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REVIEW

RESTORING SIGHT: EXPLORING CATARACTS AS THE LEADING TREATABLE CAUSE OF BLINDNESS: A NARRATIVE REVIEW

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ABSTRACT

Cataracts are the leading cause of treatable blindness worldwide, affecting millions of individuals. According to the World Health Organization, cataracts account for nearly half of all global blindness making them the leading cause of treatable and preventable blindness. This narrative review aims to explore the global prevalence, modifiable and non-modifiable risk factors, and symptoms of cataracts, as well as the transformative power of cataract surgery. Additionally, it discusses the impact of cataract surgery on visual outcomes and quality of life. The review synthesizes current literature on the global burden of cataracts, highlighting its prevalence across different regions. It examines various non-modifiable risk factors such as age, gender, race/ethnicity, and myopia, as well as modifiable risk factors such as smoking, alcohol consumption, nutrition and ultraviolet radiation exposure in relation to cataract development. It also explores and draws comparisons between the available techniques of cataract surgery such as phacoemulsification, extracapsular cataract extraction, and manual small incision cataract surgery. Understanding the challenges and advancements in cataract management is crucial for healthcare professionals and policymakers striving to address the global burden of blindness. With advancements in surgical techniques and access to quality healthcare, especially in developing countries, millions of individuals globally can be cured of blindness - restoring their sight. By raising awareness about cataracts, their identifiable symptoms and modifiable risk factors, as well as promoting timely interventions, we can work towards eliminating preventable blindness and empowering individuals to regain their vision, leading to a brighter future for all.

Keywords: Blindness, cataract, cataract extraction, quality of life, vision disorder

INTRODUCTION

Blindness, a global public health concern, affects millions of people worldwide, profoundly impacting their quality of life and hindering their ability to perform daily activities, work, and engage with their communities (1). However, amidst this darkness, there is a glimmer of hope: cataracts, the leading treatable cause of blindness (2). Cataracts, characterized by the clouding of the eye's natural lens, can be effectively addressed through surgical intervention, allowing individuals to regain their vision and restore their independence (1). This review article aims to explore the significance of cataracts as a treatable cause of blindness, delving into its global prevalence, risk factors, symptoms, and the transformative power of cataract surgery in restoring vision.

Cataracts have emerged as a major global health issue, affecting people of all ages, races, and socioeconomic backgrounds (3). According to the World Health Organization, the leading contributors to vision impairment and blindness are primarily uncorrected refractive errors and cataracts, with cataracts accounting for approximately 46.53% of global blindness making them the leading cause of treatable blindness (4). While there has been a general decline in prevalence, it is currently estimated that more than 10 million individuals globally suffer from blindness caused by cataracts, and over 35 million people experience moderate to severe vision impairment (5). This alarming statistic highlights the urgent need to address cataracts as a public health priority and underscores the potential impact of interventions on a global scale (2).

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By examining the current state of knowledge and advancements in treatment options, this narrative review seeks to shed light on the impact of cataract interventions, highlighting the potential to alleviate visual impairment and improve the lives of individuals affected by this pervasive condition. In recent decades, significant progress has been made in understanding the epidemiology, risk factors, and development of cataracts, as well as the connection between cataracts and certain systemic diseases (5). Through a greater understanding of the global prevalence, risk factors, symptoms, and advancements in treatment options, healthcare professionals, policymakers, and communities can work collaboratively to prioritize early detection, timely interventions, and improved access to cataract surgical services (5). Ultimately, this collective effort can contribute to reducing the burden of blindness and empowering individuals to lead more fulfilling lives, restoring not only their vision but also their hopes and dreams for the future (5).

Global Prevalence

The World Health Organization estimates that approximately 2.2 billion individuals worldwide are affected by either near or distant vision problems (4, 6). Alarmingly, almost half of these cases, totaling around 1 billion people with vision impairment that remain untreated to this day, could have easily been prevented (4, 6). This group of roughly one billion people can be divided into individuals with near vision impairment as a result of unevaluated presbyopia (826 million), and individuals with preventable blindness (202 million) (4, 6). The group of 202 million individuals with preventable blindness can further be broken down and presented as cataracts (46.53%, 94 million), followed by unaddressed refractive errors (43.76%, 88.4 million), age-related macular degeneration (3.96%, 8 million), glaucoma (3.81%, 7.7 million), and diabetic retinopathy (1.93%, 3.9 million) (4, 6). There are therefore 94 million individuals globally who are blind due to cataracts, that do not have to remain blind, because their cataract-related blindness can be cured through a simple ten-minute surgery (7).

Regional disparities exist in the prevalence of vision impairment as well, low- and middle-income regions have about four times higher rates of distance vision impairment compared to high-income regions (6). More than 90% of individuals in low- and middle-income nations who experience visual impairment caused by cataracts face obstacles in accessing cataract surgery, a relatively straightforward and affordable treatment (8). These barriers include limited awareness of available services, a scarcity of eye care facilities, and the burden of high user fees and transportation costs (8). The prevalence of cataract-related blindness in adults aged 50 years and older has been collected and presented by the Vision Loss Expert Group of the Global Burden of Disease Study as seven separate super regions (6). These super regions as well as their prevalence of cataract-related blindness in adults aged 50 years and older is listed as follows in ascending order (6):

- High-Income Countries, Western Europe & North America (17.50%),
- Central Europe, Eastern Europe & Central Asia (22.40%),
- North Africa & Middle East (33.60%),
- Latin America & Caribbean (35.40%),
- Sub-Saharan Africa (39.80%),
- South-East Asia, East Asia & Oceania (48.30%),
- South Asia (63.10%).

High-income countries such as the United States, Norway and Ireland enjoy the lowest prevalence of cataract-related blindness in adults aged 50 years and older at 17.50%, whereas countries in South Asia such as India, Bangladesh and Pakistan suffer from the highest rates of cataract-related blindness at 63.10% (6). Factors such as aging populations, limited access to eye care services, and socioeconomic disparities contribute to the higher prevalence of cataract-related blindness in these low- and middle-income regions (8). Moreover, the global prevalence of cataracts is expected to rise due to increasing life expectancies and changes in lifestyle factors (8). Understanding the magnitude of the problem and identifying strategies to address the global burden of cataracts are essential for achieving the goal of restoring sight and improving the quality of life for individuals affected by this treatable condition.

Pathophysiology and Classification

Cataracts, a prevalent age-related vision disorder, involve the progressive clouding of the eye's natural lens, leading to impaired vision and potential blindness if left untreated (9). The pathophysiology of cataracts is characterized by the accumulation of protein deposits and oxidative damage within the lens, resulting in its opacity (10). These changes disrupt the lens' transparency and refractive properties, leading to visual disturbances like blurred vision, glare sensitivity, and decreased color perception (10). Cataracts are broadly classified based on their location within the lens: anterior subcapsular cataracts (ASCs), posterior subcapsular cataracts (PSCs), cortical cataracts (CCs), and nuclear cataracts (NCs) (11). ASCs form just beneath the front surface of the lens and may cause significant vision problems, especially with near vision tasks (10). PSCs form just beneath the posterior lens capsule, often causing visual difficulties in bright light conditions (10). CCs develop in the outer edges of the lens, and their growth towards the center interferes with light passage (10). Lastly, NCs occur in the central nucleus of the lens, progressively impacting distance vision and causing a yellowing of vision (10). More than one type of cataract may be present in one patient (10). Prompt diagnosis and appropriate management remain crucial to restore clear vision and enhance the quality of life for affected individuals (10). Figure 1 demonstrates a diagrammatic representation of the eye's lens, and the expected locations of the four aforementioned cataracts (11).

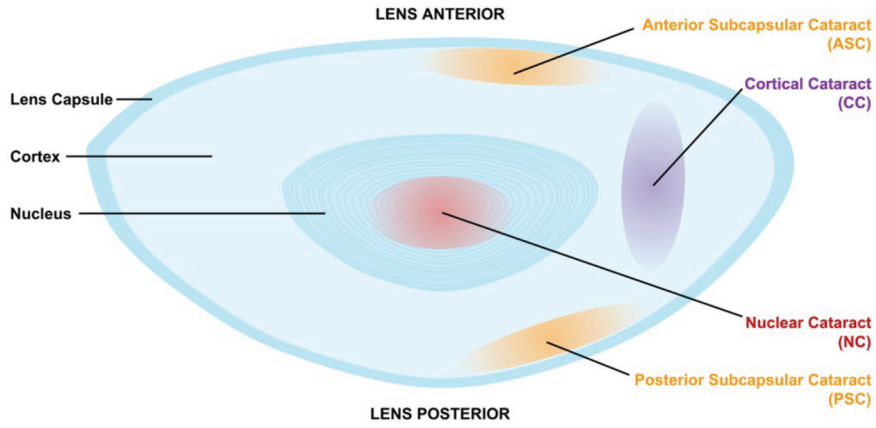

Figure 1: Simplified illustration of a lens and the locations of cataracts.

Symptoms

The symptoms of cataracts can vary depending on the stage and severity of the condition (12). In the early stages, individuals may experience gradual blurring or hazy vision, as if looking through a smudged window (13). As cataracts progress, vision may become increasingly impaired, leading to difficulty in reading, driving, or recognizing faces (13). Sensitivity to light and glare, particularly at night or in bright sunlight, is also common (12). Colors may appear faded or yellowed, and the overall clarity of vision is diminished (12). Some individuals may have frequent changes in their eyeglass prescription without significant improvement in vision (13). Additionally, cataracts can cause double vision in one eye or a halo effect around lights (13). It is important to note that cataracts do not cause pain, redness, or discharge from the eye (12). Recognizing these symptoms and seeking early medical intervention can greatly improve the chances of successful treatment and restoration of visual function (12). The diagnosis of cataracts is typically determined through a slit-lamp examination performed after the dilation of the pupils (12). This examination enables the classification of the opacity patterns based on their anatomical distribution, which can assist in guiding any further investigations related to the underlying causes (12). The Lens Opacities Classification System III is a commonly employed subjective grading system that is widely utilized to evaluate the severity of cataracts (14).

Risk Factors

Understanding the risk factors associated with cataracts is crucial for effective prevention and management strategies (5). Series of both non-modifiable as well as modifiable risk factors that contribute to the development of cataracts have been identified (5).

Non-modifiable Risk Factors

Several non-modifiable risk factors have been identified in association with cataract development (5). Age is the most significant non-modifiable risk factor, as the incidence and severity of cataracts increase substantially with advancing age (5). According to the findings of the Beaver Dam Eye Study, a population-based cohort examining the incidence of age-related diseases of the eye in around five thousand participants, there was a noticeable rise in the incidence of PSCs, CCs, and NCs with advancing age (15). The study revealed a significant increase in the overall occurrence of NCs, which escalated from 2.9% in individuals between the ages of 43 and 54, to a striking 40% in those aged 75 or above (15). Similar patterns of cumulative incidence were observed with age for CCs and PSCs (15). The incidence of CCs exhibited a notable rise from 1.9% in those aged between 43 and 54 to 21.8% in those aged 75 and above, while PSCs increased from 1.4% to 7.3% (15). Similar findings were observed in the Blue Mountains Eye Study in Australia, confirming an increase in incidence as well as severity of cataracts with advancing age (16). Another non-modifiable risk factor is gender, particularly the decline in estrogen levels during menopause, which has been suggested to contribute to cataract formation (5). There is a hypothesis suggesting that estrogen might possess a safeguarding influence on the development of cataracts (17). It is well known that estrogen has protective effects against cardiovascular as well as neurodegenerative diseases (18). Lower levels of cataract surgery incidence were observed in women with a larger accumulation of reproductive years, and therefore exposure to estrogen, indicating a protective effect of estrogen against cataract formation (19). The Barbados Eye Study consisting of 4,709 participants over five years compared the prevalence of cataracts between men and women among five separate age groups; 40-49, 50-59, 60-69, 70-79, and those above the age of 80 (20). The average age of menopause onset globally is estimated to be 48.8 years as of 2022 (21). The Barbados Eye Study included an age group of 40-49 which provides information on the prevalence of cataracts in women prior to or during the beginning of menopause, where the effects of estrogen deprivation have not yet made themselves apparent (20). In the age group of 40-49, the prevalence of cataracts is reported to be 4.2% in women and 4.3% in men [relative risk (RR) 0.98, 95% confidence interval (CI) 0.58-1.65], indicating that pre-menopausal women or women that recently had menopause onset have a lower prevalence of cataracts than men (20). However, moving to the

age group of 50-59, the prevalence increases drastically, with women showing a rate of 24.2% and men at 18.6% (RR 1.30, 95% CI 1.02-1.65) (20). The most notable increase is observed in the 60-69 age group, with the prevalence of cataracts reaching 55.2% in women and 40.0% in men (RR 1.38, 95% CI 1.20-1.59) (20). This trend continues in the 70-79 age group, with women having a prevalence of 72.4% and men 65.7% (RR 1.10, 95% CI 0.99-1.22) (20). The final increase is observed in the age group of ≥80, where the prevalence of cataracts in women was a staggering 85.3%, in comparison to their male counterparts with a prevalence of 82.9% (RR 1.03, 95% CI 0.91-1.17) (20). The only age group where women had a lower prevalence of cataracts in comparison to their male counterparts was in the 40-49 age group before the onset of menopause, hinting at the protective role of estrogen in preventing cataract formation (20). Consequently, the decline in estrogen levels that occurs during menopause may potentially elevate the susceptibility of women to cataract development (17). Studies have demonstrated the presence of estrogen receptors on the lens epithelium, and *in vitro* experiments conducted on animals have revealed a considerable reduction in lens opacity among rats treated with estradiol (E2) and estrone (E1) (17). Nevertheless, the existing evidence remains inconclusive, and additional investigations are warranted to gain a comprehensive understanding of the precise impact of estrogen on the development of cataracts (17). Additionally, race/ethnicity plays a role, with studies indicating that individuals of African and Asian descent are at higher risk compared to Caucasians (5). In the Salisbury Eye Evaluation Study, a comparison was made between the rates of lens opacity progression and incidence among older African Americans and Caucasians in the United States (22). The findings revealed that African Americans exhibited higher incidence and progression rates of CCs when compared to Caucasians (22). According to the Singapore Epidemiology of Eye Disease Study, a study conducted on more than ten thousand Asian adults including Chinese, Malaysian and Indian participants, cataract occurrence was found to be twice as prevalent among Asians and manifested approximately 10 years earlier compared to Caucasians (23).

Lastly, myopia has been associated with an increased risk of cataracts, although the exact mechanisms underlying this relationship require further investigation (5). In a meta-analysis study, twelve population-based studies involving nearly forty thousand participants were analyzed, and the findings indicated a positive correlation between myopia and the growing prevalence of NCs and PSCs (24). While conflicting data exist on this matter, some studies suggest that the presence of myopia does not seem to predispose individuals to cataracts (25). Instead, it is proposed that the increase in cataract development may lead to refractive changes resulting in myopia (25).

Modifiable Risk Factors

While certain risk factors for cataracts are beyond individual control, there are several modifiable factors that individuals can actively address to reduce their risk (5). Smoking has consistently been linked to an increased risk of cataract development, and quitting smoking has been shown to decrease the risk over time (5). Researchers from the Beaver Dam Eye Study discovered a significant association between smoking and a heightened occurrence of NCs (26). Notably, this association persisted even after adjusting for age and sex (26). The Korea National Health and Nutrition Examination Survey, a cross-sectional study conducted on more than fifteen thousand participants, yielded similar outcomes, demonstrating that smoking was linked to a heightened risk of NCs among both men and women (27). Cannabis smoking has also been linked to an increased incidence of cataract development, with cannabis users developing cataracts 5 years earlier than individuals that did not smoke cannabis (28). It is not surprising to find a connection between cannabis smoking and the emergence of cataracts (28). Tobacco smoke and cannabis smoke are similar in that they both contain a plethora of organic and inorganic chemical compounds (28). Cannabis tar exhibits chemical similarities to the tar found in tobacco smoke, and more than fifty known carcinogens, such as nitrosamines and reactive aldehydes have been identified in cannabis smoke (28).

Lower-income and education level have also been identified as modifiable risk factors, possibly due to limited access to healthcare and lower health literacy (5). Higher incidences of cataracts are observed in those with lower household incomes as well as lower education levels (27).

Excessive alcohol consumption has been associated with an elevated risk of cataracts, emphasizing the importance of moderation, however the data is not yet conclusive (5). The researchers conducting the Blue Mountain Eye Study found that exceeding a daily consumption of two alcoholic drinks was linked to a higher probability of requiring cataract surgery (29). Notably, they also observed that refraining from alcohol was similarly connected to an increased likelihood of needing cataract surgery, in comparison to consuming one to two drinks per day-indicating that mild alcohol consumption may have a protective effect over cataract development, whereas excessive alcohol consumption may be a causative factor (29). However, a meta-analysis study including nearly one hundred twenty thousand subjects found there to be no association whatsoever between alcohol consumption and the risk for cataract development, indicating that further investigation is warranted (30).

Proper nutrition including a healthy diet made up of vegetables and fruits, as well as multivitamin supplementation may help protect against cataract formation (5). The Antioxidants in Prevention of Cataracts Study, a five-year placebo-controlled clinical trial, concluded that the supplementation of antioxidants such as beta carotene, vitamin C, and vitamin E did not have an impact on the progression of cataracts (31). Another study found that while nutritional supplementation with vitamin C, lutein and zeaxanthin might provide benefits for specific populations such as individuals with inadequate nutrition or heavy smokers, its impact on cataract progression in the

majority of patients is unlikely (32). Despite the differences of opinion with regards to the relationship between nutrition and cataract development, it is suggested that following a nutritious diet that includes fruits and vegetables rich in vitamins A, C and E as well as considering the use of multivitamin supplements might offer some protection against cataracts (33).

Lastly, the role of exposure to ultraviolet (UV) radiation, both from sunlight and artificial sources in cataract development has been implicated, highlighting the need for adequate eye protection and sun avoidance measures (5). It is thought that oxidative stress from UV radiation exposure and the consequent inflammation contribute to the development of cataracts (34). While the lens has the ability to absorb both UV-A and UV-B radiation, research indicates that UV-B radiation is the main culprit responsible for the development of cataracts (35). In a study involving more than eight hundred watermen working on Chesapeake Bay, it was observed that high cumulative levels of UV-B exposure substantially raised the risk of CCs (35). It was found that watermen whose average annual exposure to UV-B radiation in the upper quartile had a 3.3 times greater risk of developing CCs than those whose average annual exposure to UV-B radiation was in the lowest quartile (35). More recent studies have further substantiated this finding by demonstrating a higher prevalence of CCs among individuals working in outdoor occupations (34).

Cataracts are a multifactorial eye condition influenced by a combination of non-modifiable and modifiable risk factors (5). While age, estrogen levels, race/ethnicity, and myopia are non-modifiable risk factors, individuals can take proactive steps to address modifiable risk factors such as smoking, income, education, alcohol consumption, nutrition, and UV radiation exposure (16, 19, 22, 24, 26, 27, 29, 35). Public health efforts should focus on raising awareness about these risk factors, promoting healthy behaviors, and implementing preventive measures to reduce the burden of cataracts and preserve visual health in populations worldwide.

Treatment and the Transformative Power of Cataract Surgery

Cataract surgery has revolutionized the treatment of cataracts and has become one of the most transformative interventions in modern medicine (36). The surgical removal of the clouded lens and its replacement with an artificial intraocular lens (IOL) has proven to be highly effective in restoring vision and improving visual function in individuals with cataracts (36). This procedure is typically performed on an outpatient basis and has a high success rate (36). A procedure that previously necessitated a hospital stay and lengthy visual recovery has now been transformed into a quick day-case procedure, thanks to advancements in technology (36). Advanced techniques such as phacoemulsification, which uses ultrasound waves to break up the cataract for removal, have made the surgery less invasive and facilitated faster recovery times (37). Additionally, the availability of various types of IOLs, including those that correct astigmatism, has further enhanced the outcomes of cataract surgery (38). The transformative power of cataract surgery extends beyond the restoration of vision, it often brings about a significant improvement in the quality of life for individuals affected by cataracts (39). Reduced visual function, irrespective of its underlying causes, is linked to a decline in quality of life and limitations in everyday functional activities (39). Studies have shown that cataract surgery not only improves visual acuity but also enhances independence, social interaction, and overall well-being (39-41). As cataracts continue to be a leading cause of blindness globally, ensuring access to high-quality cataract surgery and post-operative care remains crucial in the effort to restore vision and alleviate the burden of blindness (36).

There are several different types of cataract surgery techniques, with certain procedures being preferred over others due to factors such as precision, minimally invasive nature, recovery times, risk of complications, lens options, and surgeon expertise and preference (42-44). The choice of technique depends on individual patient factors and desired outcomes that are determined during the preoperative evaluation of the patient (45).

Phacoemulsification

Phacoemulsification, which derives its name from the Greek term for lens "phakos", is a modern surgical technique used to remove a cataract by emulsifying it (46). It is the most common method for cataract surgery and involves using an ultrasonic device to break up the cloudy lens into tiny fragments (46). These fragments are then gently suctioned out of the eye through small corneal incisions that are typically 2 to 3 millimeters in size (47). Once the cataract is removed, an artificial IOL is usually implanted to restore clear vision (48). Phacoemulsification is widely practiced across the globe and is considered the standard technique for cataract surgery in developed countries as well as many developing nations, however its use in developing countries is limited due to higher costs of the procedure (49). The average cost of phacoemulsification surgery can vary depending on factors such as the geographical location, the surgical facility, the surgeon's experience, and the type of IOL chosen (50). The average cost of cataract surgery by phacoemulsification can be as low as 25.55 United States dollar (USD) per eye in developing countries such as India, up to 4,030 USD per eye in developed countries such as the United States (50, 51). Expected outcomes of phacoemulsification surgery are generally positive (52). Patients can experience improved visual acuity and clarity following the removal of the cataract (52). The procedure is known for its rapid recovery time, minimal discomfort, and reduced risk of complications compared to older techniques such as extracapsular cataract extraction (ECCE) (52, 53). Many patients report enhanced quality of life and the ability to resume daily activities with improved vision after undergoing phacoemulsification surgery (54).

Extracapsular Cataract Extraction

Extracapsular cataract extraction is a surgical technique used to remove a cataract where the surgeon removes the cloudy lens

while leaving the posterior capsule intact (43). It is commonly used in developing regions where resources for advanced techniques like phacoemulsification may be limited (49). The average cost of ECCE can range anywhere from 16.25 USD per eye in developing countries such as India, up to 1,500 USD per eye in developed countries such as the United States (50). The expected outcomes include improved vision but with a longer recovery time and a slightly higher risk of complications compared to more modern techniques like phacoemulsification or laser-assisted surgeries (49).

Intracapsular Cataract Extraction

Intracapsular cataract extraction (ICCE) is a surgical technique used to remove a cataract where both the cloudy lens and the surrounding lens capsule are removed together (55). This older technique is now rarely performed due to advancements in cataract surgery (55). Modern techniques like phacoemulsification have largely replaced the use of ICCE as the procedure is associated with higher risks and complications (56).

Laser-assisted Cataract Surgery

Laser-assisted cataract surgery (LACS) is a modern technique where a femtosecond laser is used to assist in various steps of cataract removal, including creating precise incisions, opening the lens capsule, and fragmenting the cataract for removal (57). LACS is commonly used in developed countries where advanced technology is available such as the United States, with the average cost of surgery being 4,365 USD per eye (51). Expected outcomes often include improved visual acuity, faster recovery, reduced risk of complications, and the potential for enhanced precision in creating incisions and positioning the IOL (57-59). This breakthrough technology has shown potential in enhancing cataract surgery outcomes when compared to all other existing surgical methods, leading to its recognition as a significant advancement in the field of cataract surgery (51).

Manual Small Incision Cataract Surgery

Manual small incision cataract surgery (MSICS) is a surgical technique used to remove a cataract through a small incision, typically around 6 to 7 millimeters in size (60). The surgeon manually removes the cataract and implants an IOL to restore vision (60). MSICS has undergone significant improvements in recent decades, resulting in comparable outcomes to phacoemulsification in specific situations (61). This type of surgery is commonly used in developing countries where access to advanced technology like phacoemulsification or laser-assisted surgeries may be limited (62). The cost-effectiveness and efficiency of MSICS make it a crucial approach in the global effort to combat cataract-related blindness (61). The average cost of MSICS can range anywhere from 17.03 USD per eye in developing countries such as India, up to 600 USD per eye in developed countries (50). Expected outcomes include improved vision, but the recovery time may be slightly longer compared to more advanced techniques, and there is a slightly higher risk of postoperative complications such as astigmatism when compared to phacoemulsification (63). However, MSICS is still considered an effective and cost-efficient alternative for cataract surgery in resource-constrained settings (61-63).

The choice of cataract surgery technique is influenced by several factors including cost of surgery, access to advanced technology, and surgeon preference (36-38). While newer techniques like phacoemulsification and LACS offer advantages such as faster recovery, reduced risk of complications, and precise outcomes, traditional methods like ECCE or MSICS still have a role in specific situations, particularly in resource-constrained settings (49, 52, 57, 63). Understanding the individual patient's needs, available resources, and surgical expertise is crucial in determining the most suitable approach, ensuring optimal outcomes and patient satisfaction in cataract surgery (45).

CONCLUSION

In conclusion, this brief narrative review article has provided a concise yet comprehensive overview of the significance of cataracts as the primary treatable cause of blindness and the various interventions available for restoring sight. Through an exploration of the global prevalence, risk factors, symptoms, and treatment options, we have gained valuable insights into the potential of cataract surgery and its impact on improving visual impairment worldwide. With advancements in surgical techniques and access to quality healthcare, especially in developing countries, millions of individuals globally can be cured of blindness - restoring their vision. By raising awareness about cataracts, its identifiable symptoms and modifiable risk factors, as well as promoting timely interventions, we can work towards eliminating preventable blindness and empowering individuals to regain their sight, leading to a brighter future for all.

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