patients who previously could not contemplate being independent of glasses or contact lenses can now select from a myriad of surgical approaches and premium IOLs. With the development of improved biometry and lens formulae to aid in hitting the refractive target, to the advancement of premium IOL designs and femtosecond laser–assisted procedures, the horizon for further advances in cataract and refractive surgery bodes well.

CLINICS CARE POINTS

- The standard IOL used in cataract surgery is the monofocal lens; however, premium upgrades include the multifocal lens for presbyopia and the femtosecond laser and toric lens for astigmatism.
- Detailed history of patients' medications and comorbidities is essential for preoperative planning and assessment; patients on α-blockers are predisposed to floppy iris syndrome, which may necessitate the need for iris retractors.
- Anticoagulation and antiplatelet therapy may be continued if medically necessary because cataract surgery is considered a low-risk operation for bleeding. However, communication between the ophthalmologist and primary care physician/internist is important because certain surgical details are modified to further lower the risk of bleeding for patients on these types of medications.
- Endophthalmitis is one of most serious complications associated with cataract surgery; however, it is rare with an incidence of less than 0.1%.

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DISCLOSURE

The authors have no relevant disclosures.

SUPPLEMENTARY DATA

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REFERENCES

1. Schein OD, Cassard SD, Tielsch JM, et al. Cataract surgery among Medicare beneficiaries. Ophthalmic Epidemiol 2012;19(5):257–64.
2. Flaxman SR, Bourne RRA, Resnikoff S, et al. Global causes of blindness and distance vision impairment 1990-2020: a systematic review and meta-analysis. Lancet Glob Health 2017;5(12):e1221–34.
3. Olson RJ, Braga-Mele R, Chen SH, et al. Cataract in the adult eye preferred practice pattern. Ophthalmology 2017;124(2):P1–119.
4. Chang DF, Braga-Mele R, Mamalis N, et al. ASCRS White Paper: clinical review of intraoperative floppy-iris syndrome. J Cataract Refract Surg 2008;34(12):2153–62.
5. Davis G. The evolution of cataract surgery. Mo Med 2016;113(1):58–62.
6. Tan N, Zheng D, Ye J. Comparison of visual performance after implantation of 3 types of intraocular lenses: accommodative, multifocal, and monofocal. Eur J Ophthalmol 2014;24(5):693–8.
7. Lan J, Huang YS, Dai YH, et al. Visual performance with accommodating and multifocal intraocular lenses. Int J Ophthalmol 2017;10(2):235–40.
8. Aruta A, Marenco M, Marinozzi S. [History of cataract surgery]. Med Secoli 2009;21(1):403–28.
9. Daviel J. Lettre sur les maladies des yeux. Paris: Mercure de France; 1748. p. 1748.
10. Rucker CW. Cataract: a historical perspective. Invest Ophthalmol 1965;4:377–83.
11. Gower EW, Lindsley K, Tulenko SE, et al. Perioperative antibiotics for prevention of acute endophthalmitis after cataract surgery. Cochrane Database Syst Rev 2017;2(2):CD006364.
12. Astley RA, Coburn PS, Parkunan SM, et al. Modeling intraocular bacterial infections. Prog Retin Eye Res 2016;54:30–48.
13. Durand ML. Bacterial and fungal endophthalmitis. Clin Microbiol Rev 2017;30(3):597–613.
14. Schmidbauer JM, Vargas LG, Apple DJ, et al. Evaluation of neodymium:yttrium-aluminum-garnet capsulotomies in eyes implanted with AcrySof intraocular lenses. Ophthalmology 2002;109(8):1421–6.
15. Dholakia SA, Vasavada AR. Intraoperative performance and longterm outcome of phacoemulsification in age-related cataract. Indian J Ophthalmol 2004;52(4):311–7.
16. Thompson AM, Sachdev N, Wong T, et al. The Auckland Cataract Study: 2 year postoperative assessment of aspects of clinical, visual, corneal topographic and satisfaction outcomes. Br J Ophthalmol 2004;88(8):1042–8.