RAJESH KHANNA, MD

REJUVENATE AGING EYES

THE MIRACLE OF PIE

See younger. Liberate yourself

Rejuvenate Aging Eyes
The Miracle of PIE

See Younger, Feel Liberated

First Edition

Rajesh Khanna, MD

Copyright © 2020 Rajesh Khanna, MD All rights reserved.
ISBN: 9798634059563

DEDICATION

This book is dedicated to all my patients; past, present and future who trust their precious eyes to my passion and skill.

CONTENTS

Acknowledgments Pg. 4

Introduction Pg. 5

1. Understanding Vision Pg. 7
2. Presbyopia and Non-Surgical Treatment Pg. 21
3. PIE - Cure Presbyopia Permanently Pg. 33
4. Advantages of PIE Pg. 47
5. Contemplating PIE & Consultation Pg. 61
6. PIE Procedure Pg. 84
7. Choosing the Best Presbyopic Implant Pg. 99
8. Success Stories Pg. 110
9. PIE After Previous Surgeries Pg. 123
10. Neuroadaptation & Fine-Tuning Pg. 143
11. Astigmatism Management Pg. 151
12. Dry Eyes Pg. 158
13. Risks and Complications Pg. 177

Conclusion Pg. 186

About the Author Pg. 187

Glossary Pg. 188

ACKNOWLEDGMENTS

I acknowledge the contributions of various researchers, engineers, and surgeons who helped develop this wonderful procedure. I would like to thank my teachers and parents who led me on the path of providing people with vision.

I am especially grateful for my wife, Kavita, who has supported me in all my endeavors, especially in writing this book. My children, Kapil and Megha, have always been a source of joy and happiness. I would also like to thank my manuscript editors Brandi Cohea and Ashley Knight for their patience and tireless efforts concerning the production of this book.

INTRODUCTION

Every few decades there is a tsunami in vision care technology. In the seventies it was the intraocular implantable lenses, which freed patients who underwent cataract surgery from wearing thick glasses with various shortcomings. In the nineties we saw the advent of Lasik eye surgery, which has become a household name. Now the first new wave of technology for the twenty first century has started.

The goal of this book is to help you ride this wave successfully. There is so much at stake when vision is concerned. A lot of information is available on the internet, as well as misinformation. The incorrect information creeps in as people to try to mislead Google's algorithms. Initially, non-medical personnel, followed by software starting to generate content, led to a plethora of confusing articles. It is not possible for an average person to sift through the truth from the marketing tactics. We learned that misinformation about Lasik eye surgery increased the fear of the consumers, affecting the overall acceptability of the procedure.

The thought of any surgical intervention induces a fear in people, particularly eye surgery. The goal of this book is to decrease the fear by simply worded explanations, which can be read and reflected upon with a peace of mind. This is more effective than a five to ten-minute medically laced jargon discussion in the doctor's office, which is barely retained after leaving the office. This book may also inspire young surgeons to obtain the necessary knowledge needed as they themselves begin the journey to master the art and skill of PIE.

The author brings three decades of experience of interacting with patients, performing surgeries and, most importantly, listening to patients' concerns, desires, and feedback after the procedure. This forms the basis of this easy to understand, scientific, educational tool so that readers may make an informed and rational decision regarding their eyes.

This book on PIE, or Presbyopic Implant in Eye, is directed at people above 45 years of age, who desire to decrease or eliminate their dependency on glasses and contact lenses. Many people aspiring to have Lasik eye surgery may not know that there is a better procedure available, known as PIE. This book explains the advantage of PIE over Lasik. PIE is also helpful for people who are currently suffering from cataracts.

It will explain the superiority of PIE over cataract eye surgery. The book will benefit younger people who are not candidates for Lasik eye surgery or have developed early onset cataracts. Furthermore, it will be a useful guide even if one has had Lasik, Radial Keratotomy (RK), or any other eye surgery.

Most importantly, this book will explain the different classes of PIE, guide you through the process of selecting the best presbyopic implant for your eye and choosing a professional PIE surgeon. Finally, the book will discuss the risks and how to prevent complications by steps taken before, during and after the procedure. This book will also introduce and delve extensively into the concept of neuroadaptation, which will help you get the best out of your PIE procedure.

This book can serve as a dependable, truthful and reputed source of important information on the functioning of the eye, vision and the PIE procedure. It is our hope that we can facilitate the spread of quality vision through the aid of this book.

Chapter 1. Understanding vision and its deterioration in aging eyes

Our eyes are our main connection to nature, on earth and beyond. They allow us to bond with a beautiful world full of various colors, shapes, and sizes. Lack of vision affects the endocrine and neurological systems, even our mental wellbeing.

What is vision?

Many people often wonder how we are able to visualize the world. All light in our solar system originates from the sun. The light carries information from the sun. As it hits objects and animals the information gets changed. Decoding this modified information allows us to create an image of the world. The eye and brain work in tandem to unravel this information. The role of the eye is to focus the incoming light on a specialized area, which is connected to the brain. The brain interprets the signal and utilizing stored information, or memories, reconstructs the world in three dimensions.

Engineers and physicists inform us that though signals have information about the surrounding world they also have unwanted aberrations. The eye must concentrate these incoming signals so that an optimum electrical signal can be generated and transmitted to the brain. The role of eyes is

obvious. It does not actually see, instead it assimilates and conveys signals to the brain. The brain is the final decision maker to differentiate relevant data from trivial data that needs to be ignored.

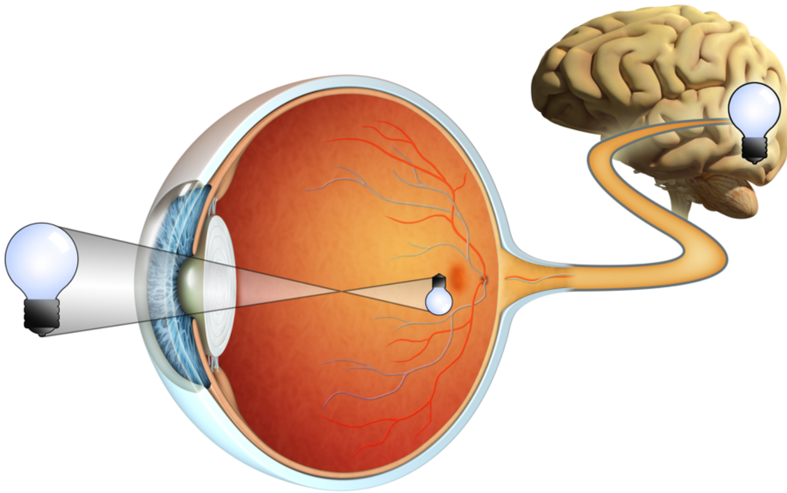


Figure 1.1 Normal eye shows object image on retina and recreation in the brain.

A normal eye is designed such that the converging power and the length of the eye match a mathematical formula. This miracle of evolution, or design, whichever you believe in, is astounding. Let us see the intricate construction of the eye.

Evolution of Vision

The world is an artist's canvas. Everywhere we turn, we see a brilliance of colors and shapes. Have you ever stopped for a moment and thought how this came about? I am not referring to the creation of the universe. I am asking you to introspect on the observation and interpretation mechanism. How did the eyes and visual cortex in the brain evolve? How are they able to develop with such precision?

This fascinating development is the key to understanding how vision works and why eyes age. Once we understand the root problem, it becomes easier to tackle it. A one celled organism troubled by light decided to move away. That may have been the first interaction between light and future eyes. Gradually, as creatures became multicellular, a specialized area developed to interact with light.

If we were to look at this from a philosophical point of view, we would ask when and which organism decided that light may not be an enemy but a friend. It may not always be a be a benefit to run away from the light. There is crucial information in the incoming light, which is advantageous to survive in the predatory world. This is a topic best left for evolutionary biology. We can jump ahead to humans.

In ancient times when humans were mainly hunters, people with vision abnormalities, like nearsightedness or farsightedness, would have been the weakest link when searching for prey and also escaping predators. Predators eliminated these visually abnormal individuals, preventing them from procreating and passing on their less than perfect genes. Hunters then settled down to start farming which made life easier for people with eye abnormalities. Even if the grain appeared blurry it would not pounce on you. Tending to a farm could still be achieved with less than perfect vision.

This status quo persisted for many centuries. It was disrupted when a visionary discovered that curved glass can help in focusing images. Curved glasses are called prisms. Prisms stacked together generate glasses. You all are aware of the benefits of glasses.

The next leap in the evolution of vision correction had to wait until the turn of the millennium. Lasik was invented to counteract the nearsighted explosive boom. Lasik can reshape the cornea and correct myopia, hyperopia and even astigmatism. Now we are on the cusp of the next revolution – to reverse the aging of the eye.

The Structure of the Eye

The eye can be compared to an onion in that both objects are composed of layers. There are three layers of the eye which are sclera, choroid and retina. Each has a unique function.

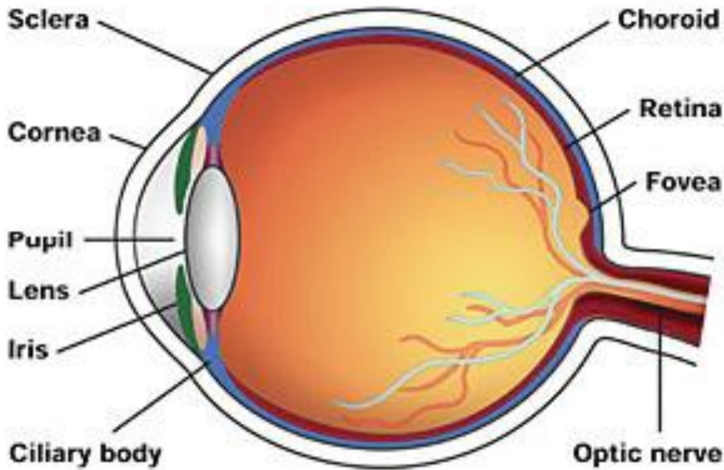


Figure 1.2 Structure of the human eye.

The outermost white layer is called the sclera. The function of the sclera is protection. The front part of the sclera is specialized to form the clear see-through cornea. The next layer is the pigmented choroid. The dark color of this layer blocks light. This converts the eye into a darkroom where the images can be processed.

The front part of this layer is called the iris and it is what gives color to the eye. The iris is behind the clear cornea. The innermost and most delicate layer is the neurosensory retina. In fact, this layer is an extension of the brain. The retina converts the light energy into electrical signals, which are then transmitted to the occipital lobe or back of the brain.

The light beam from the sun is the ultimate power source of all. The photons from the sun traverse millions of miles, are

reflected off objects, and then ultimately enter our eyes. The photons stimulate receptors, which are like computer chips, generating electric signals. The maximum number of receptors are located in the area of the retina known as the macula. The center of the macula is called the fovea.

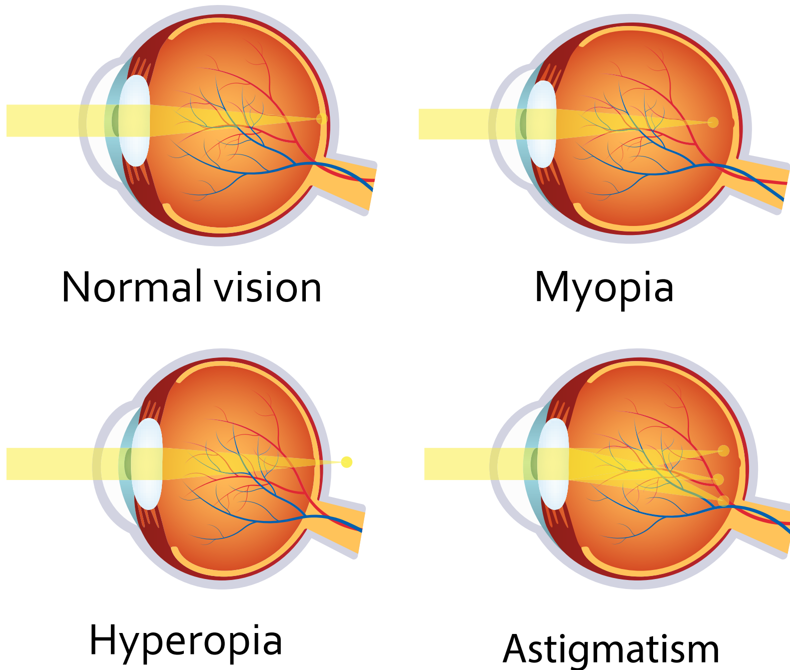


Figure 1.3 Errors of refraction

Errors of Refraction

If the information carrying photons converge to a point in front of the retina, then the patient is nearsighted. If the light comes to focus at a single spot in front of the retina, this is termed as myopia, or near sightedness. The person will be able to see things at a close distance but unable to see far.

On the other hand, if the photons are not brought to focus at all by the time the light crosses the retina, it is defined as farsightedness, or hypermetropia. This person has trouble seeing near and middle distances and even far. In astigmatism, the photons are brought to focus at different points in the eye.

In more complicated cases, some light beams may come to focus in front of retina and others behind the retina. In each of these cases some amount of information is lost. The brain then constructs a defective view of the world. A person will see blurry at all distances and may need to squint in an effort to improve vision. This can give rise to eye pain and headaches.

These errors of refraction are different from presbyopia. Presbyopia is defined as the thickening and loss of elasticity of the lens, preventing the lens from changing shape. This manifests as the inability to see near with the natural aging process. These anomalies of refraction are physical limitations, whereas presbyopia is a physiological defect. In other words, these three errors occur because of a mismatch between the shape or power of the cornea and the length of the eye.

Presbyopia is due to the weak action of internal eye muscles. With increasing age, presbyopia can occur with myopia, or with hypermetropia and astigmatism. The function of refractive surgery is to ensure that the maximum number of photons of solar energy are brought to the receptors without a loss of the encoded information.

The optic nerve and its pathways carry the signals from the retina to a super specialized area of the brain called occipital lobe. If we were to draw a perpendicular line through the optic nerve, the fibers towards the ear are the temporal fibers, whereas the fibers towards the nose are termed as nasal fibers. On the way to the occipital lobe, half the fibers from each eye cross over to the other side. It results in the nasal half of the fibers from the right eye reaching the left occipital lobe.

The temporal fibers proceed without crossing. So, the left occipital lobe gets information from the left or temporal half of left eye and nasal half of right eye. Nasal half fibers actually

receive information from the temporal half of the visual field. When the electrical signals reach the occipital lobe, they are converted into images which are interpreted by the higher centers of the brain.

The neuroelectric pathway from the retinal receptors to the occipital lobe need to be functioning properly for us to enjoy the sensation of vision and perceive the world. Glaucoma, which affects the optic nerve, can lead to defects in vision. Strokes or tumors in the region of the optic pathways can cause blindness in half the field of vision. If the occipital lobe has a decreased blood supply or bleeding, it results in cortical blindness.

The eye is an engineering marvel; it is dynamically assembled and must modulate its converging power to see things at different distances. The eye can be compared to a highly sophisticated camera, because of the similarity between the lens system of a camera and the human lens of the eye. The camera film or computer chip is similar to the macula of the retina. In turn, the beams of light must be brought to a focus onto photographic film or a chip, which can be compared to the retina of the eye.

Basic optics tells us that objects at different distances will be brought to focus at different points. Some of these may be in front of the retina, some on the surface of the retina, and others behind the retina. The retina is an extension of the brain. We can only see the image which falls onto the retina. It then becomes imperative that to enjoy the natural world we need to have a mechanism to adjust the focal length of the eye.

Unfortunately, it is not possible to adjust the actual length of the eye; however, there is the option of modulating the focusing power of the lens used. This is achieved by a dynamic change in the curvature of the lens, which results in a corresponding change in the power of the eye. The lens is formed in the eye while one is still in their mother’s womb. After birth, the lens continues adding new material for the rest of one's life.

Physically, the human eye lens is a clear oval biconvex shape (like a magnifying glass), which can change curvature as needed. In youth, the lens changes its curvature to adjust its power and retains the image on the retina. Age begets an older, thicker lens. Curvature adjustment becomes a progressively difficult chore and begins failing by sixty years of age.

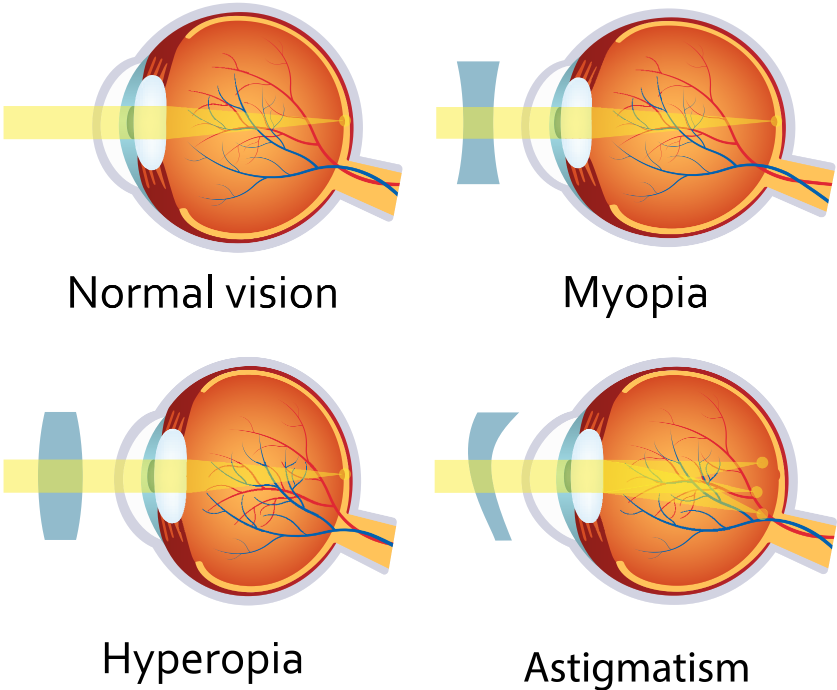


Figure 1.4 Correction of vision disorders using appropriate lenses.

Unlike a camera, the human eye is biological tissue and needs nutrients to survive. Yet the central portion must be kept clear so that there is no interference with light. Blood vessels normally supply these nutrients to other parts of the body. However, they cannot be used for this particular function for

the cornea or the lens, because blood vessels would interfere with light and vision.

This brings us to yet another physiological marvel. Tears, and the liquid inside the eye, supply nutrients to the clear cornea and the lens. Nutrient waste is then also carried by a similar mechanism. Therefore, anything which affects the harmony of this carefully crafted and delicately balanced system, can affect our vision.

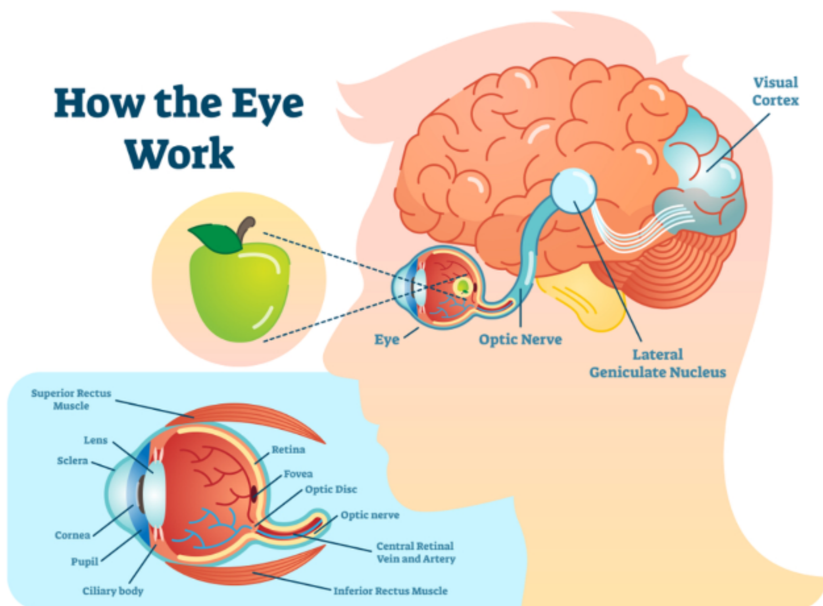


Figure 1.5 The optic nerve and its pathway in the brain to the visual cortex where vision is generated.

Any physical system has a bell-shaped Gaussian distribution. That means most are normal, but some will be on either side of normal. Let us take the example of height. The average height may be 5 feet 6 inches. Around 80 % will be +/- 2 inches. Some will be 6 feet, but a few may even be 4 feet or 7 feet. This is universal truth. What do eyes or vision have to do with this? A lot. Some eyes will be shorter and a few longer in length. Some eyes will be excessively curved and some flatter than normal. We have seen that the photons of light have to

converge on the macula at the center of the retina in a single spot to enable visualization. If there are any errors in the optical system, the light may not come to focus at the required spot.

The ratio of length to curvature needed to focus the incoming light signal on the macula breaks down. In such situations there is distortion, spoiling the incoming signal. As the percentage of noise increases it becomes more difficult for the brain to decipher the surrounding worlds.

If the focusing mechanism is unable to concentrate all the incoming information to a single focus, it gives rise to astigmatism. When the converging power is weak, the signals are not focused by the time they cross the macula. Conversely, if the eye power is too strong, the signals converge before hitting the macula and start diverging by the time they interact with the macula. In all these cases, the visual center of the brain is not able to create a well-defined image of the world.

Static vs Dynamic Vision

We need fluid vision to see at all distances. We do not realize in our youth how much the power of the eye changes as we focus on objects of interest at varying distances. At a ball game, as we see a home run and turn to our phone to check on stats, our eye might increase power by 5 to 7 diopters. As we look at the scoreboard, to the outfielders and then to the guy selling candy, our eyes are constantly changing their focal length.

This fluidity helps us to traverse the world. It helped us survive thousands of years. As we enter the fifth decade of life, the eye gradually begins to lose the fluidity to change focal power. The vision becomes more stagnant or static. The range of available vision decreases so a person can see only distance or near. Our goal is to convert this static vision to a dynamic form and help restore the fluidity of vision.

There is a difference in natural vision and vision delivered through PIE. Natural vision improves more slowly. As a newborn, the child can see near and gradually increases the

distance of the visual filed. Usually 20/20 is achieved by 7 years of age. There is a learning curve with the development of visual acuity. The same way there is a learning curve with vision improvement after PIE. The difference is that after PIE the vision starts at three foci: distance, near and middle. With neuroadaptive training and practice, the gaps between the three foci are filled.

Having PIE vision is an advantage over the type of vision we are born with. The change with PIE vision is dramatic as it is a sudden change from the vision we grew up with. Even so, most people adapt right away. It is better to do PIE in both eyes as close to each other as possible to avoid confusing the brain. If both eyes are done at the same time, the brain adapts faster, as it does not waste time and energy comparing the two types of vision.

The best part of neuroadaptation is that it never ceases. This allows eyes with 20/20 to improve to 20/15 and beyond. An adaptative brain also allows faster reading, quicker responses, as well as adaptation from light to dark. The adaptive brain also continues decreasing, or even eliminating, useless side effects like shadows, glare and haloes.

What Exactly is Aging?

We have discussed all about eyes and defects in vison. Now we need to tackle one more – the changes which befall the eyes as we grow older. Once again, we will first look at our ancient forefathers to get a better grasp. Paleolithic men and women had a tough life. Their diet was healthy, consisting of nuts, fruits, vegetables and occasionally meat. Yet the rigors of existence caused their life to end in their thirties. Imagine being considered old by thirty with broken teeth and a few broken bones.

Once we started living longer, new issues crept up. It became apparent that the focusing mechanism in the eye was designed to last about forty years. Our body may have only been

designed to last that long as well. People gradually lost their ability to see objects close up.

You may wonder why this happens. Unlike the lens of the camera, the human lens is living tissue. It is enclosed in a bag, lined by living cells. These cells produce protein fibers which make up the substance of the natural human lens. The new, young fibers are moldable and clear. As fibers mature, they become less pliable and finally, rigid. The clear, see through color of the lens, which helps in vision, gives way to a yellowing.

Very old fibers turn white, red and even black. Light is unable to pass through these mature, older fibers. The lens fibers are similar to hair in that both are made of proteins and grow longer. The only difference is we can cut our hair. There is no natural mechanism to remove the old fibers. The newer fibers continue to push the older ones towards the center.

In summary, the fibers increase in quantity and become darker and firmer. The lens function reflects these changes. The lens gradually loses its ability to change shape. This affects the auto zoom mechanism. The lens is not able to change its shape to become stronger as objects come near. This inability to increase power of the natural lens as interest is shifted from a distant to near object is termed Presbyopia.

No one is thrilled with aging. We all want to look and feel young. So, let us explore why the lens fibers, or for that matter, any eye cell in and around the eyes age at all. We seldom delve into the actual factors which make us appear older. If we know and understand why our appearance changes with time, we may be able to prevent and reverse the travesty of time.

We are going to focus on the aging of eye. That is my area of interest and expertise as an ophthalmologist. Let's explore the multiple factors that age the eye. These can be divided into external and internal factors. The external factors are gravity waves, yellow sun and nanoparticles falling from space. We are all familiar with gravity, as made famous by the apple falling on Isaac Newton. It is the attraction between bodies having mass. Gravity is exerted through waves.

Earth exerts a pull on our eyes and eyelids. The unsupported eyelids get pulled down causing sagging, or ptosis. The radiation from the sun contains ions, which lead to cell and DNA damage. We know you can get cancer from unprotected, long term exposure to the sun. That is why sunscreen is applied when we go to the beach. Less well known to most people are the nanoparticles constantly bombarding us from outer space. The final pathway of these external factors is cell injury at various levels

Internal factors are genetic and physiological. Apoptosis is the cells dying due to an intrinsic genetic time clock. That means there is a time limit on cells, even in the best of conditions. The cells, in the normal course of their activities, produce waste which is carried away by the blood.

Unfortunately, eyes require clarity and cannot afford the presence of blood in critical areas like the cornea and the lens. This lack of an efficient waste removal pathway can get overwhelmed with time. It's like the garbage disposal in your kitchen sink getting clogged or breaking down. The atrophy, or breaking down, of material produces aging changes. Most of the disease processes can be traced to waste material stagnation.

Problems in Aging Eyes

We are going to discuss Presbyopia, Dry Eye, and Cataracts in detail in later chapters. For now, we will discuss some topics which are often on the mind of most patients.

Macular degeneration: When the cells at the macula accumulate waste, they display aging changes. This occurs in the middle choroid layer. It is clinically manifested as drusen. If the nutrition to the macula is compromised to a great degree, then new blood vessels try to reach the macula to supply nutrition.

This is termed as wet macular degeneration and leads to decrease in vision. We will discuss more about this condition in the section on PIE.

Glaucoma: This is a manifestation of the atrophic matter accumulating in the draining channels, blocking the passage of fluid through the sclera to the small blood vessels. The amount of fluid inside the eye increases, causing a rise of pressure within the eye. The increased force generated from the pressure damages the nerve fibers causing defects in vision.

There are two types of glaucoma. Open angle and narrow angle. The more prevalent of the two is the slow onset, and usually slowly progressing, open angle glaucoma. Narrow angle glaucoma is due to blockage of fluid flow from the pupil. This is an emergency and may cause severe pain and blurry vision. When this occurs, a laser is used to create a channel in the iris to counter the blockage.

Floaters: The space between the natural lens and the retina is filled with a jelly-like material consisting of liquids and solids. With the effects of gravity and aging, the liquid component settles down and solid strings of protein float in the liquid. The solid strings are what appear as floaters.

Corneal Degeneration: You may have noticed white rings in the periphery of the cornea. These are again due to accumulation of degenerated material.

Wrinkles and Droopy Lids: Degeneration of the fat cells, along with the decrease in the strength of the muscles and skin display as wrinkles around the eyes. Further, the constant pull of gravity leads to droopy eyelids.

Retinal Detachment: This is separation between the layers of the retina due to entry of fluid from degenerated areas.

Chapter 2. Presbyopia and Non-Surgical Treatments

What is Presbyopia?

Presbyopia is a nice term to convey the inability to read up close. The onset of this problem starts around 40-45 years old. This can gradually make it difficult to see even smart phones. Realization dawns on the person that he or she needs longer arms to be able to place the phone at a distance they are able to bring it into focus. The scientific reason for this occurrence is the inability of the old, thick, natural lens to change its shape and focusing power.

The lens is the part of the eye that brings the light to focus. It is encapsulated in a membrane called the lens capsule. On the inner surface of the lens capsule are specialized cells that give birth to new fibers throughout life. The newer fibers cover the preceding ones. This resembles the rings on a stem of a tree. You may have noticed as the tree matures the stem becomes thicker. The natural lens also becomes fatter and less pliable.

At the same time, the muscles involved in the movement of the lens weaken with age. Physics teaches us about the inverse relation between force generated and the distance from the fulcrum. As there is less space for the ciliary muscles to function because of the thicker lens, they generate less force. The deterioration of the lens usually starts around the age of

40. Some people, who are far sighted to begin with, may have an earlier onset, while others do not face the discomfort until well into their fifties. Suffice to say, most people are desiring better reading by their late forties. As the years go by, there is an increased difficulty in reading small print, seeing time on wristwatch, operating a computer or cell phone. It worsens progressively over the next few years, with loss of even the intermediate vision. This means there are difficulties in seeing the dashboard of the car or a cell phone. Even with the largest font setting on the cell phone, it is not possible to see clearly.

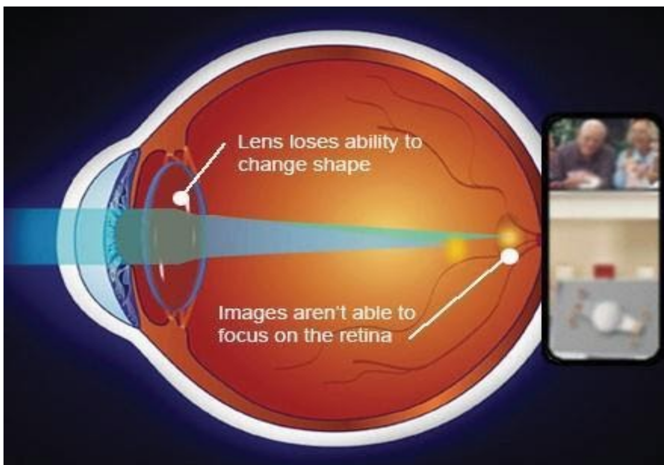


Figure 2.1 With presbyopia the eye is unable to focus near objects.

Why does presbyopia occur?

As discussed in the previous chapter, in early human civilizations, most people lived initially as hunters and then later as farmers. People with poor vision did not fare well against the wild animals but managed to get by working in the fields. Following the industrial revolution, modern society evolved. The need for crisp far and near vision became greater. People had to work on machines which could seriously maim or kill them if they were not careful. Good near vision became

important to prevent accidentally getting caught in a fast-moving mechanical device.

Travel to work, as well as interacting with coworkers and bosses, further demanded great sight. Thus, there was renewed interest in the treatment of vision disorders. Various methods of vision treatment evolved, merged and diversified which then gave way to new techniques. Glasses became more popular. This interesting and challenging period of discoveries and inventions is still the foundation of modern Cataract, Lasik and PIE surgeries.

Defining Baby Boomers & Generation X

The population which is currently facing the challenge of presbyopia is mostly Baby Boomers and Generation X. This has created a boom for the development of PIE, as demand from Baby Boomers has spurred many technological advances. "Baby Boomers" is a cultural term, referring to people born after World War 2. The US Census characterizes this group as being born between 1946-1964. They are now 56 years or older. Their parents had to sacrifice a lot, from the great recession and then through World War 2.

The GI bill and economic progress led to families having many kids and indulging those kids. Fathers worked and mothers stayed home. This drove demand for the development of diapers to designer clothes, then later better colleges. The Baby Boomer generation is predicted to outlive the previous generation and the succeeding one.

They are the spearheads for many advances in the field of vision. In the sixties, while the peace movement and the race to space was going on, there was the introduction of contact lenses. Contact lens development made life easier; however, recurring expenses, foreign body sensations in the eye, induction of dry eyes and infections frustrated contact lens wearers.

As the demand for a better option increased, it led to a swell in Lasik eye surgery. Now, as they are aging and Lasik is failing them, they demand the latest technology of PIE refractive eye surgery. Generation X are those who were born between 1965-1979. They are now 41-55 years old and have entered the age group to be candidates for PIE. These people live in a more complicated society, where needs for precise vision are more demanding than ever before.

Women entering the workforce in greater numbers has allowed increased and disposable income for families. Entrepreneurship and the need for self-fulfillment is the characteristic of this cohort. Some compete with Generation Y (those born 1980-1994), on roads and in the workplace. They desire versatile vision.

Our interaction with the universe through our various senses influences our achievements and state of mind. Hearing, smell, touch and taste are all important, but our vision is indispensable. The way we see this world influences our behavior, our thinking and our well-being. From the moment we get up and look for the alarm clock, to the time we retire at night, we depend on our eyes.

Reading newspapers or a kindle, watching television, cooking, solving crosswords and other activities at home require good vision. When people drive to work, they need good distance vision for obeying traffic signs, intermediate vision for the dashboard of the car, and near vision to interact with maps.

At work we need intermediate vision for computers and iPads and near vision for reading documents. The ubiquitous Android and iPhones bring out the importance of intermediate vision. For the sports minded, vision becomes critical. Excellent binocular vision, with depth perception, is a prerequisite for almost all athletic activities, especially tennis, basketball, baseball or football. Swimming, hiking, cycling and triathlon athletes benefit from eyes that can see well without glasses or contacts. For the adventurous that fly, sky dive,

parasail or climb mountains, clear vision is of paramount importance. Precise eye coordinated activities such as knitting, sewing, needlepoint, analyzing jewelry or machinists require quality binocular near vision.

Figure 2.2 Demonstrating different vision needs: near for map reading, intermediate for dashboard, and far to see road traffic.

Exercise and Yoga

Can eye exercises strengthen the eye muscles and improve reading ability? We regularly hit the gym to develop our biceps, triceps and other muscles. A question arises that why not apply the lessons learned from Pilates and other workout regimens to the eye. If we could strengthen the eye muscles, we could improve near vision and then, funnily, be able to read the newspaper or the screen while on the treadmill.

Many people from different fields of life from scientists, to exercise physiologists, to physical trainers have attempted to develop exercise regimens to achieve this goal. Exercises involving lighted candles, focusing on reading material as it is moved closer to the eye and computer-based regimens have all been attempted. There have been attempts by researchers and surgeons to surgically improve the length, or strength, of eye

muscles to improve the function. This modality has also been met with little success.

Yoga has gained a lot of popularity in the west in recent years. Deep breathing coupled with stretching multiple muscles at the same time is the secret to its success. Yoga has been instrumental in decreasing blood pressure, chronic pain and improving general well-being. There are even special movements for the eyes, yet the reading ability has not been reversed.

This makes us think - what is special about eye muscles? How come their abilities do not mimic the muscular abilities of the biceps? It is because they are different kinds of muscles. Biceps are striated voluntary muscle. Ciliary eye muscles are smooth, non-voluntary. They are like intestinal or heart muscles. But really, the problem may not be in the muscle itself, but what the muscle is trying to move, which is the lens.

Food for the eye

Every living thing needs nutrition to survive the daily grind. In the human body, the cells are constantly requiring nutrition to generate energy to carry out their assigned duties. The cells of the eye are no different. The cells of the conjunctiva cornea, ciliary muscles and retina work extra hard and require even more nutrition for their highly specialized functions. Further, the epithelial cells of the cornea are constantly being replenished.

Eating nutritious food and staying well hydrated help eyes function at optimum levels, allowing us to see at our full potential. When a person is fatigued from fever, exercise, malnutrition or severe dehydration, the vision suffers a casualty. In such instances, fusion (the ability of the brain to fuse the slightly dissimilar images from the two eyes) and accommodation (the ability of eyes to change focus from distant to near objects) can be especially challenging.

Maybe vitamins can help?

The most important vitamin for the eye is Vitamin A. It is an essential requirement for new cell regeneration. The best source of Vitamin A is liver, eggs and milk. For vegans, there are great alternatives such as Beta-carotene which is a precursor of Vitamin A. Beta-carotene is abundant in yellow fruits like sweet potatoes, butternut squash and carrots, as well as in green leafy vegetables like kale and spinach.

Figure 2.3 Healthy foods for improving eyesight.

Lack of Vitamin A is manifested as Bitot's spot, which are yellowish brown degenerations resulting from the buildup of keratin superficially in the conjunctiva. Continued deprivation of Vitamin A can lead to night blindness and even the melting of the cornea.

You may think if a little is good, more may be better, so why not load up on Vitamin A capsules from the vitamin shop? The old adage, excess of anything is bad, is relevant here. Vitamin A excess can cause serious problems. It causes decreased vision, bone pain and can affect liver and brain function.

Glasses

The first non-natural method to improve eyesight was glasses. There are many indications people may have used pin holes, slits and even water filled glass bowls to see better or magnify things. Reading stones were invented by monks and these early reading stones morphed into monocular glasses. In Italy, someone joined two monocular glasses to get binocular glasses which rested on the nose. Benjamin Franklin is credited with inventing bifocal glasses.

The Disadvantages of Glasses:

1. Causes marks on the temple and nose.
2. May fog up in rain or smoky conditions.
3. Heavy use may cause discomfort.
4. Lenses can get scratched.
5. They sit at a distance from the eye which causes optical aberrations. The higher the prescription, the more aberrations.
6. Exact refraction is built on the center of lens. People with astigmatism need to see through the center of the glasses for clear vision. As they look away from the center, they get distorted or blurry images due to the prismatic effect.
7. Problems will occur if the two eyes are not symmetrical. Eyes cannot tolerate more than two diopters difference between them. This can even lead to amblyopia (lazy eye).
8. Separate glasses may be needed for distance and near vision.
9. Recurring investment, needing to spend money every year.
10. Glasses can correct only two axis.
11. Bifocals or progressives take time and can be difficult getting used to.

12. Some people consider glasses a visual crutch or handicap
13. Many people don't like wearing glasses for cosmetic reasons.
14. People forget where they put them.
15. May cause musculoskeletal problems requiring physical rehabilitation.
16. In some instances, poor adaptation to vision fluctuation may cause depression.

Contact Lenses

Contact lenses have a cosmetic advantage over glasses. They sit closer to the eye than glasses, therefore they afford a better field of vision than glasses. Contact lenses have advanced from hard lenses to rigid gas permeable (RGP) lenses to soft lenses. Today, daily disposable lenses have increased the safety of contact lenses by getting rid of any dust or dirt accumulated. Astigmatism can be corrected with Toric soft lens. It's become fashionable to use color cosmetic contact lenses to change the color of the eye.

The Disadvantages of Contact Lenses:

1. A contact lens is a foreign body in the eye and may cause irritation, watering and redness.
2. Long term wear leads to dryness of the eyes and persistent redness and irritation masquerading as allergies.
3. More prone to infections which can lead to loss of vision.
4. Contact lens may tear or fall out
5. With every blink, the contact lenses move. In patients wearing toric lenses for astigmatism, or wearing multifocal lenses, blinking causes the lens to jump, confusing the brain.

6. With problems such as Alzheimer's, Parkinson’s, tremors or Rheumatoid Arthritis, contact lenses are difficult to handle.
7. Handling contact lenses may a pose a challenge in outdoor activities such as camping, swimming, surfing, snorkeling, or scuba diving.
8. Decreases oxygen supply to the cornea by interfering with the tear film.
9. Long term damage to the inner lining of the cornea, which maintains the clarity of cornea.
10. Allergic reactions to the contact lens solutions may develop.
11. Recurring investment, spending money every day to wear contact lenses

PIE is much better than progressive eyeglasses or multifocal contact lenses

I can remember the day a young single woman in her forties told me why she hated her readers so much. She said her dates considered her to be in her thirties until her readers came up to check out the menu. Since then, and after speaking with many youthful looking individuals, I realized that wearing readers is a true nuisance.

As we continue to stress the importance of physical activity and good diets, we are able to keep our bodies younger for a longer amount of time, but the eyes seem to be from a different world. People also hate to carry around the readers or hang them from their necks. If they forget them on a trip or the glasses break, it can affect the working day, especially for a pilot. What have the other options for vision correction been for these people until now?

Let’s consider multifocal glasses, termed bifocal, trifocal and progressives. Bifocals have two foci points - distance and near. Trifocals have an additional focus point for middle, while progressives have multiple foci – near, middle and far. The first

deficiency of any eye wear is the limitation of the peripheral visual field. This can vary from a nuisance of turning your head to see in your periphery to difficulty performing critical tasks like driving. During rainfall, or in foggy conditions, glasses of any kind can create a real problem and you may as well forget about water activities.

Are progressives really safe? This might seem like a joke but there are people with progressives who get so tired adjusting their head and shoulders to see better that they begin developing neck and shoulder problems which can then require physical rehabilitation. A few might even become susceptible to depression.

Contact lenses can be used to create monovision. In this method contact lens on the dominant eye is worn for distance vision while the other eye receives contact lens for reading vision.

Multifocal contact lenses are soft contact lenses which have alternating rings for distance and near zones. In the center is a primary viewing zone. This is usually for distance (called a center-distance design), but in some models, center-near designs also are available. The latter are more often used in non-dominant eyes and with large pupils.

The near add power for near zones can be low, mid or high power. These multifocal lenses differ from PIE, as they are refractive lenses and not diffractive lenses. Refractive PIE implants have been abandoned.

Why do multifocal contact lenses not work? With each blink of the eye, the lenses move. We know that even a few microns of movement of PIE can affect vision. Now imagine constant movements with every blink, and a different amount of movement each time. That means a different version of the world every few seconds.

Neuroadaptation in such circumstances is exceedingly difficult. Less than 30% of people can adapt to the use of multifocal contact lenses. This may seem like a big number but remember, very few people can tolerate contact lenses in that

age group. Like any contact lenses, they are difficult to wear, especially with dry eyes, hand tremors, or for people with small eyes. There is always the chance of scratching your eye or developing an eye infection.

PIE eliminates the movement aspect. PIE uses diffractive implants, which are superior to refractive ones. The vison with these continues to improve with time. Once the PI lens is implanted in sterile conditions, the eye is not susceptible to infections. It does not cause dry eyes and works incredibly well for amnesiacs, who forget where they have placed their glasses or contact lenses.

Presbyopia Drops

Research is being carried on with drops, which will constrict the pupil. The small pupil works like a pin hole camera to increase the depth of field. The near vision is improved; however, the drawback is that the drops will require daily instillation. If you forget the drops, then the effect will wear off. It is similar to being chained to glasses.

Chapter 3. PIE – Cure presbyopia permanently

What is PIE?

PIE procedure treats the ailment known as Presbyopia. Let us understand the meaning of each word in the acronym. The expanded form of PIE is "Presbyopic Implant in Eye". The term has nothing to do with the mathematical term pi, used in mathematical calculations.

We have learned in the previous chapter that presbyopia is a natural change that occurs over time and affects one's ability to see near objects. Generally, around age forty- five, individuals begin to experience this condition and it continues to progress as we age. To correct this condition, most people begin to wear reading glasses.

Even those individuals that have undergone Lasik earlier in life feel the need to reach for reading glasses. People who were already wearing glasses would graduate to more cumbersome bifocals or progressives. This condition makes it increasingly difficult to focus on objects near, middle and far. Presbyopic, in the term "Presbyopic Implant in Eye" means that it cures presbyopia.

The implant is a newer synthetic biocompatible lens placed in the space of the remaining natural lens. Biocompatible means that the body will tolerate it and not develop any

allergies, nor reject the new lens. Presbyopic Implants (PI) are specialized, groundbreaking lenses developed by optical engineers utilizing the latest techniques of Nano engineering.

The implants allow the eye to see near, middle and far. They are of different shapes and sizes, as will be discussed later in this book. PIE can therefore be defined as exchanging the contents of an improperly functioning, old natural lens with a newer, artificial, inert presbyopia implant, which can help us see at all distances and decrease, or even eliminate, dependency on glasses or contact lens.

How long has PIE been around?

This new technology has evolved over the last five decades. Over the past fifteen years, millions of implants have been implanted in patients all across the United States. The author alone has implanted thousands of them, with incredible results.

The alignment of various fields of science has culminated into a new and exciting technology. PIE is the product of the merger between cataract surgery and Lasik. It originated before Lasik but was handicapped by the lack of methods to take out the non-working lens through a small wound, as well as the ability to refine results.

Nano engineering helped develop the advanced lenses, which are used in the procedure. This procedure has been around for a few decades but has reached a higher level of sophistication and patient satisfaction only in the 21st century.

What are Cataracts?

Our hair grows longer every year and finally turns grey. Likewise, new layers of cells and fibers are added to the natural lens every year. We can get a haircut and maintain the volume of our hair, however the lens fibers have nowhere to go. The new layers envelop the older layers. Therefore, the lens increases in volume and it becomes harder and less pliable.

It becomes less efficient at adaptation. Finally, as the aging process continues, the lens starts turning yellow or white. This discoloration affects the transmission of light and is termed cataract.

Figure 3.1 White reflection seen in the pupil of the eye with a cataract.

Cataract is a Greek word meaning waterfall. It denotes that the cataract, or change in color of the lens, is due to accumulation of water in the natural lens. Studies have proven that more than half of all Americans over age 65 will experience a cataract in their lifetime. Cataracts are a normal part of aging, but they can be hastened by various factors.

Endocrine disorders such as diabetes, or thyroid abnormalities, can cause early onset cataracts. Wilson's disease, or infections like rubella are associated with lens opacities. Trauma and radiation have been found to cause sudden cataracts. Steroids delivered through injections, pills and inhalers, as well as some other medicines are known to lead to cataracts. PIE will obliviate the need for future cataract surgery as it removes the degenerating human lens.

Cataracts gradually progress over years, interfering with vision and the ability to carry out various activities. Based on the location and type of opacity cataracts are classified as nuclear, cortical, and sub capsular cataracts. Nuclear cataracts are central and most commonly due to aging of the oldest lens

material. Sometimes this type of cataract can improve reading vision by acting as a magnifying lens. People with nuclear

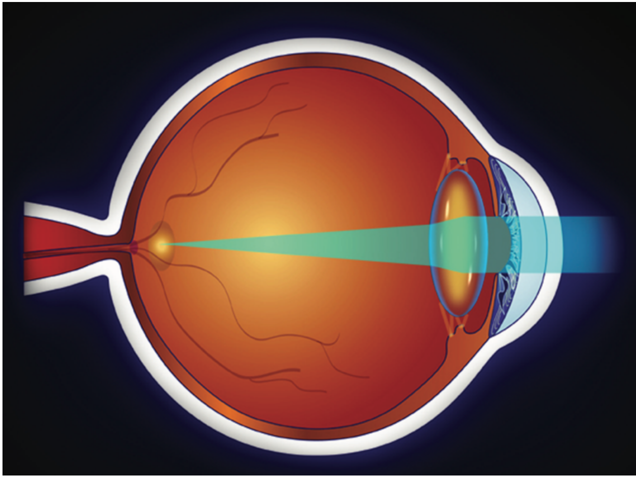


Figure 3.2 Cataract restricts light reaching the retina.

cataracts require more light to read, have difficulty in seeing road signs and other objects in the distance. Finally, everything becomes blurry, despite glasses or contact lenses. Cortical cataracts are like spokes and are responsible for glare at night and sensitivity to light during daytime. Posterior sub capsular cataracts are in the line of sight and can progress quite quickly, affecting vision in a matter of weeks.

Cataract Surgery

When a person has cataracts, not even glasses or contacts can correct their vision. This can make activities of daily life, like driving to work or reading, very difficult. The more a person is dependent on their eyes for their job-related responsibilities, the sooner their desire is to have cataract surgery. With the advancement of technology, cataract surgery can be performed at an earlier stage of cataract progression.

Figure 3.3 Vision in normal eye and eye with cataract.

Prior to the development of cataract surgery, there was no hope, and people often times ended up blind. In order to retain and restore one's vision, cataract surgery is necessary. The earliest cataract surgeries were performed in India 2000 years ago by a method called couching, or needling.

Couching means to place a sterile needle into the eye and physically push the lens further back into the eye. This used to be done once the cataract had become so advanced that is had changed color to white, red or even black. This is still practiced in some African nations.

European nations began experimental cataract surgeries in seventeenth century and dominated the field for the next several hundred years, until the inventions shifted to the United States. In those times, a surgeon waited for the cataract to become ripe – white or red - and make the person totally blind in that eye.

The patient appreciated whatever vision the surgery yielded. This trend continued until the sixties when advances allowed microscopic surgery, stiches led to faster recovery and implantable lenses led to better vision.

In the nineties, a typical cataract surgery required admission to the hospital. The trend was to use general anesthesia. Big incisions required multiple sutures. Some surgeons implanted lenses and others felt it was a foreign body and best avoided.

At the end of the surgery, the eye was patched, and the patient stayed overnight in the hospital. The patient wore thick glasses after surgery and it took a few days, sometimes weeks, to recover. The patient still suffered foreign body irritation from the stiches, which had to be removed. The large size of the wound was an invite for the bugs to play havoc with an infection.

In the next thirty years, general anesthesia was replaced by injections around the eye. The incision size became smaller, requiring less stiches and surgery shifted from hospitals to ambulatory surgery centers. The eyes were still patched, and people still required glasses for the best vision and definitely for near. Modern day advanced cataract surgery may be done without injections, stiches or patches and faster recovery is the norm. Glasses are still required after the surgery.

The term 'Cataract Surgery' encompasses these various surgery styles from the last five decades. As cataract surgery is reimbursed equally for any style of cataract procedure, it is difficult to grade doctors. When your surgeon says he does cataract surgery, it is imperative that you find out which type of cataract surgery he or she performs. Choose the most advanced, painless, no stich, small incision with a presbyopic implant for the best outcomes. To be assured of the best vision outcome possible, pursue patient testimonials from those that have gone before you.

PIE is performed to avoid dependency on glasses by replacing the degenerating lens before it becomes opaque. As noted above, there are innumerable techniques for cataract surgery. PIE is derived from the most advanced techniques of cataract surgery and Lasik. It also takes refractive status into account, therefore, after PIE glasses are not required. In older styles of cataract surgeries glasses are still required at all distances. Since the PIE procedure is performed before the lens has hardened, it is easier to remove the dysfunctional lens with minimal energy. This prevents unwanted surgical consequences like damage to the clear part of the eye. The patients in this age

group, forty-five and older, are generally healthier than the ones who undergo cataract surgery. That means the chance of diabetes or hypertensions affecting the results are reduced. Therefore, PIE is safer than cataract surgery.

Differences between Cataract and PIE surgery

After cataract surgery, implants may or may not be inserted. If implants are inserted, most are a monofocal type lens. PIE requires presbyopic implants. In the United States, cataract surgery is partially covered by medical insurance. PIE is considered an elective lifestyle procedure and therefore is currently not covered by insurance.

Advantage of PIE surgery over Cataract surgery

Cataract eye surgery, as mentioned, was invented in India over 2000 year ago. The concept was to let the cataract mature until the patient could not see at all. The doctor performed a procedure called needling, which pushed the cataract back. Whatever the patient could see was considered a blessing. Over the centuries, the techniques and skills of cataract surgery have evolved but the basic concept remains the same; remove the cataract and accept whatever the result.

PIE, or presbyopic implant in eye, is a paradigm shift in this thinking. Almost like how the theory of relativity jolted our concepts. PIE is a goal directed surgery, so we define the goals or outcomes before we begin the journey. The patient and surgeon decide which zones of vision would be of utmost importance. The patient shares history of previous surgeries, current diseases and medications with the surgical team. The surgeon then does a state-of-the-art eye exam, including three dimensional scans of the macula, cornea and optic nerve. The PIE surgeon then needs to reflect on the combination of all the information obtained to set up a realistic goal to be achieved.

We can turn to football to understand the difference between cataract and PIE surgery. Cataract surgery is like the quarterback throwing a ball. The direction and distance of the ball is not guaranteed. His job was to throw the ball and that was it. In PIE, the quarterback must throw the ball to score a touchdown. Most of the time it will be on the first attempt. Sometimes it will be a little short of the goal line and the wide receiver must catch the ball and take it across. In every throw, a touch down is essential.

Cataract surgery is only performed when the cataract is so advanced that it interferes in daily work/life. The doctor has to determine if the cataract is ready for surgery. Furthermore, the insurance guidelines have to be met and in the cases of HMO's, someone needs to approve it. A person above forty-five is free to choose PIE whenever he so desires. The doctor and patient make the decision. There are no middlemen, so a person does not have to suffer with deteriorating vision.

Cataract Surgery is a term encompassing various techniques. The entire lens could be removed, or some parts could be left behind. Injections, sutures and patches might be employed. After the procedure the patient needs some type of glasses. PIE involves a very specific technique. There are no injections, no pain, no patches and no sutures. A presbyopic implant has to be placed and well-centered in a pristine position. After the successful procedure, the person should meet the predetermined goals of seeing at various distances without glasses.

PIE has evolved from combination of cataract and Lasik eye surgery. It utilizes principles of astigmatism and power correction of Lasik eye surgery and applies them to an evolved form of cataract surgery.

Can we reverse the changes of the natural lens?

This is the holy grail of presbyopia and all other anti-aging cures. Can we become young again? Scientists and investigators

have been toying with stem cells to regenerate many tissue organs. Natural lens regeneration may be a reality in the far future. Lasers are involved in lens modulating experiments. Early changes could possibly be reversed based on animal experiments. This has yet to progress to animal studies or human trials.

Can we remove only the older fibers?

This makes lot of sense. As our hair grows, we go to a hairdresser. Some may prefer supercuts and others a hairstylist. If we apply the idea, we could have a chain of super lens cutters - wishful thinking. The moment we open the lens, fluid enters the lens fibers and makes them cloudy. It accelerates the process of cataract formation.

Last and yet the Best!

Don't give up hope. A time-tested method is the best solution currently. It involves taking care of all the causes of the increasing presbyopia and delivering a lifelong and lasting solution.

The solutions humanity considered to reverse aging eyes

The mission was pretty clear. Revive the autozoom function of the natural lens. Engineers like to first identify the problem so it can be solved. When the question was pondered, "why doesn't the lens move after forty years," two main causes were identified and led to distinct scientific groups.
One believed the muscles were to blame. They postulated that as the lens grew bigger, the muscles moving the lens had less place to act. Thus, the force tension relationship was adversely affected. The resultant loss in muscle action was not enough to change shape. In addition, age related weakening of all muscles should also weaken the individual ciliary muscle fiber.

The rival camp hypothesized that as newer and younger fibers compressed the older fibers, the ratio of old and stiff kept increasing every year. When the magical ratio was reached it resisted change in shape.

Many animal experiments were devised, and primates were studied. Labs invented new instruments to study and record the dynamic changes in lenses as our focus shifted from distance to near. After a century, the debate still continues. Study outcomes and surgical results favor the lens is the main problem. Still some scientists and inventors persevere with inventions to try to improve muscle action.

Who is a candidate for PIE?

PIE is a great and relatively safe alternative for individuals' ages forty-five and above looking to decrease or eliminate dependency on glasses and contacts. PIE can be performed even if a patient is nearsighted, farsighted, or has astigmatism. A person who does not want to wear readers or glasses for distance or near is a good candidate. It can even be performed if a person previously had Lasik, Radial Keratotomy (RK), Conductive Keratoplasty (CK) or various other surgeries. The aim is to rejuvenate the eyes and regain the full range of vision. This means if you are on a hiking trip you can pull out a map and read it without glasses. Or if you are a pilot, you may still retain your license without worrying about not seeing all those fancy dials.

The PIE procedure is the process of replacing the patient's dysfunctional natural lens with an artificial presbyopia implant. The newly implanted lens will provide clear vision at all distances, without the use of glasses. An additional advantage to PIE surgery is that once you have had the procedure, you will not require cataract surgery later in life, as cataracts are unable to develop in an artificial lens.

Is it a painful, long procedure?

The anti-aging PIE procedure itself is brief and painless, taking only 5 to 10 minutes. Prior to the surgery, the patient will be given a small dose of an oral pill such as Xanax, to help relax and mitigate surgical anxiety. The patient will also get anesthetic numbing drops, which are dropped into the eye to ensure the patient will feel no pain for the duration of the surgery, even though the person is awake. The eyes are securely kept open using eyelid retainers. This allows for the surgeon to work cautiously without the possibility of the eye blinking or closing. The recovery time after the procedure is also extremely quick and most patients are able to return to work and even drive the day after their surgery. The presbyopic implants used in the PIE procedure are FDA approved. Before and after the procedure the surgeon and the staff will go over specific instructions and answer any questions you may have.

Will PIE prevent cataracts?

Cataracts are caused by the entry of water into the natural lens. Presbyopia implants are nonliving and inert so water cannot enter them. Initially, the amount of vision impairment with cataracts may be small, but as cataracts grow, so will the impairment, potentially causing blindness. The most common cataracts are related to aging.

PIE is the only method known to prevent the development of cataracts. This is because it removes the lens fibers that are destined to degenerate, change color and cause cataracts. Since there are no fibers left, even Houdini cannot make a cataract reappear.

There is no need to worry if you've already been diagnosed with cataracts, even early ones. PIE can still be performed. In these instances, besides fixing refractive problems, it will also remove cataractous fibers. Removing early cataracts will avoid the fluctuation and progressive slide in vision.

Why have the PIE procedure?

Having poor vision can limit your life in innumerable ways and cause unnecessary boundaries between you and the natural world. Inadequate vision can cause major struggles in many aspects of one's life. It limits working abilities and places restraints on everyday activities, thus ultimately costing you time and effort. Poor vision is often the cause of car, boat, and various, dangerous accidents, simply because one cannot see as well as he or she should.

In today's time, we have the superior advantage to live without these pressing worries or struggles. One has the opportunity to fix poor vision with this relatively safe, easy, and effective procedure.

The PIE procedure has been performed on hundreds of thousands of people over the last two decades. These individuals are now able to see with the clearest and most precise vision they have ever experienced. PIE is a remarkable procedure and has even granted vision to legally blind patients.

Will it prevent other eye diseases?

This advanced procedure may decrease the chances of the development of glaucoma, which is caused by a thick lens pushing on the exit channels of the eye. PIE will not prevent development of macular degeneration nor retinal detachment.

Will my prescription still change?

Any residual refractory error like astigmatism or myopia should present in the first few months. If it is significant, it should be treated. Once stability has been achieved after the PIE procedure, the vision will not fluctuate year to year. Presbyopic implants are synthetic and inert and do not absorb water nor change in dimensions.

Am I too old to have PIE?

One is never too old to fall in love or have PIE. Age is but a number. People as mature as their nineties have loved the improved vision with PIE. Their testimonies are poignant human-interest stories. They were grateful for the benefit of being able to renew their driver's license. One patient, who was hunched from back problems, had had difficulty in seeing with glasses as his eyes faced down and he had to look obliquely, causing aberrations. PIE gave him freedom to live alone and defer assisted living. Improved vision has been proven to significantly prevent the incidents of falls and hip fractures. This has been our experience, as well as studies published in peer-reviewed publications. Many falls are misdiagnosed as fluctuations in blood pressure or imbalance, when actually it's a visual misperception of leaning against a table or walking down the stairs.

What if I have Parkinson's or other movement disorders?

Trembling hands and movement disorders make it difficult to wear contacts or even glasses. PIE helps people with Parkinson's, with head throbbing movements or even shaky eyes.

Is Alzheimer's a problem with PIE?

People who have memory problems can forget where they put their glasses or that they even wear glasses. PIE is especially helpful for them.

Who should not have PIE?

Patients suffering from advanced diabetic retinopathy, wet macular degeneration, end stages of glaucoma or optic nerve damage are not suitable for this procedure.

Frequently asked questions

People want to plan life after PIE.
They are especially interested in learning when they can do the following activities after PIE?

Fly: When can I fly is often asked by people interested in PIE. Many people may travel from out of town to have PIE with an experienced surgeon. They want to plan their return tickets, so for them this question holds even more importance. Typically speaking, two or three days will be safe to fly back.

Swim: It is common for swimmers to be doing their laps within a week of the procedure. It is beneficial to wear swimming goggles to prevent pool water irritating sensitive eyes.

One eye or both eyes at the same time: It sounds so Shakespearean. One eye or both, that is the question. The answer lies within you. If you want to conserve time and are not afraid, it would be best to have both eyes done at the same time. Even though we do two eyes at the same time we treat them as two separate persons. This means we re-prep, drape, employ a fresh set of surgical instruments and even have medicines from separate lot numbers.

Within 1-2 weeks to do each eye: This has been the most common choice of people. It decreases anxiety, allows one eye to heal so down time is even less.

As late as a few years to wait and do the other eye: This has also worked, though very rarely used. Financial difficulties, scheduling conflicts or patients loving the combination of unoperated monofocal distance in one eye with a presbyopia implant in other eye have been the reasons.

Chapter 4. Advantages of PIE Over Lasik and Other Refractive Surgeries

Presbylasik (specialized Lasik for presbyopia), Presbyopia Intra-Corneal Implant (PICI), Implantable Collamer Lens (ICL) & PIE

These procedures are treatment options for correcting Presbyopia.

The treatment options devised can be divided into three categories based on their anatomical place of action - **corneal, between the cornea and lens, and lens based.**

Corneal procedures include: Laser vision correction, Conductive Keratoplasty (CK), Laser Thermo Keratoplasty (LTK) and Presbylasik where the corneal shape is modified. Please note that Presbylasik has not been approved by the FDA They also include an additive procedure known as Presbyopic Intra-Corneal Implant, where synthetic implants like Raindrop and Kamra inlay are inserted in the cornea.

Everyone today is familiar with Lasik eye surgery, a type of Laser Vision Surgery. Lasik invented in the previous century is one of the most popular procedure in the history of refractive surgery. It has liberated millions from the bondage of visual crutches of glasses and contact lenses. There have been tremendous improvements over the last two decades in the way

the laser vision correction procedures are performed. It has increased the safety and efficacy of the outcomes.

What is Laser Vision Correction?

Laser Vision Correction is the reshaping of the cornea using a cool beam laser to eliminate the imperfections of the eye: nearsightedness, farsightedness and even astigmatism. This quick procedure is performed in a clean Laser suite. Healing is fast but varies with the exact type of procedure chosen. The resultant changes obtained with modern technology are permanent. We will look at requirements and outcomes of modern Laser eye surgery and its variations.

What is Lasik Eye Surgery?

Lasik eye surgery is a type of laser vision correction where a flap is created to reach the stroma of the cornea. This flap may be fashioned by a femtosecond laser or an automated machine called microkeratome. The flap is lifted so that the excimer laser can work its magic. After the laser application, the flap is repositioned. It quickly attaches due to the negative suction created by the inner lining of the cornea. In 48 to 72 hours the epithelium anatomically closes the incision. This closure gradually gains strength as fibrinogen is laid.

Who is a good candidate for Lasik?

Experience has shown that it is best suited for the age group 18 to 45, where vision is stable. The corneal shape should be symmetrical, and the corneal thickness distribution map should be normal. The usual range of nearsightedness that can be treated is -0.5 D to around -10 D. Astigmatism up to 5 D can be treated. The upper limit will vary on the combined amount of myopia and astigmatism, the corneal thickness and the percent tissue removed. Hyperopia usually +0.5D to + 3 D.

can be targeted. With the use of the Allegretto laser, higher treatments of +6 D can be delivered.

If Laser eye surgery is contemplated, there should be no cataracts or other intraocular disease. Severe dry eyes would preclude this procedure.

What are other options of laser vision correction?

Laser vision correction can be performed even without making a flap. PRK, or photorefractive keratotomy, predates Lasik. The epithelium is mechanically removed exposing the top of the stroma called the bowman's membrane and the laser is applied. The epithelium heals over the next 3 to 4 days with a gradual return of vision. In the nineties, the lasers were primitive, healing modulators were unavailable and the mechanical irregular removal and trauma to underlying layers often led to corneal haze in the postoperative period.
If the epithelium is removed with a chemical, which is usually tetracaine or 20 % ethyl alcohol, the procedure is termed Lasek.

Lasik and PRK have evolved into Epilasik, or Superlasik. Superficial Lasik, shortened to Superlasik, employs an automated machine to tangentially push away the epithelium. This does not harm the Bowmans membrane, nor the surrounding epithelium cells. The resultant ultrathin flap of approximately 50 microns can be repositioned or can be discarded.

SMILE

In this variation no excimer laser is used. Instead, the femtosecond laser carves out a disc of corneal tissue. There is no flap made. A small incision created by the femtosecond laser is used to pull out the thin sliver of lasered tissue.

Fast & Precise Data Acquisition: The iDesign Wavescan sends over a thousand beams of light into the eye. The light travels through all the imperfections to the retina. The light is reflected from the retina and gathered back by a receptor. iDesign performs micro-refractions in over 1257 zones. The iDesign Wavescan uses Fourier Algorithms (advanced mathematics) to capture the unique aberrations for the eye. These include lower and higher order aberrations. This latest technique uses 100% of available data points to ensure the best plan for the eyes. Like the brain, it analyzes the data obtained quickly, which is more than any human or any other machine can perform.

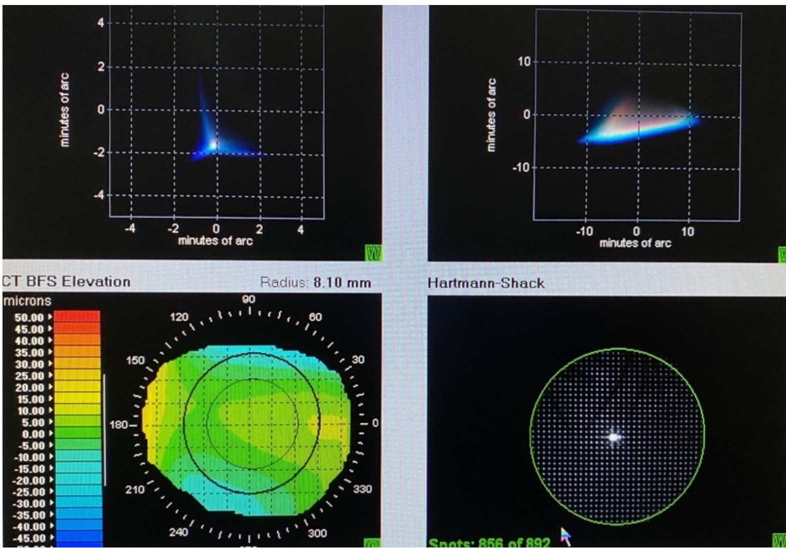


Figure 4.1: Lower and higher order aberration elevations of the cornea is measured in over a thousand zones.

At the same time, the ridges and valleys of the colored part of the eye, or iris, are photographed. The pupil margin and the sclera are documented. The software on the fast and efficient computer is able to sift through the various readings obtained

to create the treatment that is perfectly tailored to the eye. This is a huge step-up from the "better 1 or better 2" method traditionally employed. The high-quality data obtained by the Wavescan machine for any pupil size up to 7mm generates a unique treatment plan specialized for the unique eye.

From iDesign Testing to Treatment:

The surgeon can then use off-line programming to confirm and modify the treatment accurately and with ease. The Wavescan data is transferred to the laser on a flash or thumb drive, where the data is retrieved. It is matched to the eye under the laser.

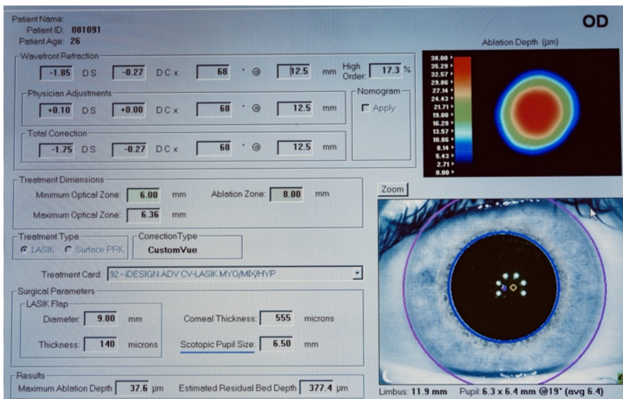


Figure 4.2 Refraction, the center of the cornea, pupil sight and sclera margins are all detected.

The chances of human error in data entry are completely avoided, making the procedure even safer than with other treatments. The laser adjusts for any rotation of the eye, from the sitting position when the measurements were obtained, to the lying position under the laser. The laser also locks onto the eye and moves along with it. These features increase the safety of the procedure which decrease the patient's fear of something going wrong. This allows them to relax, improving the delivery of the laser beam and allowing the best possible outcomes.

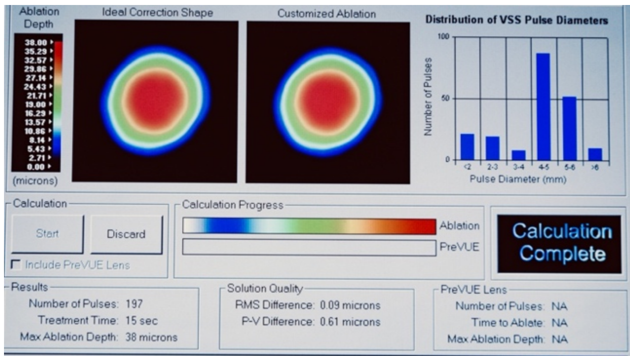


Figure 4.3 Calculation of unique treatment map for the eye to be operated.

Laser Delivery:

The room humidity and temperature are kept under strict control as the laser is very sensitive to variations. Calibration of the laser is performed at beginning of day to ensure it is at optimum manufacturer mandated accuracy. The calibration is repeated before Laser beam delivery on every eye. The laser

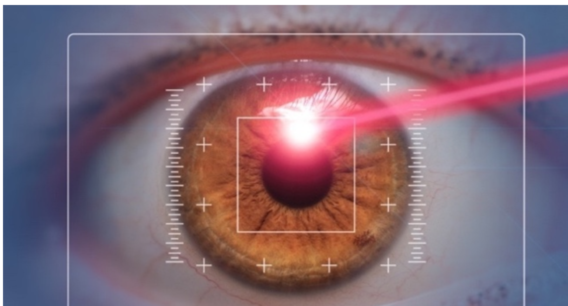


Figure 4.4 Laser beam reshaping the cornea.

locks onto the cornea and reshapes it using fast, variable spot scanning. It also removes the generated plume of debris with a suction tube.

Advantages of Lasik

It is one of the best procedures to eliminate astigmatism, nearsightedness and low levels of hyperopia. In qualified patients it has proven to be very safe. Quick healing allows returning to normal activities very soon. Superlasik expands the range where laser eye surgery can be performed. Patients that are not candidates for Lasik eye surgery may still be able to have Superlasik eye surgery performed.

Shortcomings of Lasik and Superiority of PIE

Lasik cannot be performed in high errors of refraction above 10 D of myopia. It delivers only one focus; distance, middle, or near. In young people, the eyes are set for distance and they can accommodate or change the power of their eye to see for middle and near. They are also able to overcome less than perfect results by employing their eye muscles. In people older than 45, who have lost the ability to read at near, it may not generate happiness. A 52-year-old restaurant owner with -3 D glasses decided to have Lasik eye surgery at a high-volume center. After the surgery he was very depressed. He could not see the cash register nor the menu which was his work for 10 hours a day. All that happened was he traded distance glasses for near glasses. Lasik eye surgery is like fire, if used correctly it will display great outcomes. If used incorrectly, it can burn. The surgeon should use it judiciously.

In certain individuals, under correcting one eye can help at least computer vision. If the dissimilarity in the end resultant powers is less than 1.5 D it is called blend vision. If the difference is exaggerated to 3 D it is termed monovision. In such cases one eye is for near and cannot see far at all. The other eye sees far and cannot see near. It sounds good in theory, but in reality, binocularity or depth perception is sacrificed, intermediate vision may suffer as well. These extreme

differences may not be well tolerated. Only 20 % of people may even like monovision. Others may experience dizziness, "jump in" images and confusion. Before attempting blend vision or monovision, the capability to adapt should be tested thoroughly by trial frames in office and contact lens trial for a few days at home and work. It has been customary to aim the dominant eye for distance and non-dominant for near. It is wise to try to see if this pattern works best for the patient or if the opposite pattern is better. That is non dominant for distance and dominant for near.

This is the advantage of PIE. Vision in all three zones is attained while retaining depth perception. To perform Lasik, a flap needs to be fashioned either by a femtosecond laser
or microkeratome. The flap fashioned in Lasik has some drawbacks. It weakens the cornea and interferes with the corneal nerves. Lasik cannot be performed on very thin corneas, or abnormally shaped corneas, for fear of causing the cornea to bulge forward. Damage to the central corneal nerves may induce dry eyes and make preexisting dryness worse. PIE can still be performed on such thin or dry corneas. Another advantage of PIE over Lasik is that the center of the cornea is not violated.

After Lasik the vision may change and worsen as the natural lens undergoes changes. A person would need to change glasses to see better at the particular distance the vision gets altered. Finally, after Lasik, when one develops cataracts, they would require cataract surgery. PIE prevents the fluctuation in vision and development of cataracts by removing the dysfunctional natural lens.

Lasik cannot be performed in high hyperopes, or farsighted people, more than 6 diopters. These numbers are not even approved by FDA. Similarly, people with extreme nearsightedness, above 10 diopters are not candidates for Lasik. In these situations, PIE triumphs over Lasik.

PIE	LASIK
Distance, middle & near vision	Distance, middle or near vision
Permanently glasses free	Need for glasses by age 45
Binocular vision at all distances	Not above age 45
Thin, thick or keratoconus cornea	Contraindicated
Avoids dry eyes	Causes dry eyes
Can be performed in extreme nearsighted eyes	No
Can be performed in high hyperopes or farsighted eyes	No
Can be performed over previous Lasik, RK, PRK	Avoided
Prevents future cataracts	No

Figure 4.2 Comparing PIE and Lasik.

In other situations, Lasik may not even be worth it to consider. Let's say a 47-year-old low myope with prescription of -1.5 D glasses for distances has Lasik. He will need reading glasses after Lasik. Therefore, he will be just exchanging glasses.

Is PIE possible after Lasik?

PIE can still be performed after a patient has already had Lasik. A small optical zone created by the laser may interfere with the functioning of the implant. The size of the flap and any interface cells will have to be addressed. The accuracy of the implant requires special calculations. After the PIE procedure the flap may accumulate fluid and delay healing. Of course, most patients are very happy to have PIE after Lasik.

They wore glasses in their youth and Lasik freed them from the glasses. Having to wear glasses again is very frustrating for them.

Lasik for Presbyopia

Various laser companies have tried to develop this technology. They have proposed newer nomenclature to differentiate their technique from previous failed ones.

In Presbylasik both eyes are operated on with an excimer laser to create alternate zones for distance and near. This pattern mimics the refractive multifocal tried a few decades ago. It has been abandoned due to poor success rate.

Intracor femtosecond laser procedure attempts to help near vision by changing the shape of the central zone of the cornea, which acts as a magnifying lens. The center sees near and the periphery of the cornea visualizes distance.

Presbyond creates aberrations to induce micro monovision.

Collagen modification to change the power of the Cornea

Conductive Keratoplasty (CK) and Laser Thermo Keratoplasty (LTK) were methods developed to employ heat to change the collagen structure of the cornea. This allowed the cornea to become more spherical. As mentioned, partial correction called blend vision allowed near, intermediate vision and some distance vision. The cornea gradually returned to its original structure negating the induced effect. Therefore, they have been discontinued.

Intracorneal Implants

We can add power to the cornea by adding a synthetic ultrathin lens. This has been tried many times over the past few decades. Human tissue inserts have even been tried. The latest FDA approved raindrop implant has been abandoned by the

manufacturer. Another option used by Kamra inlay is utilizing the pinhole effect. A dark circular plastic with a hole in the center is implanted at a predetermined depth in the cornea. Patients have not been enthusiastic with the outcomes.

Phakic Implantable Lenses

Phakic Implantable Lens are thin artificial lenses which are placed in the eye to correct extreme refractive errors. The prescriptions are usually beyond the range of Lasik eye surgery. There are three kinds of phakic implants: Anterior chamber implants, Iris implants and Posterior Chamber implants. The artificial implant may be placed in front of the colored part of the eye, or iris. An example of this is Alcons' Cachet lens, which has never received FDA approval. They may also be clipped on the iris itself. FDA approved Verisyse Artisan phakic implant from AMO is in this category. The third kind is placed between the natural lens and the colored part of the eye, or iris. Visian ICL (Implantable Collamer Lens), an FDA approved lens from Staar, belongs to this category. It is the most popular in the United States and therefore we will discuss this as an example of the phakic implants.

Advantages of Phakic Implants

1. The quality of vision for highly nearsighted patients may be better with Staar Visian ICL than Lasik eye surgery.
2. This can even be performed when Lasik eye surgery is not an option.
3. Recovery is faster than with PRK.
4. There is no need to remove the implants at night like contact lens.
5. The risk of infection with phakic implants is less than with ordinary contact lenses.

Description of Staar Visian ICL

The Visian ICL is also referred to as implantable contact lens. It is manufactured by Staar. The Visian ICL is a refractive phakic implant intended for placement in the posterior chamber of the eye. This is the region between the colored part of the eye, or iris, and the clear natural lens. The collamer used to create the Visian ICL is very similar to the natural occurring collagen, making it very friendly to the eye. It is rectangular shaped with a central round optic and four haptics at the four corners. The approved models are indicated for the correction of myopia or nearsightedness in adults of the age group 21 to 45 years with myopia ranging from -3.0 to less than or equal to -20.0 diopters with astigmatism less than or equal to 2.5 diopters at the spectacle plane. For patients 21 to 45 years of age with myopia ranging from greater than -15.0 to -20.0 diopters with astigmatism less than or equal to 2.5 diopters at the spectacle plane the approved models can help in the reduction of myopia. The anterior chamber depth (ACD) 3.00 mm or greater is optimal. This is the distance from the cornea to the natural lens. Another point of importance is that a stable refractive history within 0.5 diopters for one year prior to implantation is necessary.

A new version of ICL called Evo is under FDA review. It has a channel for the flow of fluid. This avoids the need to make a separate laser channel in the iris. The channel does not induce visual symptoms like double vision, glare or haloes.

Placing the Visian ICL

Two openings in the iris are made at least two weeks prior to the procedure using a YAG laser. Alternatively, these openings can be made surgically during the implantation procedure. The eye is maximally dilated. The softness of the ICL allows it to be folded, making the necessary incision

smaller. The ICL is carefully loaded, inserted into the eye filled with special artificial viscoelastic and placed on the iris. The four haptics are tucked under the iris. The viscoelastic is removed and the wound is closed. Recovery is quick after the ICL procedure, most people return to work in a day or two.

Preventing Risks of Implantable Collamer Lens Operation

There are two important risks of the ICL implant procedure. Cataracts may occur in a few patients. That is why the anterior chamber depth must be measured and found satisfactory. The surgeon must be skilled and perform the surgery very delicately without damaging the natural lens. Angle Closure Glaucoma is another important side effect. This can be prevented by making two channels in the colored part of the eye. Less common side effects include corneal edema and glare.

Contraindication to Phakic Implants

The FDA has not approved ICL for hyperopic, or farsighted, patients. It is not recommended for patients above age 50 or with presence of cataracts.

A common drawback with corneal procedures is they attempt to treat presbyopia at the structure, which is not the root cause of the problem. We know that the natural lens is the dynamic structure which is undergoing change and degeneration. When we operate on the cornea, we do not halt the deterioration of the natural lens. Even if the cornea procedure is successful it may not last long. The lens may add aberrations, both of lower order and higher order. Corneal procedures cannot prevent cataract formation, instead they may interfere with the cataract procedure and make the calculation of the required lens power difficult. A person may not be able to avail themselves of advanced multifocal lenses if the corneal implants are still present. In the majority of cases,

corneal procedures last for a decade or two. Either natural regression, or the natural changes in the human lens leads to dampening of results.

The natural lens is the root cause of all problems related to presbyopia. The inability to change shape to increase power as objects move closer to the eye is the basic problem. It is due to the increased volume and stiffening of the natural lens and may be exacerbated by weakening muscles and zonules.

Let us explore the methods that have been tried to strengthen the muscle power of the natural lens. Scleral relaxing incisions and scleral inserts have been developed and refined. Their goal is to allow the ciliary muscles more space to expand outwards. This increases the length of the muscle and the space in which it can act. Force length relationship delivers more energy to increase the curvature of the natural lens. The surgery is more difficult to perform than say a laser. Unlike corneal and lenticular surgery there is bleeding involved. A surgeon will have to pay more attention to physical health including bleeding time when on anticoagulants. Automation of instruments is making it easier. The results remain unpredictable. The flaw in this method of treatment is that it does not address the decaying natural fibers which are stiffer.

Where does this leave us as far as curing all aspects of presbyopia?

Its lenticular, my dear reader! The cornea has been easier and more fun to modulate. Corneal procedures are considered relatively non-invasive as they avoid entry into the eye. Therefore, there is no chance of infection inside the eye. Retinal, macular, lenticular side effects are almost zero. Yet they cannot deliver what PIE is able to do. So, we have to declare PIE the winner.

Chapter 5. Contemplating PIE and the initial consultation

From the previous chapters we have learned that as one's eyes tend to worsen, the possibility of wearing contacts or glasses is often considered. An optometrist dispenses glasses and contact lenses. They can be very vexing, costly, and ineffective. In previous generations, the freedom to permanently correct poor vision was not an option. Through decades of modern science and technology we have had Lasik. Now with more recent innovations, the advanced procedure of PIE has become prevalent. It can prevent aging eyes from worsening, correct vision problems, and allow for clear vision without the hassle of glasses and contacts. The PIE procedure is aimed at the age group of forty-five and older. This unique procedure allows for one to see at all distances in both eyes. This is not monovision. In monovision one eye sees far and the other sees near, whereas in PIE both eyes see near, far, and in between. It is better than Lasik for people above forty-five as it preserves binocular vision and depth of field. It will last a lifetime and also prevents the development of cataracts. Undergoing the PIE procedure can save money by avoiding repetitive expenditure on contact lens replacements, glasses, and constant eye exams. It can also save costs on cataract surgery that will likely be needed in the future.

Things to consider while contemplating PIE:

Now that you might have realized the benefits of the PIE procedure, the next step is to plan for the procedure. You would need to find a great surgeon and a good surgery center.

Figure 5.1 A typical couple contemplating PIE.

The monetary aspect would also have to be considered. Please take your work and social calendar into account when planning your procedure, and plan to have someone accompany you to and from the procedure. This decision is an important one, almost as important as marriage or a career. In the next few pages we provide guidance to accomplish these objectives.

Choosing a good PIE or PIE surgeon

PIE is a procedure which lasts a lifetime. It is especially important that the surgeon you choose to deliver this life changing event has very good communication with you. There is no substitute for great bedside manners, accompanied by the ability to listen to you. Sometimes the results are instant, while at other times they can be delayed. The surgical team should be

considerate towards you. This will occur if the surgeon is an actual part of your treatment follow up. Going to an assembly line surgeon will sacrifice the personal attention, which could affect the speed of outcome, as well as the anticipated result. When you can tell the surgeon is compassionate, caring, and tolerant it will make you feel comfortable and will be immensely helpful.

There is no substitute for good qualification and experience. The surgeon should be Board Certified by the American Board of Ophthalmology. They should be fellowship trained in the art and science of Refractive Surgery from a reputable University. This demonstrates that the surgeon has been vetted by his peers. Choosing a charming doctor with poor experience is not ideal. Be bold in asking about the experience of the surgeon. The surgeon should have performed thousands of Lasik eye surgeries and cataract surgeries. It goes without saying he or she should have also generated great outcomes from thousands of PIE surgeries. He or she should have excellent surgical skills. Do not hesitate to check the surgeon's hands for tremors. At our surgery center we received feedback from an anesthesiologist that a surgeon was having major tremors while operating, leading to increased complications. We had to do an intervention to empathize with the surgeon regarding the medical condition he was suffering from, but at the same time we make sure to put patient safety first. The surgeon stopped doing surgery and still thanks us.

Please do ask questions to make sure the surgeon is not biased and loyal to one specific brand of presbyopic implants, which may not be in the best interest of the patient. The surgeon should be compassionate and have a good reputation in the medical community. You can look up your surgeon on the state medical board for any major transgressions. You can read reviews on various sites to assist in making your decision. Of course, all five-star reviews should make you pause and think whether the reviews have been manipulated. Genuine reviews will have negative shades. You can read and decide if it

really is an issue. For example, sometimes people are happy with the surgery but upset with the scheduler. You can also watch video testimonials. The best is to talk to actual patients who have undergone the procedure.

Happy patients who are willing to give unbiased feedback are the best input one can get. They can also educate you on the nuances of the procedure and what to expect after the procedure.

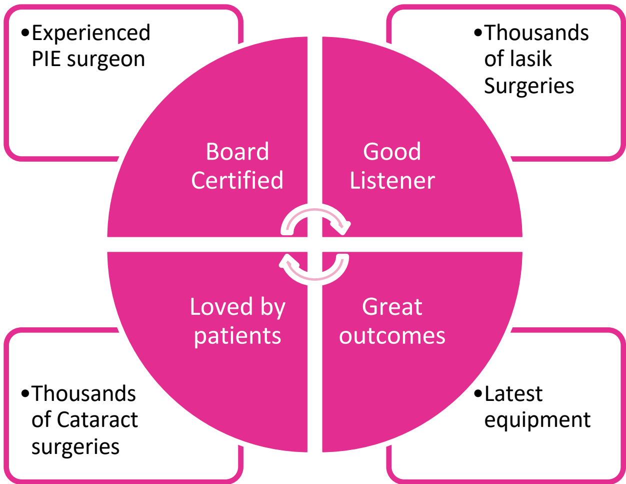


Figure 5.2 Qualities of a good PIE surgeon.

A consultation appointment is required where one will gain knowledge on the surgery and select the specific lens to be implanted based on lifestyle preferences. This allows for the patient to become comfortable with the procedure and develop a rapport with the surgeon and staff. Equally important, it will allow the surgeon to ensure the person is a good candidate. Generally, most practiced and prominent surgeons like to conduct a thorough examination themselves. They review the medical and vision history, dilate and examine the eyes, and perform diagnostic tests on the eyes using sophisticated

equipment. They will learn about the individual; their specific vision needs and lifestyle requirements.
Doctors will often present slide shows, models, or digital presentations of the actual procedure to patients so that they will completely understand what they will be experiencing. Patients are also given the option to speak with past patients who have previously had the surgery to help gain a better understanding and insight to the surgical experience and life after PIE.

PIE involves exchanging the contents of the natural lens for a presbyopic implant lens. There are a variety of different lenses to choose from including Panoptix, Tecnis and Crystalens. The exam will help the patient and doctor together select the appropriate lens that best fits the individual's specific needs, occupation, and daily activities. Great surgeons will give their patients every opportunity to be informed and become comfortable with the procedure before the surgery date. Patients can make plans for any necessary arrangements before the procedure.

Preparing for your eye exam

It is advisable that you come prepared for your appointment. It's a good idea to complete all the forms prior to coming in. It's better to give too much information than not enough. Sometimes patients withhold medical information thinking that it is not relevant to the eyes. Let the doctor make that determination.

You will need to provide information concerning any past or present eye problems, eye surgeries, or any injuries to the eyes. It is important for the eye surgeon to be aware of any medical conditions like Hypertension (blood pressure elevation), Diabetes (blood sugar level and Hemoglobin A1C), Thyroid disease, Arthritis and so on. Please bring a list of any medications you may be taking, or you can even bring in the medicine bottles. Family history of any eye problems like

Macular Degeneration, Glaucoma and medical diseases are helpful. If you see a primary care physician, their name and contact information would be useful.

You should bring your glasses and/or contact lenses as well as sunglasses because your eyes might be dilated. If possible, bring along somebody who can drive you.

Eye Examination Day

Many people are nervous on the day of the exam, which is normal, but rest assured that surgery will not be conducted that day. To alleviate the anxiety, it's better to know what's going to happen during the exam and how long it's going to last. Generally speaking, a screening can last 15 minutes, whereas a full and thorough exam can be between one to two hours. It's prudent to plan for around one hour when you arrive so that all your questions are answered, and any follow-up questions are also addressed.

Different practices may vary in the order in which they carry out the exams but overall there is a lot of consistency. An exam can be divided into 3 parts. The 1st part would be testing by the technician, the 2nd part would be the counselor explaining the procedure, and the 3rd part would be the doctor examination.

The goal of all these examinations is to make sure you're a proper candidate for surgery. What that means is the doctor wants to be sure you're not suffering from Glaucoma, Macular Degeneration, any visual field loss, any choroidal or retinal problems and document if you have cataracts.

Part 1 - Measurements, Scans and Data Acquisition

The diagnostic measurements are the foundation on which the surgery is performed. The latest equipment should be used. If the data is doubtful, it should be repeated after recalibration.

Treating dry eyes first or being out of contact lenses for a longer period is also recommended for the best results.

Ocular Coherence Tomography (OCT)

Ocular coherence tomography, or OCT for short, is a system that uses infrared light, an interferometry, to obtain the detailed scans of the eye. These scans include scanning the cornea, the anterior chamber, the angles of the eye, the vitreous, the retina and the choroid. This instrument has seen a lot of advancement and refinement in the last decade and has moved on from being an ancillary test to one of the most important measurement devices. The cross-sectional scans can be displayed in black and white or even in color. The views are similar to viewing live tissue under the microscope. Therefore, it allows the doctor to have an insight to actual stuff happening in the body and eye. The optic nerve and the macula can be studied and documented in detail. OCT can give the doctor information which cannot be seen with naked eyes. It is adept at picking up details which may give information about future progression of diseases.

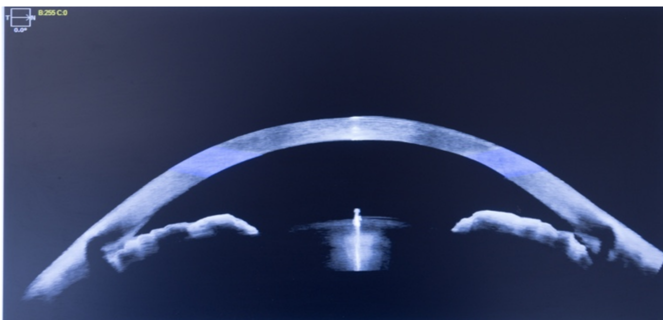


Figure 5.3 OCT of the anterior chamber.

Corneal Pachymetry

This is another instrument whose time has come to the market in the last decade. It has moved on from being an

afterthought to an essential part of any refractive surgery procedure. It uses the same principles of the OCT to determine the thickness over various areas of the cornea. This allows detection of astigmatism, asymmetric astigmatism or irregular astigmatism, which may indicate keratoconus, pellucid marginal degeneration, or other cornea abnormalities. Further advancement now allows the distribution of epithelium to be mapped and displayed.

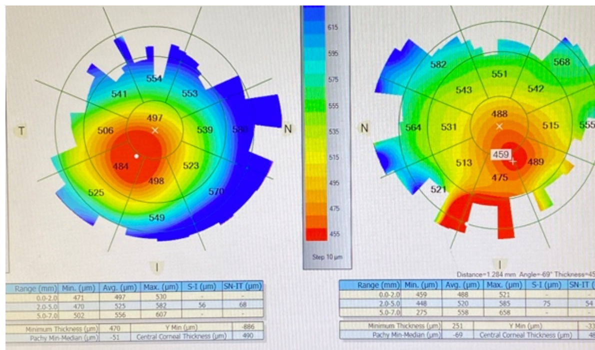


Figure 5.4 Corneal pachymetry map - thin areas are red colored.

Autorefractor

This automated instrument detects the refraction of the eye. That means it’s checking if you have a prescription, meaning you're nearsighted with -4 diopters and hyperopic or have astigmatism. This can augment a manual refraction. It will tell you if you’re 20/20.

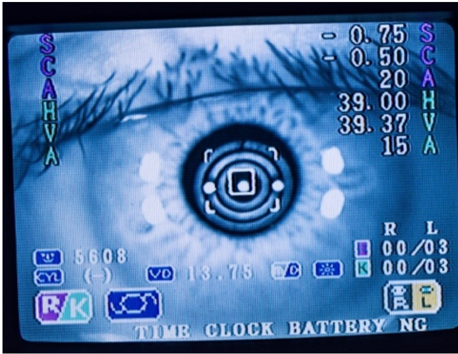


Figure 5.5 Autorefractor screen as seen by doctor.

Vision Testing

This is the backbone of all testing because what we are trying to do is improve your vision; hence the documentation at the first exam and then subsequently at each and every exam is of paramount importance. Distance vision, intermediate vision and near vision of each eye is tested separately and then together. You may be familiar with the Snellen chart, which contains a series of black letters that vary from big to small font put on a white screen.

The results from the visual acuity test are expressed as 20/20 or 20/40. The first number expresses the fixed distance of twenty feet, at which the test is conducted. The second number is the distance a person with perfect vision can see the same letter from. For example, if your visual acuity is at 20/40, then whatever you are seeing at twenty feet, a person with perfect vision can see at forty feet. If your vision is 20/80, your vision is one-fourth as good as normal. At 20/200 a person is considered legally blind.

Corneal Topography

This test is very important in refractive surgery, whether it be Lasik or PIE. It is essential as it displays in a colored form

the power of the cornea in different areas or zones. There are different ways to interpret the data generated such as elevation, height, instantaneous refraction and many more views that are now available.

The amount of astigmatism detected will play an important part in selection of different implant, as will be discussed on the chapter on astigmatism. Modern software can also predict if patient has keratoconus. It can also detect if patient had previous hyperopic or myopic refractive surgery. This helps in applying the correct formula to calculate the power for PIE.

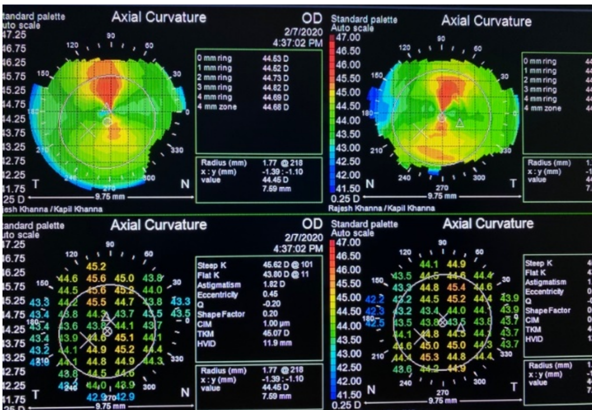


Figure 5.6 Color topography of cornea. Steeper areas are in warmer colors.

Axial length

Axial length is the distance from the cornea to the back of the eye. This is the fovea, which is the central part of macula. This crucial information is essential to the success of PIE, for every eye receives a unique presbyopic implant which must be tailored to that specific eye. The length of the eye is very important. Other parameters, which are measured and can be incorporated into different software to generate predicted presbyopic implants power are the shape of the eye, or

keratometry, the thickness of the lens, the distance of the lens from the cornea and many more.

Modern instruments like IOL master 700 and Lenstar are able to do these measurements as well. IOL master 700 uses swept source OCT technology. Swept source incorporates light beams in different directions and repeated over time, making this the most accurate. Lenstar relies on ultrasound which uses sound waves that are similar to the sonar used by dolphins or bats.

Older methods, like immersion A scan, are rarely used as their measurements may vary and are prone to errors. Contact ultrasound, where the probe touches the cornea and may indent it, as well give rise to false readings and should not be used.

Figure 5.7 Display of measurements from IOL master 700. On the right are the predicted powers for the implants.

Effective Lens Position

The natural lens is around 3 to 4 mm thick. Once its contents are removed an empty bag is left. In this empty bag, we insert a synthetic, biocompatible inert lens which is 1/3rd the thickness of the contents removed. The new implant has the

freedom to sit anywhere in the space of the old lens. The exact final position where the new synthetic implant settles is known as the effective lens position. The ELP determines the real power of the lens. This variability has a bearing the on outcome. If the final vision is not the desired one, it may require a laser fine tuning. This is predicted by the formulae utilizing measurements from IOL master 700 and Lenstar.

Different formulae use this information and display it on the screen as shown above in Figure 5.7. The surgeon's experience is paramount to choose the best implant from the suggested implant power.

Visual Field Measurement

This is a test to detect how much area of space the eye can see. It can be done two ways. The first is where the examiner and patient sit opposite each other and objects are introduced in between them. The more formal, computer-based test utilizes a perimeter where the person looks at a central light and peripheral lights are flashed on different spots. This test is useful to document any visual field abnormalities arising from Glaucoma, Macular Degeneration or drug induced side effect.

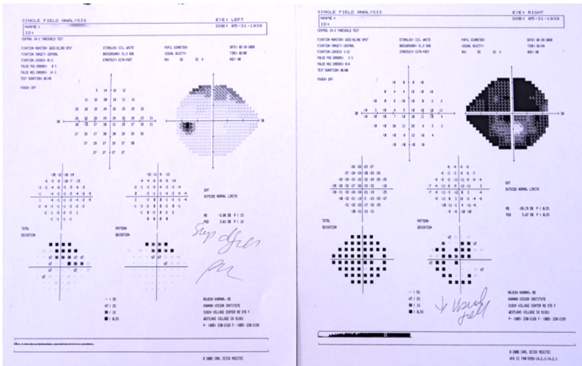


Figure 5.8 Left: Normal Visual Field. Right: Visual field defect

Contrast Sensitivity Testing

Contrast sensitivity is a measure of the ability of an eye to detect variations in contrast. This test replicates vision in subnormal conditions like twilight, dawn, or when it is foggy. Cataracts, glaucoma or diabetes can suppress it.

Part 2 - Clinical Exam

Refraction

This is the traditional test the eye doctor does when he or she asks, “better one or two?” The information gleaned from the autorefractor is then put in front of the patient's eyes in an instrument called a phoropter. Various permutation combinations are shown until the patient chooses the best one. The numbers generated are called the refraction of the eye.

Intraocular Pressure Measurement

This is a test a person should get used to because it's going to be performed before and after surgery. It measures the pressure inside the eye. Elevated pressure may indicate Glaucoma and must be brought down into physiological levels. This is a requirement before PIE procedure. A Tonopen, Non-Contact Tonometer or the best method; the Slit Lamp Applanation Tonometer may be used.

Iris Pupil Examination

The size of the pupil in the dark, as well as in bright conditions, are measured. Both the pupils should be round, equal and reactive to light and accommodation. Any abnormalities with this test may indicate problems with the optic nerve pathway.

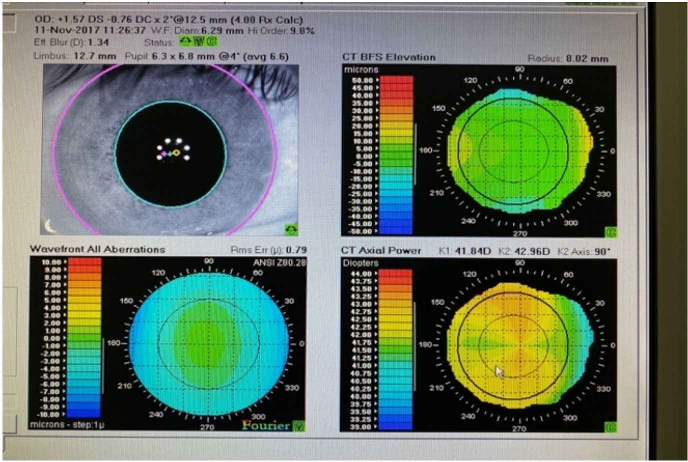


Figure 5.9 Measuring the pupil size in dark.

Slit-Lamp

The slit-lamp projects a slit of light on the eye. The slit creates a cross-sectional view of the structure on which it is focused. The brightness of the light, size, orientation and width of the slit is adjustable. The slit lamp allows the examining doctor to study the details of the eye, starting at the underside of the lids, then the cornea, anterior chamber, iris, lens

Figure 5.10 A slit view of cornea and cataract lens

and the vitreous retina. All of these can be examined with great detail.

Dilation

The structures behind the iris are hidden due to the pigment in the iris. When the pupil is dilated using drops, visualization of these structures becomes easier to examine. The effect of the drops lasts for a few hours. It is advisable to bring along someone to drive you home whenever your eyes are dilated; however, most people are able to drive themselves wearing dark glasses. There are drops currently being developed to safely reverse the effects of dilatation.

In patients suffering from narrow angle glaucoma, dilatation should be performed with due precautions. Drops like Phenylephrine may increase blood pressure.

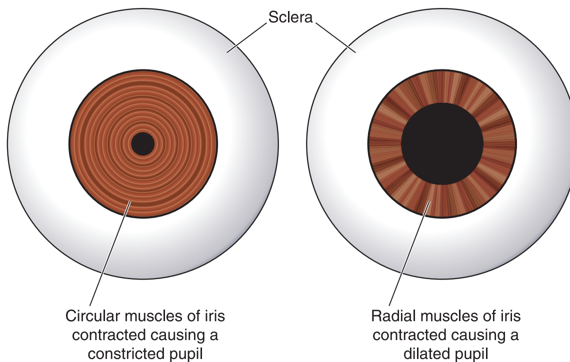


Figure 5.11 Muscles controlling size of pupil.

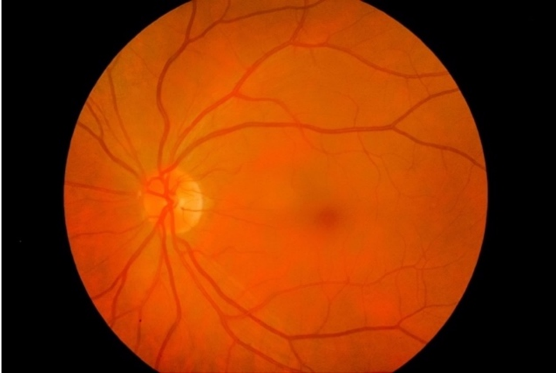


Figure 5.12 A view of the fundus. Orange disc is the nerve head with radiating blood vessels. Macula is in center.

The exam can be done in an un-dilated pupil, or with a monocular direct scope. Binocular fundoscopic examination after dilation gives the pupil the best chance of detecting minute abnormalities in the lens, vitreous, macula and peripheral retina. Binocular fundoscopic examination of the back part of the eye is very important. With this, the doctor is able to see the retina, any blood vessels or optic nerves. The eye is the only place in the body where blood vessels can be directly seen. This helps detect hypertension, diabetes and various other pathology. You may wear sunglasses after dilation to overcome light sensitivity.

Part 3 - PIE Counseling

Now that the surgeon has had a good view of your eye and received all the diagnostic tests, he would listen to your requirements and goals. To make sure all the information has been collected, you may be asked to complete a questionnaire describing your current vision status and what activities are most important to you. A sample of such questionnaire is shown in Figure 5.13. He or she should be in a position to offer

you the choice of implants best suited to your desired outcome. An assistant, specializing in explaining the PIE procedure, may help review the choices recommended.

Which PIE is best for me?

A very common question posed by patients sitting in the examination chair is, "which PIE is best for me?" Many patients state the same wants - "I want the best lens" or "please insert the best presbyopic implant". Who would not want the best lens? The real fallacy in these demands is who determines which is the best lens - the FDA, the patient, the doctor or the surgeon? If the FDA had found that one lens was the best, why would it approve other implants. The FDA would also have to withdraw other previously approved implants from the market. The same logic applies to the surgeons. If the surgeon favors a particular lens, then he may not be putting the patients' needs first.

It took us a long time to figure out what the consumer was really trying to say and now we understand the intent of the question. It can be rephrased as

"Please use your experience to help me choose the best presbyopic implant for my eye. If you do not use the implant which is the best for me, please refer me to a skilled presbyopic implant surgeon who is experienced with that technology."

This synopsis is so crucial. This is the question I was trying to answer when I wrote the first book on presbyopic implants. At the time, the FDA approved choices were limited, and few surgeons performed the procedure. As Baby Boomers have aged, their focus has shifted from Lasik eye surgery to PIE. Many of the Lasik surgeons have followed suit. Newer graduates are choosing to specialize in PIE rather than Lasik eye procedures. There has also been a plethora of new FDA

approved implants. The art of matching the most appropriate lens to your lifestyle and visual goals has become more important.

From the consumer's point of view, they need to first find and trust a PIE surgeon. They need to sit with this person to explore the best options. This book will serve as a reference point for those discussions.

Checking the Ambulatory Surgery Center (ASC)

The surgeon is your liaison to the ASC where these procedures are most commonly performed. Some surgeons might use a hospital setting in a smaller town. Few may perform this surgery in an office-based setting. We prefer an ASC, which has been certified by Medicare and Accredited Association for Ambulatory Health care (AAAHC). This third-party certification gives more confidence, as they have visited the site and reviewed the ASC policies regarding sterilization. You still may have to inquire if the microscopes are the best. If the surgeon cannot see through the scope clearly, it is more difficult to perform the operation.

Zeiss, Wild or Leica are the top three microscopes, with their latest models having superior optics. These advanced instruments are connected to cameras which can record the procedure for later viewing. Some centers have introduced 3D screens to linked microscopes so that the surgeon does not have to look through the oculars. You may want to confirm the machines are current and the latest generation. Similar to newer computers and phones, phacoemulsification machines evolve. Newer features allow the use of less energy and also increase safety. The top products currently are Centurion by Alcon, Stellaris Elite by Bausch & Lomb and Whitestar Signature Pro by Johnson & Johnson.

Quality of Vision Questionnaire

Name: ______________________ Date: __________

This Questionnaire assists us in providing the best biocompatible lens for your PIE (Presbyopia Implant in Eye) surgery. Please understand, though PIE allows freedom from glasses, some patients may require glasses in certain conditions. Please circle all that apply

Do you suffer from any of the following conditions? Diabetes mellitus, Macular degeneration, Glaucoma. Any other? ______________

Symptoms: Have you had difficulty with: Reading medication instructions newspaper or food labels, fill out forms, watch TV, work, sewing, needlework, crafts, playing golf, tennis, cards, swimming & games. Y N

Have you been bothered by: Poor night vision seeing rings around lights, glare, seeing in poor/dim light, blurry vision, driving at night, have you had any driving accidents? Y N

Are you responsible for the care of others at home? Y N Do you work at night? Y N
Do you play contact sports? Y N

How is your vision without your glasses or contacts now? Very Bad, Bad, Good

Zone 1	**Zone 2**	**Zone 3**
Reading	Computers	Driving
Sewing	Smartphone	Golfing
Applying make-up	Cooking	Cycling
Crossword puzzles	Reading labels on shelf	Watching movies/TV

Which zone of vision is most important to you? Please choose only one

Zone 1 Zone 2 Zone 3

If required for which zone would you be willing to wear glasses?

Zone 1 Zone 2 Zone 3

How important would it be for you to be free from glasses for your daily activities?

_____Very Important_______Moderately Important _____Not Important

Please place an "X" on the following scale to describe your personality as best as you can:

____

Easy going Perfectionist

How do you expect PIE procedure to improve your quality of life? ________________________

____

Patient Signature: ______________

Figure 5.13 Lifestyle questionnaire. This helps in matching the PIE based on work, sports and leisure activities.

A lot of surgery centers may have decorative lobbies but ancient machines. Older machines are not recommended. Another important thing to keep in mind, especially if you end up choosing an office-based setting, is that there should be a battery backup for the microscope & machines. In case of an unexpected power failure this can prove especially important. Your anxiety can ease if friends, relatives, or other patients recommend the surgery center.

A little more investigation, with the input of the surgical staff, can confirm if they carry all needed backup equipment & lenses. If there are ever any problems like the instrument falling on the floor or the intraocular presbyopic implant getting scratched, the center needs to have operational backups. If the bulb on the scope blows out, a backup could replace it immediately without affecting the surgery. That is why all equipment should be maintained by the manufacturer. There is no substitute for passionate, caring, certified staff. Well trained, experienced staff makes the procedure simpler and safer. It doesn't hurt to be aware of the protocols in place for the surgical center if there were to be an emergency. This could include protocols in case of catastrophes like earthquakes or fires. If you have a medical emergency, you can ask which hospital you would be transported to.

Another important topic that is asked about is allowing family or friends to watch the surgery. If they cannot, is there a place for them to wait during the procedure? In a big metro city, parking could cause problems on the day of the procedure. It's good to be aware if parking is paid or free. It sounds silly, but on the day of surgery having to waste time finding parking increases anxiety.

Check the price - the devil is in the details

Many years ago, a family member had to have a surgical procedure in the hospital. We budgeted for what was quoted to us. To our surprise, the bills kept coming for many months.

Even a year later we received a final bill. When we questioned the billing department of the hospital, they politely replied that doctors, surgeons, anesthesiologist, and hospital bills were separate. Hospital charges vary on what was used during the procedure. If this was confusing to a physician like myself, I imagined what a lay person would experience. They could be looking at overruns, especially if they had set a monthly budget for the procedure. The best method is to have a fixed maximum price. That is what we have done for our patients and we recommend a person get that same commitment from their treating provider. Various tests are charged individually in case the patient decides not to have surgery at the last moment. But there is a cumulative maximum price, which the patient is informed of right in the beginning. It includes the consultation, full ophthalmological exam, pre-op measurements, the cost of the presbyopic implant, surgeon fees, anesthesiologist fees, surgery center fees, including nurses and technicians, and post-op visits (follow-up exams after surgery). We also include a lifetime guarantee of fine tuning the outcome: utilizing lasers/Yag/punctal occluders. Prices would be less if this protective guarantee is not included. You would need to be aware of what these costs may be. This way you get the most accurate final maximum cost for the procedure. It would also help in comparing quotes from competing practices. It goes without saying that all these quotes should be obtained in writing and signed by a counselor or the surgeon. We have had many patients come to us after a procedure elsewhere after learning that their vision could be enhanced by Lasik eye surgery, but it was not included in their price. They were told that they were charged only for the procedure. If their eyes misbehaved it was their luck.

We believe the paradigm needs to shift to outcome-based procedures. Therefore, check if enhancements are included, and if so, for how many years. Please look for the number of the included postoperative visits and the duration of the post-operative period. Look for any disclaimers or exclusion clauses.

This will help in comparing various places on a level playing field.

Payment options

The mode of payment and when each payment is due can vary across the country, nearly all practices will accept cash and credit cards. Many will even offer third party financing like Care Credit, Wells Fargo, Alphaeon or others. These may include zero down and no interest financing for various periods of time. You may have a choice to do part cash, part credit card and remaining on installments. Rarely, a practice may allow internal financing. Some may ask for the entire amount upfront so that the procedure and visits can move along without interruptions. Others may allow payments based on the stage of the process. For example, one payment for an exam, another for preoperative measurements, one to the surgery center, another to the surgeon, another to the anesthesiologist and later for enhancements if needed. Yes, it can get confusing, that is why we prefer one, all-inclusive price upfront.

Now for some great information. Do you like free money? Would you want Uncle Sam to help fund your procedure? That may be possible by using pretax dollars through your Flex Spending Accounts (FSA) and Health Savings Accounts (HSA) to pay for the procedure. But wait, there is more! If you can prove that your eyes are very important to your profession, then expenses for PIE could be tax deductible. You would have to discuss this with your CPA regarding your particular situation and the latest IRS rules. Another way to save money may be by qualifying for discounts. Some practices offer cash discounts to save money on financing fees. Sometimes there may be promotional pricing being offered. Of course, you have to stay away from Groupon and similar heavily discounted giveaways. Please do not hesitate to inquire if there are special discounts for police officers, firemen, veterans and the like.

Summary of a good consultation:

- Review of medical and visual history
- Check vision, refraction, and auto refraction
- OCT of macula and nerve
- Corneal topography to analyze shape of the eye
- Pachymetry to measure the thickness of the cornea
- Slit lamp: to observe tear film, cornea, and lens
- Intraocular pressure to rule out glaucoma
- Dilated exam to rule out pathologies like diabetes, hypertension, glaucoma, and macular degeneration
- Axial length measurement of the eye
- Explanation on eye model, visual charts
- Get a chance to talk to the surgeon
- Patient testimonials are important to read and will verify the doctor's intelligence and proficiency
- Optional tests like visual field

Chapter 6. PIE Procedure

What is the goal of PIE procedure?

The goal of PIE procedure is to have an eye which can see at all distances easily without side effects like glare and halos. This is achieved by passing through the cornea, opening the natural lens, removing the old, degenerated, nonfunctional contents and inserting the new bio compatible presbyopic implant. Each step involves minimal invasiveness and a lot of skill with the goal of safer procedure and faster healing.

The procedure - from tolerable to enjoyable

A person should be comfortable and relaxed during the procedure. The more relaxed a person, the better the outcome. If a person is squeezing their eyes or thrashing about, the eye can move unexpectedly and cause problems. Reading an educational book like this helps one understand and remove the fear of the unknown. Anxiety can be allayed with anti-anxiety oral pills, like Xanax or Versed. Another option is by the intravenous administration of sedatives like Versed, or painkillers like Fentanyl. IV Propofol can help relax tense muscles. The patient can discuss the best option with their anesthetist. Previous experience with anesthesia drug allergies and current state of emotions would be decisive factors.

Nowadays topical anesthesia is the preferred method for PIE procedure. Most of PIE procedures are performed with topical anesthesia. This means drops are put in the eye to numb it, there are no needles or injections in or around the eye.

Further, to numb the eye intracameral anesthesia is employed. This involves preservative free Lidocaine anesthetic, with or without preservative free dilating drops, delivered inside the eye. Whatever type of anesthesia is chosen, there is no substitute for communication between the surgeon and the patient during the procedure. Patients trust the surgeon and so the surgeons comforting words can be a big factor in inducing relaxation. We term this as vocal anesthesia. The surgeon guides the patient and receives feedback about discomfort and pain. The ability to express anxiety and fear reduces the fear and makes one comfortable. We have also found soothing background music can help elevate stress. Background music, a relaxed surgeon and staff who are attentive can make it like a walk in the park.

Relaxation starts before the day of the PIE surgery

Try to be calm. It's just like all the examinations you have taken previously in your life. Last minute watching YouTube videos may scare you. Calling relatives and friends, or relatives of friends, or friends of relatives to ask them about their surgery is not a good idea. This just generates anxiety and panic. Instead, watch a relaxing movie and put your mind and attention towards other stuff. Maybe take a walk on the beach or go to the park.

This is the time to bring out your pre op instructions and go over them. Don’t keep any questions for the last minute on the operating table. Keep all your papers and directions together. You have to remember to put your antibiotic drops starting three days before the procedure. Some patients may have to start anti-inflammatory drops. Continue any other drops like those for glaucoma or dry eyes. As instructed by your surgeon,

you may or may not have to stop certain medicines like Flomax and blood thinners. Do continue taking all other oral medications.

It is also good idea at this time to confirm your ride for the next day and double check the location and the time for arrival. Time for arrival is usually an hour or more earlier than the time for surgery, so please don't get confused between the two.

On the day of surgery

The day for the procedure has finally arrived. All your preparations and the surgeon's test have led up to this point. It is important not to get nervous or panic about what's going to happen. Try to be in a positive cheerful mood. This also helps the staff relax and improve your care.

Avoid eating or drinking for six to eight hours before the procedure. This includes avoiding coffee, milk, juice and the like. The reason for this is because if you're going to be having some anesthesia the side effect can be vomiting. Vomit may enter your breathing apparatus and lungs which can cause choking and further problems. We don't want any stomach contents to come into the field. Finally, if for any reason you have to be intubated; that means airway tube is put in, the vomit should not obstruct the view.

It is best to take all your eye drops and oral medications with you to the surgery in case there is a question. Be sure to wear a comfortable outfit. This is for your own comfort during the 15 minute the procedure. It also enables the nursing staff to easily place EKG leads, blood pressure cuff, pulse oximeters and other monitoring equipment Avoid any clothes that are uncomfortable or itchy and especially ones with sharp hooks. Clothes with buttons may be fine. Jewelry, strong perfumes, hair bands or clips should be avoided. Centers may ask you to change into a surgical gown, while others ask you to put one over your clothes.

Preoperative Area

When you arrive at the reception area please have all your information ready. Usually a driver's license, a credit card if payments are due and your insurance card, if insurance is being used, should be presented if insurance is being used. Forms will need to be completed – the forms and consents for the surgery center are different than the ones you sign at the doctor's office. Soon a nurse will take you into the preoperative area and confirm your name, the reason you're there and the eye to be operated. Don't get offended if multiple people keep checking on the eye to be operated - this is a safety protocol. It's better to have multiple checks than an error. Therefore, one of the first things the preoperative nurse will do is after confirming the eye to be operated is put a sticker or a mark to identify the operative eye.

History will be taken, and allergies confirmed by the preoperative and/or operation room nurse. Any travel history or symptoms are important to be documented. EKG, pulse, blood pressure, pulse oximetry and other vitals will be documented.

Most surgery centers like to have an intravenous (IV) line started, so if needed, fluids can be pushed through. If an anesthetist is going to be helping during your procedure, you will again go through the history and physical with them. They will also ask questions to understand your levels of anesthesia desired. Either an oral medication like Versed or Xanax will be given to you or the anesthetist will push IV medications. The surge.on will come and meet you.

It's a common practice to mark the eye with a sticker or a pen to avoid instilling drops in the incorrect eye. The eye to be operated on will have anesthetic drops, as well as dilating drops instilled. Once the eye is dilated and the preoperative nurse, anesthetist and the surgeon are all satisfied you will be transferred to the operating room.

Into the Operating Room

Once inside the operating room the nurse will again confirm your identity and eye to be operated on. The staff will position you under the microscope and make sure you are comfortable.

Figure 6.1 Positioning under the microscope.

An oxygen a mask or line will be provided so that you get enough air under the upcoming drapes. Blood pressure monitors, pulse oximetry and EKG will be activated. These are monitored by the nurse or the anesthetist throughout the procedure to ensure your safety and comfort.

The next step is to clean your eyes with Betadine or Povidione Iodine, which is a strong antiseptic. Even though painkilling drops have been put in the eye, the betadine might sting a little. That indicates it is working. It is best to leave it on for a few minutes so its action can take place. Then it's washed off with a balance salt solution. If a person is allergic to Iodine, then Lid Scrubs without iodine may be used. The Betadine should be left on for at least three minutes and then wiped off, so that it does not interfere in the sticking of the tegaderms.

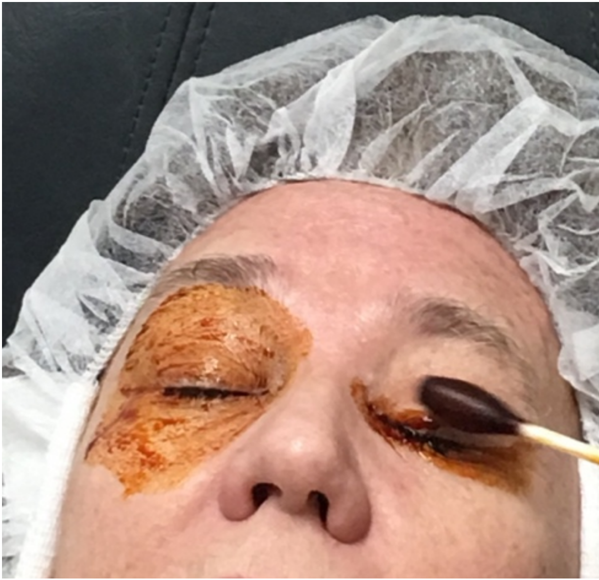


Figure 6.2 Betadine prep of the eye.

The eye is then draped to maintain a sterile surgical area. The drape sticks to the skin and forms a well-defined barrier, especially from the nose. Lashes are pulled away and covered with clear see-through tegaderm. An eye retainer, or a speculum, is then inserted to prevent the person from blinking and to expose the eye for surgery

Figure 6.3 Protecting the other eye.

A beautiful entry

A stable building is built on the strong foundation. A successful PIE surgery begins with creating a wound which will be stable and leakproof during the procedure and even be strong after the procedure. There are certain qualities of a well-crafted entry wound. It should avoid the blood vessels of the conjunctiva so that visualization is not hampered during the procedure. The instruments, especially the tip of the Phako hand piece, should be able to enter and exit without damaging the undersurface of the cornea. The foldable lens should be able to be inserted through the wound without tearing the edges, which would enlarge the wound. In such an instance, the self-sealing nature of the wound is compromised and would allow fluid, or the iris itself, to leak out. If the wound is too tight there can be heat generation and corneal burn. On the other hand, if the wound is too loose, besides fluids, the iris will start egressing from the wound. This same applies to the smaller side openings (one or two) used for the smaller instrument entry and exit.

Procedure has begun

Figure 6.4 Patients view of the microscope.

Intracameral anesthesia is instilled through the side wound in the form of preservative free lidocaine drops. Shugarcaine is a type of intracameral, where the lidocaine is mixed with dilating drops like epinephrine. The drops may sting but it numbs the inside of the eye. It also helps keep the pupil dilated.

As you know, any system which develops a leak, whether it be a tire, balloon or a ball will collapse. We have made a wound in the eye and the same thing is likely to happen. To prevent this, viscoelastic which is a jelly like substances is utilized. The viscoelastic might be a cohesive or a dispersive type. Their varying properties are utilized to benefit different steps of the surgery. For example, cohesive which is sticky, is used to protect the endothelium right from the beginning of the procedure. The dispersive maintains the space in the eye to prevent collapse as instruments move in and out of the eye. It is also used before the lens insertion.

The lens contents are held in a bag. We need a method to open the bag using a pointed instrument, like forceps. This opening of the capsule is termed capsulorhexis. It should be a continuous curvilinear pattern so as to avoid any tear which can spread to the back of the bag, leading to loss of contents into the vitreous cavity. The size of the opening can vary from 4.9 to 5.5 mm. A flat cannula is placed in the gap between the lens capsule and the lens fibers. A fluid wave of balanced salt solution is generated by a syringe and it cleans the lens contents from the capsule all through out.

Breaking the lens - a true labor of Hercules

The lens can be broken down using ultrasound, or laser energy. A computer controlled, ultrasound machine can modify the amount of energy liberated, the longitudinal length of excursion of the tip, the torsional twist, vacuum generated and the attraction of the lens fragments. With pulsating pressure waves the lens is emulsified into small pieces. These are then aspirated out from the gap between the phako handpiece and

its sleeve covering. The outgoing fluid also helps cool down the handpiece and the cornea.

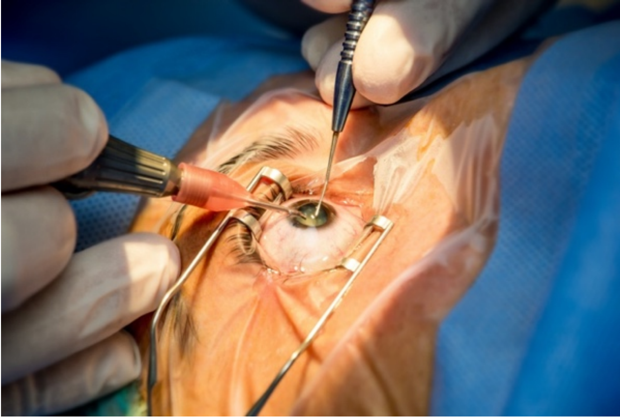


Figure 6.5 Dismantling the dysfunctional natural lens.

Once all the fragments have been removed, the lens capsule is polished with the rubber sleeved tip of the phako or by using specialized surgical instruments. Then our attention is turned to the presbyopic implant. The type of implant and its power is confirmed. The lens is inspected under the microscope to detect for any flaws.

Figure 6.6 Loading the presbyopic implant.

Once its perfection has been confirmed, it is loaded onto a special cartridge which helps to fold the implant, as well as push it through the small, main wound into the capsular bag. There it gently unfolds like the petals of a delicate flower.

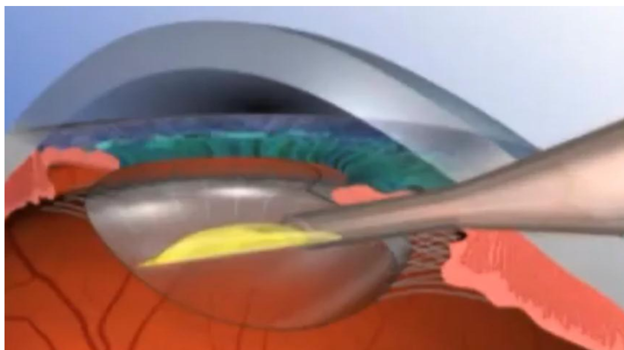


Figure 6.7 Inserting a folded lens through an opening less than a tenth of an inch.

The presbyopic implant is dialed into place, making sure the haptics are below the anterior capsule inside the capsular bag. This part is very important because if the one of the haptics is left over the anterior capsule it can lead to inflammation of the iris, as well as astigmatism. Toric implants will have to be aligned along with the pre-marked axis

The previously inserted viscoelastic is then aspirated out. If it's left behind it can clog the drainage system and cause a rising pressure. BSS may be used to hydrate the wounds to make them self-sealing. It's also always important to check the pendency of the wound and make sure that is no fluid coming out of the wound or going into the eye.

The most physiological place to implant the artificial lens is from the place that we are removing the contents of the natural lens. This means that we implant it in the capsular bag. There are rare cases where there is no adequate support of the posterior capsule and the integrity of the capsular bag is

violated. In these cases, a modified presbyopic implant may be placed over the anterior capsule.

Modulating the response of the eye

We have discussed before that the lens contents do not have any blood supplying them. If there's no blood vessels, there can be no inflammation. The inflammation arises from trauma to the vascular iris. The wound is a sort of trauma to the cornea. During the procedure, the cool fluid suppresses these inflammatory incidents. After the procedure this is modulated by the use of steroidal and non-steroidal drops.

After the surgery:

1. Do not rub the eye.
2. Avoid lifting heavy weights. Do not do strenuous exercise.
3. Avoid visiting hospitals or urgent care centers.
4. Instill drops as instructed.
5. Wash your hands before installing the drops and touching your eyes.
6. Do not wipe eyes. Wait for the tears to reach the cheeks before touching.
7. Wear sunglasses during the day.
8. A shield at bedtime prevents inadvertent rubbing in sleep.
9. If someone else is volunteering to put drops for you, ask them to wash their hands.
10. Do not put drops in the freezer, although it is okay to put them in the fridge.

In order to avoid touching the eye with the dropper, keep the dropper at least 4 inches away from the eye. If your eye constantly closes, it is OK if the drop falls over your eyelashes. To make it easier, pull your lower lid down and look up, this

will ensure that you will get the drop in. If you are still unable to get the drops into your eye, ask a nurse or ophthalmology tech to train you. If you are still not successful, an ointment may be prescribed, although drops are usually preferred since they can be measured, calculated, and tapering can be done. Also, ointment may often cause blurred vision.

Femtosecond lasers for cataract and PIE procedures

In a painless procedure lasting under two minutes the laser can make openings in the eye. It can also make relaxing incisions to correct astigmatism. The laser can now make a desired size opening of the lens bag. It is exciting to know that the laser can even break the lens into multiple pieces of desired shape and size. This makes it easier to remove the lens pieces with least amount of energy.

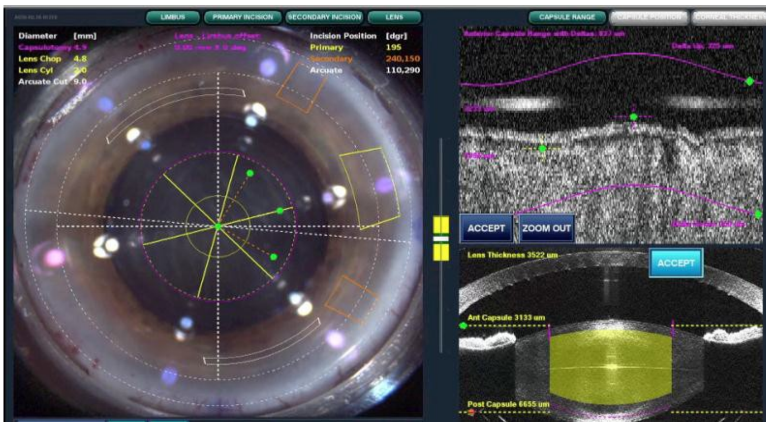


Figure 6.8 Overlay of the proposed size and depth of incisions in the cornea, lens capsule and lens.

The patient is wheeled into the laser suite after the eye has been dilated and anesthetized. A marking pen is used to make orientation marks. The patient is then positioned under the laser and an eye retainer is placed. The patient is asked to look at the blinking red light. Even if the vision is obstructed by

advanced cataracts, patients are still able to perceive the direction of this light. The docking mechanism is engaged, and the laser works to carry out the instructions programmed.

The opening in the lens bag or capsulorhexis is made first. This is followed by the patterned breakup of the lens. It can be cut into 2, 4 or 6 pieces. The center core may be delineated too. The depth of these lenticular cuts can also be controlled. Next, the accurate incisions for decreasing the astigmatism are made if needed. Either one or two incisions can be made. The length, the distance from the center and the depth of each astigmatic keratotomy incision can be coordinated independently.

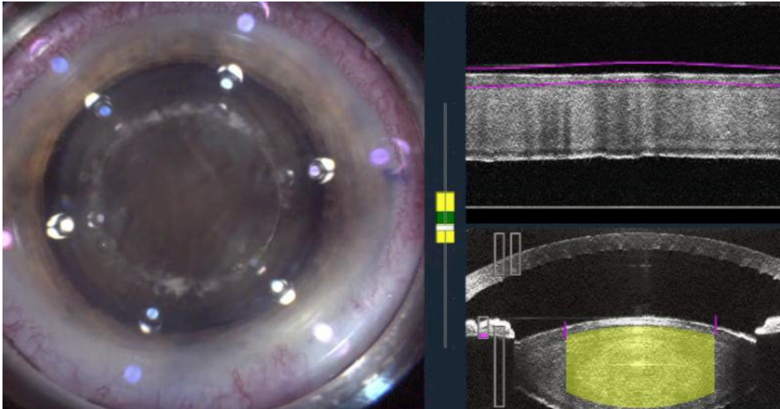


Figure 6.9 Capsular opening being performed. Right side displays the opening in pink lines.

Finally, either one or two side port openings and the main incision is constructed. At all times, a real time scanning image of the cornea and lens is displayed on the monitor. After the laser has done its beautiful work the patient is taken to the operating room to remove the lens fragments and begin the insertion of the new presbyopic implant.

There are various advantages of employing the laser. The surgeon can plan the exact openings and pattern of breakup lens pieces he or she desires.

If the support of the lens is weak, manipulating the capsule by hand can lead to further weakening of the support. Laser cataract surgery is safer as it does not stress the lens capsule or its support. The same holds true in traumatic cataract cases where trauma weakens the support. The laser is beneficial in making openings in eyes with thick capsules, like in children. In people with white or red cataracts the capsule needs to be stained manually to be visualized and still it may be difficult to get a good view of the capsule. The laser overcomes this as it employs imaging in real time and splitting vertically avoids any traction on the zonular support system.

The opening in the capsule can be controlled by the laser down to a tenth of a millimeter. The diameter can be made to vary over a great range, for example 4.2 to 6 mm. The laser consistently generates an opening of the desired diameter and shape which is difficult to reproduce manually. An experienced surgeon can be very good in making the openings, but sometimes the shape may be eccentric or oval. When implanting presbyopic implants, the more circular, central and precise the opening the better it is. For Panoptix, Symfony and Tecnis, the openings are usually a tad smaller than for Crystalens. With the Crystalens symmetrical opening is important. Otherwise, chances of torque in the lenses, known as Z Syndrome, may develop. If the bag were to tear, Crystalens cannot even be implanted.

The laser precision is equally useful in wound creation. Precise openings allow the entry and exit of instruments and insertion of the presbyopic implants without undue stress and consequently, inadvertent enlarging of the wound. This prevents leakage at the end of the case and faster healing.

Let us look at the painless splitting of the lens by laser. It is important to realize this is done without any stress on the capsular bag or the zonular support system. The depth of the incisions can be controlled in real time. The energy is delivered from the bottom towards the top. This allows gas generated by the conversion of the lens material into plasma to escape, as

well as allowing the subsequent beam to work without interference from the gas bubbles. In dense cataracts the bottom is difficult to perceive so the capsule can be accidentally ruptured. Real time display with the ability to be precise and avoid the bottom of the bag is a boon when using the laser for cataract or PIE procedure. Breaking apart these hard lenses is time consuming with traditional sound wave technology. Lasers decrease the time and energy required to accomplish this feat. Further progress in laser technology will be even more helpful.

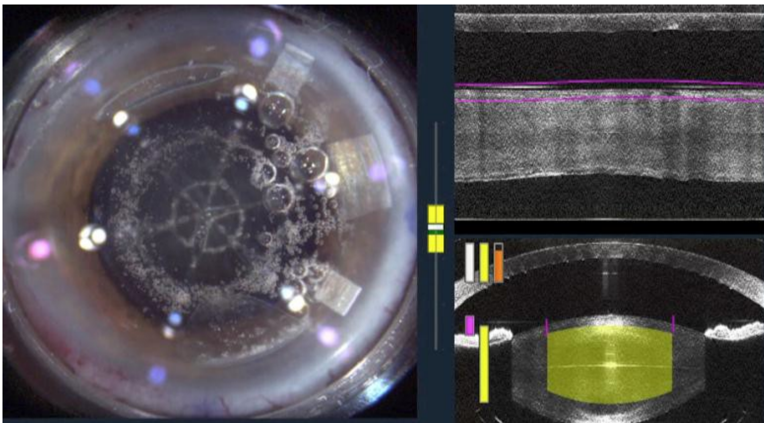


Figure 6.10 Air bubbles can be seen. The depth and width of the lens cuts is displayed in yellow.

The disadvantages of employing the laser are increased cost and time. The laser also leads to use of more energy. It heats up the lens fibers, making them stick to the capsule. This make their removal difficult. If pupil is smaller than 5mm, then a capsule opening of an adequate size is not possible. The wounds created by the laser tend to be more central and not as consistent with surgical blades. Studies from various parts of the world have documented that experienced, skilled hands are even better than laser for routine PIE procedure.

Chapter 7 Choosing the Best Presbyopic Implant

The heart of the PIE procedure are the Presbyopic Implants (PI), which are synthetic biocompatible inserts. Their function is to allow seeing far and near in each eye. We will understand their qualities in this chapter. We will divide the chapter into two parts. The first part gives an overview of the different types of presbyopic implants. In the second part we will delve into technical details and compare various implants. Though we encourage you to read the entire chapter, for most non-technical readers the first part may suffice.

Types of Presbyopic Implants

There are four classes of FDA approved presbyopic implants. They are Accommodative, Extended Depth of Field (EDOF), Trifocal and Multifocal.

Accommodative Presbyopic Implants

This class of presbyopic implants were the first to be approved by the FDA in 2005. They heralded the advent of PIE. Crystalens was the first out of the stable. It had various modifications until it evolved into Crystalens HD and now we have Crystalens AO and Trulign. They are made of silicone.

Crystalens AO has aspheric optics whereas Trulign has aspheric optics and built in astigmatism correction. They work by assuming a curved shape in the eye, increasing the range of focus. This shape and the unique design of the lens may also allow it to move forward and backward, mimicking the natural lens. This lens has proved very useful in patients who have had previous eye surgery like Lasik vision correction, Radial Keratotomy and other corneal procedures.

Extended Depth of Field (EDOF) Presbyopic Implants

These are in a class of their own. They resemble multifocal presbyopic implants in appearance, but function on a different optic principle. They increase the natural depth of field which provides a continuous field of vision, though the range is not as extreme as in multifocal. Symfony and Symfony Toric are the two contenders here. As you may have guessed from the name, Symfony Toric can also correct astigmatism. Hence, they find great use in eyes with astigmatism. EDOF are used as an alternative to Crystalens in previously operated eyes. They can also be used when trying to replicate a person's monovision and in amblyopic eyes.

Multifocal Presbyopic Implants

They are truly bifocal but were labelled multifocal to distinguish them from bifocal glasses and contact lenses. Their mechanism of action is totally different than bifocal glasses. In bifocal glasses the top segment is for distance and lower for near. These are refractive lenses. This method was tried in implants in the previous century but was not successful.

Multifocal presbyopic implants can be either refractive or diffractive in construction. The refractive multifocals, like Array, have been discontinued. The diffractive multifocal implants have apodiazations (concentric rings of different heights) which split incoming light. They have a focal length

for distance and one for near with an overlap for middle. One does not have to tilt the head to see near. They are best for near and distance vision. Restor and Tecnis are the two lenses in this class.

Trifocal Presbyopic Implants

Currently we have only Panoptix and astigmatism correcting Panoptix Toric. These presbyopic implants have apodiazations or rings in their center similar to Restor multifocal. Optical engineers can modulate the height of rings and distance between rings to design varying focal length for each zone. The unique heights of the rings of this lens allow the incoming light to be split into three foci. One for distance, second for intermediate and third for near. This lens is great for people who devote most of their time to computers and intermediate vision like financial analysts and computer programmers.

A surgeon who is a PIE expert needs to be proficient in all different classes and types of presbyopic implants. Success is truly achieved when the patient's goals and desires are understood and the best presbyopic implants for those needs are implanted. Personality, work, hobbies and sports all influence the decision for the final implant chosen. This may even sometimes involve implanting a different class of presbyopic implant in each eye. This is truer when we deal with unilateral eye disease, like epiretinal membrane or amblyopia.

We now have an overview of different varieties of available presbyopic implants. We have put this information in a simplified chart in Figure 7.1

We will now proceed to look at them more minutely.

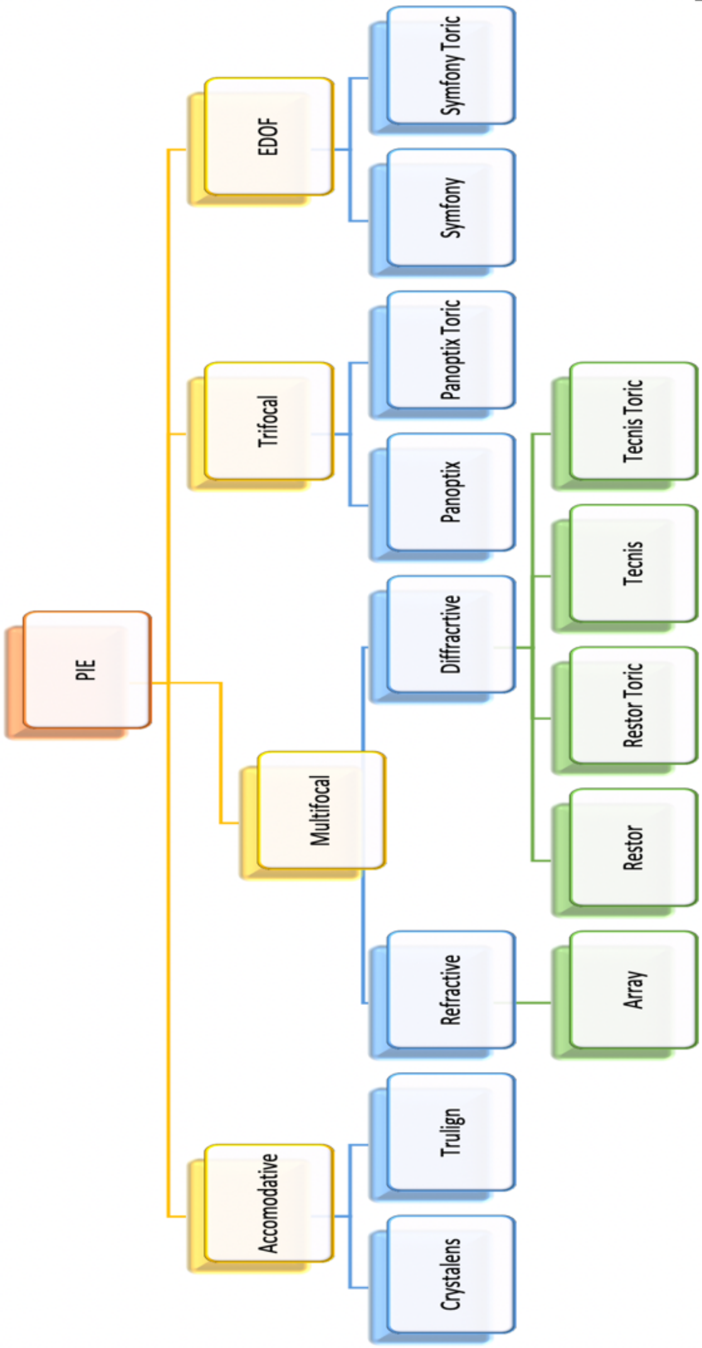
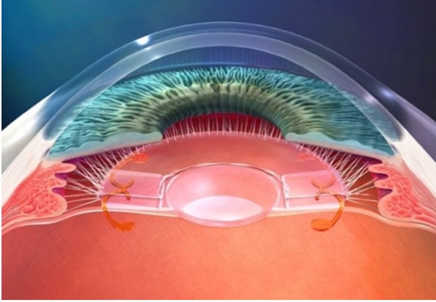


Figure 7.1 Types of FDA approved Presbyopic Implants.

Crystalens AO



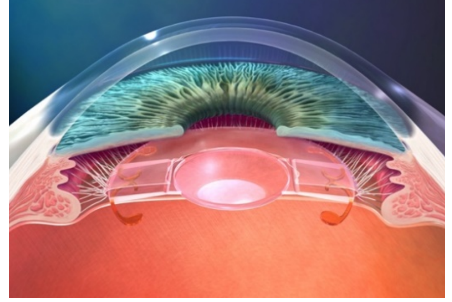


Figure 7.2 Normal position Figure 7.3 Bowed anteriorly

Crystalens is an accommodating posterior chamber intraocular lens made of silicone. It is a modified foldable plate haptic lens with hinges across the plates adjacent to the optic. Two flexible colored polyamide loops are attached to the distal extremity of the plates. It has a 5 mm optic zone, excellent contrast sensitivity, and minimized issues with halos and glare across a range of vision. The lens moves mechanically to yield 1.0 diopter of monocular accommodation. Safety profile is good, as hinge of one billion cycles movement at ten cycles per second has been documented without degradation. Approximately 95% of visible light is transmitted. It transmits all light rays independent of pupil size. This aberration free aspheric lens allows great contrast sensitivity. Patients with astigmatism can tolerate this lens better. It also allows some torque without affecting vision. It should not be placed in the ciliary sulcus and should not be implanted if the bag is not intact or there is any zonular rupture.

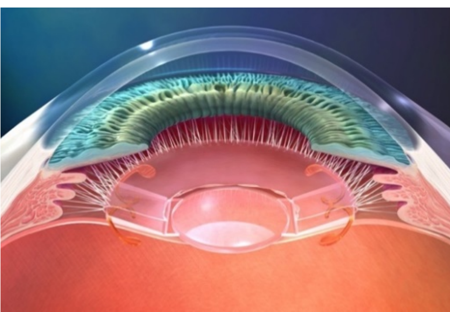
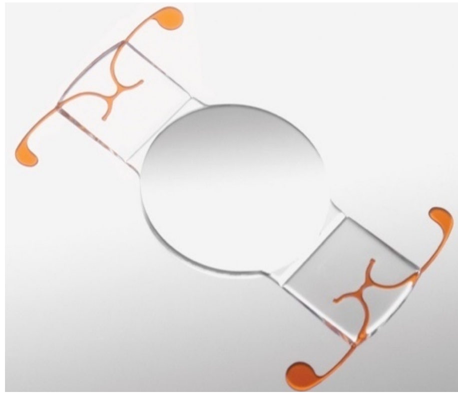


Figure 7.4 Bowed posteriorly



Trulign

Trulign Toric lens Model BL1UT has an aspheric front (anterior) surface with alignment marks and an aspheric toric back (posterior) surface.

Figure 7.5 Trulign toric

Restor

This acrylic IOL has a central optic and two arms, or haptics, for stabilization. It can be a one piece that is implanted into a bag or a three piece, which is implanted in the bag or ciliary sulcus. The anterior apodised refractive optic that forms the diffractive zone is found within the central 3.6mm optic zone of the lens.

It has nine concentric steps of decreasing heights allocating energy based on lighting conditions and activities. This lens does not require any ciliary muscle movement to function. The +3.0 diopter on the lens yields a power on the cornea

Figure 7.6 Restor Multifocal

equal to wearing +2.5 readers, which allows for near vision. A refractive region that directs light to distal focal point surrounds the diffractive region. The asphencity of the optic compensates for the corneal spherical aberrations.

The chromophore filters blue light but clinically may impact color vision and the quality of distance vision. People with this lens require more light in dark conditions. There is a clear center zone for intermediate vision and peripheral clear zone for distance.

Restor Activefocus

This lens is a modification of Restor. The add power for near is only +2.5 D. The central clear zone is focused for distance instead of intermediate, so the patient gains intermediate vision at the expense of near vision.

Tecnis Multifocal

Tecnis is made of UV blocking hydrophobic acrylic. It is biconvex like a magnifying glass with diffractive rings on the posterior surface. It is manufactured in a proprietary diamond cryolathing process. It means the material and the shape are created in the same step. Being clear, it transmits more light, but increased number of rings may cause glare. The near addition can be a +4 D which is optimized for those favoring near-vision activities like reading and knitting. It delivers tailored clarity at a theoretical

Figure 7.7 Tecnis Multifocal

reading distance of 33 cm. Plus 3.25 D is better for longer reading distances, such as reading newspapers. It delivers tailored clarity at a theoretical reading distance of 42 cm. A

+2.75 D is best for intermediate vision activities like computers. It delivers tailored clarity at a theoretical reading distance of 50 cm.

Panoptix Trifocal

This is a single piece biconvex lens with a central optic made of a high refractive index hydrophobic acrylic material capable of being folded without damage prior to insertion through a smaller wound. The central 6.0 mm optic has two haptics on either end, giving an overall lens diameter of 13 mm. In the central 4.5 mm of the optic there is a diffractive portion which divides the light to create +2.17 D intermediate (+1.65 D at cornea) and +3.25 D near (+2.35 D at cornea) add power. The front surface of the lens has negative spherical aberration to counteract the positive ones generated from the cornea.

Figure 7.8 Panoptix trifocal

Panoptix is actually a quadrifocal lens which has been modified to behave like a trifocal lens to improve distance vision. In simpler terms, it means it provides a more continuous field of vision.

It comes in two colors, yellow and white. The yellow color is blue light blocking and theoretically protects the macula. In real life, it affects the clarity of vision, especially in dim light. Hence, the clear Panotix model is preferred.

Toric Monofocal

Figure 7.9 Toric monofocal and simple monofocal implant

"Mirror, mirror on the wall, which lens is the best of all?"

No one lens is the best. Otherwise others would not exist. The art is to match what lens is compatible with a patient's lifestyle and work.

Tecnis overcomes the hindrance of needing extra light, so it is desirable in patients working in lowlight conditions, like telephone maintenance people working at night. The drawback is that it is accompanied by glare and haloes while driving. Vision for computers is not perfect with this implant.

Panoptix is best for middle distance like computers.

Crystalens has the least glare and the best vision for computers.

The surgeon brings the above knowledge to the table, where you bring your lifestyle requirements. Together an optimum presbyopic implant can be chosen.

	Advantages	**Disadvantages**
Crystalens	Clear vision for 2.5/3 zones. Works in post RK, post Lasik and early macular degeneration	May need glasses occasionally. Can develop Z syndrome.
Restor	Full range of vision (3/3)	Extra light for reading. Waxy distance.
Tecnis	Full range (3/3)	Initial glare & adjustment period for computers
Symfony	Stable lens. Clear vision for 2.5/3 zone.	Cobweb against lights
Symfony Toric	Can correct astigmatism	Susceptible to rotation which can change astigmatism
Panoptix	Best intermediate with full range	Material can develop glistening's
Panoptix Toric	Can correct astigmatism	Rotation less likely but can still affect result

Figure 7.10 Advantages and disadvantages of presbyopic implants.

	Restor	**Tecnis**	**Crystalens**	**Symfony**	**Panoptix**
Far	Yes	Yes	Yes	Yes	Yes
Middle	Yes	Some issues	Yes	Yes	Best
Near	Yes	Yes	Read at arm's length	Variable	Yes
Glare	Some	Most	Least	Cobwebs	Some
Extra light at night	Yes	No	No	No	No
Lens movement	No	No	Yes	Possible	No
Tolerate astigmatism	No	No	Yes	Yes	No
Tolerate Dry Eye	No	Better	Yes	Yes	No

Figure 7.11 Comparing the presbyopic implants.

Chapter 8 Success Stories

If I have heard this question once, I have heard it a thousand times. "I know you have performed PIE successfully on numerous patients, but will it work for me?" This line of reasoning stems from fear. People are afraid of their eyes being touched, least of all operated upon. Many feel they are unique with respect to their visual needs. Even though no two patients are alike, our vast experience of interacting with thousands of patients helps us make appropriate choices with respect to timing and candidacy for PIE, choosing implants and predicting outcomes based on personality and lifestyle. Let us look at some people who have chosen PIE before you. I believe you will find your story in one of these anecdotes.

Physicians/Medical Personnel

Physicians - People look up to physicians to see if they are adopting the latest technology. You would be happy to know that physicians have embraced and been happy with PIE. The advent of electronic medical records has forced doctors to use near vision and while talking to patients at intermediate distance. In these situations, juggling glasses interferes in patient interaction as well as increasing the chances of spreading infection.

Physicians make tough patients, as they are not used to following directions. They are often exposed to drug resistant bugs in hospitals or nursing home settings. Physicians are asked to take a three day leave from seeing patients following the PIE procedure, however they can still do administrative work.
Within the physician community there are different needs depending on the specialization. An urgent care doctor needs all distances during his course of work. A radiologist spends a lot of time doing near work, as in reading MRI and CT scans. A surgeon must be cognizant of the effect of the lens on visualization through the microscope. There are different personality types within this huge group which also determines the final choice of the type of presbyopic implant. Refractive surgeons in general tend to be more athletic and into extreme sports.

Figure 8.1 Yes, physicians enjoy PIE too!

A nurse needs to read instructions on medicines -
Nurses have a need for reading small drug labels. Their shifts vary between days and nights in well lighted hospitals, so PIE needs to deliver good vision during the day and at night. Distance and middle have to be good, but near has to be exceptional.

32-year-old nurse and half marathon runner -
"At 32 I needed cataract surgery on my right eye. Now I feel old and handicapped as I need readers. Can you make me young again?"

Figure 8.2 Water sports are fun with PIE – no fear of losing glasses.

Business Professionals

The Brilliant CEO - "I had just turned 52 and was skiing in Lake Tahoe. I got a novel idea for my business. It was a game changer. I needed to write it out immediately. I got off the slopes and grabbed a paper and pen to draw out the schema. Oh darn, I had forgotten my readers and now could not put to paper my idea. Oh, I longed for my youth."

The Financial Analyst - "I love numbers. I look at 5 monitors as I track and day trade on wall street. Trades nowadays are about speed of execution. Some monitors are in focus with my glasses, while others require a different set."

The International Consultant - "I am a consultant to companies around the world. During my frequent travels I would end up losing my progressive glasses, affecting my work. Progressives, unlike readers, cannot just be bought off the shelf."

Sports Enthusiasts

55-year-old golfer and executive - "Golf is an extremely popular sport. It tests the mental patience and eye hand mind coordination. The vision plays a very important part even more than the clubs. For example, you could give the worst club you have played with to a professional and they could still end the round. On the other hand, if you blindfolded them, it would not be possible. A nice long drive, but where did the ball go? Am I under par? I wish I could see the ball clearly as I tee off. Even struggling to write the score without glasses diminishes the joy of playing golf."

Figure 8.3 Golf scores improve after PIE.

52-year-old tennis player and businessperson - Let's take the example of golf up a notch to tennis. "Tennis requires

speed, quick reflexes, depth perception and force to hit the ball. Sometimes I play under artificial lights. Quick responses to the incoming ball demand good central and peripheral vision. Glasses can interfere especially when I'm serving the ball".

47 yr. old kick boxer and salesperson - Now we are not only talking good vision to hit the ball but to also prevent injury to self. Glasses and contacts can interfere in effective performance.

Iron man - "Whoever thought I would run, swim and bike for such distances past 50 years of age? A lot of sweat clouds my contacts when I am partaking in triathlons. I developed an infection from swimming with the contacts in the pool."

My boat goes fast and so do my contacts - "The thrill of speedboat racing is great. The wind pounding against my face and hair is fun, except it blows away my contact lenses away."

A lost hiker - "A map is a hiker's best friend in the backcountry where there is no cell phone signal, provided you can read it. I forgot my reading glasses and had to be rescued. I felt so embarrassed."

Service Industry

Housekeeper - "I have been working for thirty years as a maid and my work speaks for itself. Yet the last few years, I have been getting complaints that I am missing spots. I tried glasses. It's difficult to work with them. I have to take them off and on. It was a family decision to invest in PIE which could retain my livelihood. I am happy that now my employers are also enjoying the fruits of my investment."

63-year-old tailor and avid reader - "As a tailor, I need good depth perception to thread the needle and peripheral vision

while pulling the thread. Stitching on the sewing machine requires middle and near vision back and forth."

Educators - We know teachers are supposed to have eyes in their back of their heads. They have to manage a class full of high energy kids. They have to switch from interacting with the children to writing on the board to reading submitted work.

Restaurant owner – Frustrated from recently performed Lasik. When a 52 years old nearsighted restaurant owner underwent Lasik eye surgery, it affected his work and happiness. His world inside the eatery, where he spent around ten hours a day, was dependent on middle and near vision. He traded this for far vision when he underwent Lasik eye surgery.

Lab Work – "My work also involves seeing through a microscope. I assemble electronic microchips used in the defense industry. I look at the instructions, pick up the microchips, and then I look under the high-powered microscope to install the necessary components of the chip. I have to make repetitive movements of my neck and shoulders to see at these three different distances. I am in physical rehab because of this."

Massage therapist - "I am a holistic massage therapist. I do deep breathing and chant while doing Lomi Lomi massage. I need to see exact pressure points. A little off can be dangerous. Every time I try to wear close up glasses, the glasses fog up from the oil vapors and it irritates my eyes."

75-year-old retired grandma – "Despite my glasses I was not able to see my grandkids clearly. Needle points and crafts are no fun with glasses slipping down the nose. When I pricked myself due to blurred vision, I knew it was time to find a better alternative. Now I can watch my grandkids, enjoy TV and do my crafts easily."

Figure 8.4 Swimming within a week of PIE.

Forgetful Grandpa - "Alzheimer's is a dreadful word. I don't know if I have it yet or I am just forgetful. I waste a lot of time looking for my readers even though I bought three pairs. One time it was so embarrassing. After three hours of getting tense looking for them, I opened the door for the mailman. He wanted me to sign a registered letter. I apologized that I could not as I did not have my glasses. The mailman laughed as he pointed to the glasses nested on my head."

First Responders

Fire captain - "As a fire captain in Malibu, I can still remember the terrifying moment that I had to rush to the fire at 4 am. Of all the thoughts that were rushing through my brain, my glasses were not one of them. Realizing that I no longer had to worry about grabbing my glasses because I had recently had the PIE procedure done made me feel more secure to do my job."

Figure 8.5 Firefighting after PIE in Malibu.

FBI – "As an FBI operative I end up in fistfights with a lot of lowlifes. Lately, I am getting hit a lot. I requested my self-defense instructor help me to analyze the problem. He pointed out to me that every time I caught the opponent, I moved my head back allowing space and time for a retaliation. It dawned on me that I was not able to see close up, so I was moving back to get a better look.

Undercover agents - "As a 47-year-old youthful looking guy and undercover agent, I was excited my next mission was to be a 36-year-old in Mexico to monitor the local drug mafia. As I took out my reading glasses to pour over the written directive, my supervisor exclaimed "A 36-year-old does not wear readers I got PIE and now am somewhere I can't disclose!"

All the single ladies

Sharon is a star salesperson for the local radio station. She is single, in her late forties and active on the dating scene. Of late she is avoiding going on dates. Her reluctance is best summed in her words which are imprinted on my mind - "My date takes

me to the restaurant thinking I am a 30-year-old. We have a good time until the menu comes. Then outcome my readers. The polite gentleman's face reflects my sudden aging"

Pilots

54-year-old stunt pilot - "As a pilot, I enjoy the freedom I feel while in the air. Since I had PIE done, it's so much easier to check gauges and read maps. Best decision I've ever made!"

Figure 8.6 Pilots feel safer after PIE.

Where did that car come from? - "The glasses block the periphery of my vision. My blind spot is bigger. Driving seems so scary to me, so I just avoid going out."

Where did the table go? - "I was placing my hand for support. I missed the table fell and broke my hip. Did the table move? Or is my vision faltering?"

Glasses and the hunchback - "At 92, driving gives me the same thrills I got at 29. Now I am hunched over. The glasses allow me to look down but when I drive, I am looking above the glasses. I want to retain my independence."

Stuck in a wheelchair - "5 years ago I lost the use of my legs as a complication of spinal fusion surgery. As I am confined to a wheelchair, I switched from a security supervision job to day trading. Occasionally my glasses fall off my wheelchair and I can't find them and then end up losing money. I want to invest in PIE."

Never too late to graduate - "I left college in my second year for family reasons. Now I am 54, I have saved some money and want to finish my education. I feel awful pulling out my trifocals in front of my new young friends."

Performing Arts

Tango not trip - "We read each other's facial and eye expressions when doing a tango with my partner. Of late, my inability to see clearly and fast at near has led to some embarrassing situations.

Twirl not fall: - "Poor vision due to astigmatism made be dizzy, sometimes leading to falls"

Forgetting the words at karaoke - "I love karaoke. I fidget so much with my glasses to read the words that my singing falters."

In front of the camera - "As an actor I need to read the cue cards without glasses. Squinting to see sans glasses affects the warranted display of emotion."

And behind the camera - "The new generation super HD cameras are shot in a red light. It was difficult for me to adjust the focus to perfection with glasses."

Figure 8.7 Unleash freedom with PIE.

Helping the detective solve the case - "You have probably seen the detective shows I have written for TV. I get inspirations at odd times. Sometimes I have woken up from dream with a perfect episode playing in my head. Inability to find glasses at that moment had prevented the world from seeing these plots. Now they enjoy and reward me with an Emmy.'

Back to square one - "A few decades ago I had radial keratotomy because I hated glasses. The continuous effect from RK has pushed me to needing glasses at all distances. I did not like this and feel my brief clear interaction with the world was momentary. Pie is eternal."

Lasik did not last - "In my late thirties, I had Lasik eye surgery to eliminate my need for glasses. I did not realize I will need another form of glasses in my fifties. I wanted permanent liberation which I got with PIE."

Sikh with a Turban - "A turban is worn the entire day and cannot be taken off like a cap. The glasses do not go over the turban, so I push them under instead. I am constantly worried the turban may fall off. PIE resolved my problem"

The results are in and the winner is……

Who cleaned the pool? "On my visits to my client's pools after my PIE procedure I was so embarrassed. There was so much algae I had missed before."

The crime rate is down - "As a cop on night duty I can see criminals in the night before they can see me. Needless to say, the crime rate is down in my city."

A hole in one - "Three weeks after my procedure, I took part in a celebrity charity golf event. On the seventh hole I achieved a hole in one. I've never made a hole in one before and I felt so thrilled! I won $10,000 on that shot, not to mention bragging rights."

Bingo - "I can focus on the bingo cards since I do not have to bother about putting my glasses on and off. My winnings take care of my monthly payments towards my PIE."

4 eyes to 2 - "I am nostalgic about my college days, except that I was called Mr. 4 eyes by my friends. The first thing after my PIE procedure was to call them and tell them I am Mr. 2 eyes and they are Mr. 4 eyes, as they still use readers."

The world is brighter - "The colors are so much more vivid. My paintings look livelier."

The world is wider - "While driving here I had to stop the car. I was seeing a much wider field of view and my brain found it difficult to process the extra information. It was like when we switched from 35 to 70 mm movies. "

No more contacts – "Contacts don't come between the camera and my baby blue eyes. My director says my eyes shine

and are more camera friendly. It dramatically improves my emotive expressions."

Dear reader, yes, you could surely add to these wonderful stories!

Chapter 9 PIE After Previous Lasik, RK & Special Situations

PIE can be a good option, even if you have had previous eye surgery. Special exams are required to calculate the exact shape of the cornea after Lasik, RK, or CK. These surgeries change the relative distance between the front and back part of the cornea. Let us first refresh our knowledge about these procedures.

PRK – Photorefractive Keratotomy
PARK – Photoastigmatic Refractive Keratotomy
DALK – Deep Anterior Lamellar Keratotomy
LASEK – Laser Assisted Sub-Epitheial Keratectomy
LASIK – Laser Intrastromal Keratomileusis
CK – Conductive Keratoplasty
AK – Anterior Keratotomy
ICL – Implantable Collimar Lens
KC – Keratoconus
CXL – Corneal Crosslinking
Intacs
Glaucoma
Cataract
Intracorneal implants

How do these surgeries affect Cataract or PIE procedure?

After any of these surgeries, determining the state of the cornea and the effective optical zone is very important. These factors would be of paramount importance in determining the choice of the lens. Measurements listed before, like color corneal topography and refractions, are to be diligently performed.

The lens calculations can be especially challenging in these previously operated eyes. The corneal power gets altered, as well as the relation between the front part and back part of the cornea. The instruments like corneal keratometer are unable to account for these alterations. It is imperative to find the true power of the central part of the cornea to generate the correct power of the presbyopic implant to be used. There are some mathematical formulae, which when used with past experiences, can give great results.

A new device or range may be used during the surgery to help come up with the exact power. After the cataract is removed, but before the lens is inserted, this device is fitted on to the microscope. It works like an autorefractor yielding the power and astigmatism of the aphakic eye. Based on this information it can calculate the lens to be inserted.

A small optical zone may hinder the effective functioning of the multifocal implant, therefore an accommodative implant, such Crystalens, would be the preference. Crystalens would also be the choice if there is irregular astigmatism or RK with more than 4 incisions or severe dry eyes. Restor and Tecnis may be implanted if astigmatism or dryness can be treated or the optical zone can be enlarged.

The preexisting corneal flap from Lasik, cuts from RK, scars from CK or other corneal surgeries may affect the sizes and locations of the openings. Water entering the potential spaces can hinder visualization. Wounds may leak and may need a stitch. The healing may be slower; however, the outcomes make the patient very happy.

Radial Keratotomy (RK)

Vertical deep incisions are made into the cornea in a spoke-like fashion. Each incision causes the cornea to bulge around the incision while at the same time flattening the center of the cornea. Therefore, the power of the cornea decreases, and myopia or nearsightedness can be treated.

There are some unique problems associated with Radial Keratotomy. The incisions decrease the tensile strength of the cornea. Its shape, and therefore the power, become more responsive to the pressure within the eye. There is diurnal fluctuation of the pressure of the eye in normal people. It is usually highest in early morning and decreases during the rest of the day and night. As a consequence, the cornea which has been weakened by RK is more curved in the morning and less so in the evening. Therefore, the vision for reading may be better in the morning but the distance vision improves during the day. The cornea bellows like the sail of a boat. The PERK, or Prospective Evaluation of Radial Keratotomy, study had found that the cornea continues to become weaker and flatter over the years after RK. The eye will continue to move from nearsightedness to farsightedness. The amount of diurnal fluctuation and progression towards hyperopia is proportional to the number of incisions made on the cornea and the thickness of cornea. Consequently, a cornea which has suffered 16 incisions would be worse off than that which underwent only 4 incisions. Believe it or not, some overenthusiastic surgeons made 32 or more incisions on cornea. These corneas end up becoming weak and irregular in shape.

To be successful with PIE in such patients we have to stabilize the fluctuations in vision and the drift towards progressive hyperopia. This can simply be achieved by aiming to make the eye a little nearsighted and let it progressively improve with the passage of time. One eye may be made more nearsighted so as to achieve immediate functionality. The eye

which is made more towards zero can be made more spherical in future by laser.

There are many techniques available to decrease the fluctuations of post RK cornea. The incisions can be freshened and sutured. The gaps may also be filled with biological glue to increase the adhesion. A newer technique of crosslinking uses riboflavin activated by UV radiation to stiffen the cornea.

One or a combination of these techniques may be utilized to achieve the desired result. These procedures can be used in conjugation with PIE.

What is Mini-RK?

Mini RK is used to treat eyes with minimal myopia with vertical incisions avoiding the central zone of the eye. Today it is used to treat around one diopter of nearsightedness in patients who are not candidates for Lasik.

Astigmatism Keratotomy (AK)

Astigmatic Keratectomy is a transverse incision made in the mid- periphery of the cornea to treat astigmatism. The incision is made in the steeper axis to relax the fibers and change the shape from oval to spherical.

Limbal Relaxing Incisions (LRI)

Limbal Relaxing Incisions, when AK is performed along the cornea margin, are longer incision and more stable; this is less effective but there are fewer side effects.

Conductive Keratoplasy (CK)

A spherical probe introduces radio frequencies into the peripheral cornea causing focal collagen shrinkage. It is like tightening a belt. It causes the central cornea to steepen and

increase power. It can therefore treat farsightedness or presbyopia. Regression is higher and, in a year, or two the effect wears off.

Lasik Eye Surgery

A corneal flap is fashioned by an automated micro- keratome or laser. Precise photoablation by an excimer laser changes the shape and curvature of the cornea.

Photorefractive Keratotomy (PRK)/Lasek/Superlasik-Epilasik

The cornea is not invaded to make a flap. The top layer of epithelium is first removed by one of these methods: mechanically (PRK), alcohol (Lasek), or epikeratome (Superlasik-Epilasik). Photoablation is then performed.

PIE after Implantable Collamer Lens (ICL)

PIE is considered when the ICL is causing lens changes affecting vision. PIE is an option if ICL no longer allows near vision to be effective. ICL do not interfere in the measurements of axial length or the curvature of cornea. Hence, the IOL calculations are not affected.

When performing the PIE procedure, attention must be paid to ICL. The haptics are moved from under the iris to over the iris. The ICL is grasped with special serrated forceps and removed through the same incision used to insert the presbyopic implant. PIE procedure can than proceed.

Cornea Transplant

Cornea transplant is the removal of the diseased cornea of a patient and replacing it with a new cornea from a generous deceased person. There are a wide number of individuals that

suffer from a diseased or cloudy cornea. When this particular area of the eye begins to have trouble, light cannot pass through this area successfully which results in blurry vision or even blindness.

Indications for Cornea Transplant

Any dense scarring or opacity in the cornea. This affects the vision and cannot be improved with glasses or contact lenses.

We can classify the causes:
Congenital - Opacity like Peters anomaly
Degenerative - Keratoconus, Macular Cornea Degeneration, ***Fuchs dystrophy***
Trauma - Central corneal injury
Tumors - Keloid
Pterygium which invades central cornea
Post-surgical - Pseudophakic Bullous Keratopathy

Corneal disease can also be classified based on anatomical location. It could involve the following areas: epithelium, top half of stoma, deep stroma, endothelium or the entire cornea. This arrangement allows in surgical decision making.

Types of Cornea Transplant

Penetrating Keratoplasty (PK): A full thickness cornea graft. This is the conventional full thickness exchange of the cornea. It requires suturing. There can be induction of astigmatism which can be moderate or high. Traditionally, manual keratomes have been used. Many cornea surgeons are now using femtosecond lasers to get better shape alignments. This helps in increasing wound apposition, strength and at the same time decreasing induced astigmatism.

Lamellar Graft (LK): Partial corneal thickness exchange for disease limited to the anterior part of the cornea. It can also induce astigmatism.

Deep Anterior Lamellar Graft (DALK): Nearly full thickness corneal graft sparing innermost layers.

Descemet's Stripping Endothelial Keratoplasty (DSEK): Inner most endothelial layer with some stroma.

Descemet Membrane Endothelial Keratoplasty (DMEK): Only the endothelium with minimal stroma is replaced. This is the thinnest graft and can be folded and inserted through a small cataract wound.

Descemetorhexis Without Endothelial Keratoplasty (DWEK): The central 4 mm of Descemet's membrane is stripped without any replacement.

Benefits of Corneal Transplantation

One of the major benefits of corneal transplantation is the fact that the sight is restored. A thorough eye exam with appropriate diagnostic tests is required. The donor tissue has to pass stringent tests to document it is healthy and disease free. After the surgery some time is required for healing and vision gradually continues to improve. It's important to note that with any type of procedure available there can be complications. Unique to cornea transplantation is the risk of short term and long-term rejection.

PIE in presence of Cornea Transplant

When we have to consider PIE in these situations, we need to know the type of transplantation. It's a good idea to endothelial cell count, pachymetry, topography and refraction.

Sometimes hard contact lenses may be used to confirm irregular refraction.

Full thickness corneal transplants have the highest chance of rejection and are usually accompanied by high astigmatism. In such instances, PIE may not be good choice. If there is minimal astigmatism and the presence of cataracts, then it could be considered.

In partial thickness transplant, like LK and DALK, PIE may be a good option, provided there is no irregular refraction. Crystalens or Symfony may be preferred.

In DSEK, DMEK and DWEK, PIE may a good option. Any of the implants may be used.

What is Keratoconus Eye Disorder?

Keratoconus eye disorder is also called KC. Keratoconus is a weakening of the cornea. The collagen fibers are short and stubby and not able to withstand the outward pressure from within the eye. The cornea thins and then bulges forward, increasing the curvature and power. The eye then becomes nearsighted. The steepened cornea is acted upon by gravitational forces, pulling the cone down. Therefore, the curvature of the cornea in vertical and horizonal meridian becomes different inducing severe astigmatism.

This is a degenerative disease affecting both eyes. It leads to progressive thinning and bulging of the cornea that results in blurred vision from an irregular astigmatism and visual loss in early adulthood. It has been the most common cause of corneal transplants in the developed world. The progression may be different in the two eyes. At presentation one eye may be more involved with keratoconus eye disorder than the other. This can lead to a mistaken impression that the disease is present in only one eye.

The cornea is made up of strands of protein called collagen fibrils. The cornea has three main functions. The first is to keep itself clear. It needs to allow the light to pass through without

distortion. Secondly, the cornea needs to converge the light so as to bring it to focus on the macula. In fact, the convergence power is stronger than of the natural lens of the eye. It also needs to withstand the pressure of the fluidic internal contents of the eye. Finally, it acts as a protective barrier preventing physical, microbiological, chemical and radiation hazards from reaching deeper parts of the eye. Gene abnormalities lead to abnormal expression of collagen proteins in the cornea and this makes the collagen less attached to each other. It's like having slippery noodles. When one tries to pile them, they slide away. This abnormal cornea is not able to withstand the outward force exerted by the internal liquids of the eye.

Symptoms of Keratoconus

Rubbing of the eye is a hallmark of Keratoconus eye disease. The same genetic factors which causes collagen abnormality also causes the release of chemical enzymes which incite rubbing. Rubbing also lifts the slippery fibers, improving the vision temporarily. Irritation, redness, headache, frequent change of glasses, progression of astigmatism and intolerance to contact lens are other complaints.

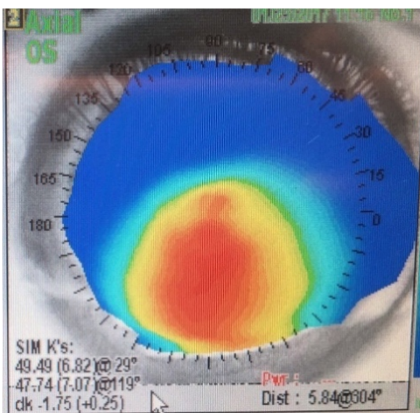


Figure 9.1 Inferior corneal steeping on corneal topography.

Signs of Keratoconus

An astute clinician can find scissor reflex on retinoscopy, as well as tanning and bulging with haabs striae on slit lamp examination. The definitive signs are picked up on corneal topography and pachymetry distribution map.

All family members of keratoconus patients, including siblings, parents and children should be screened for keratoconus eye disease. They should also be warned to choose Epilasik procedure over Lasik eye surgery.

Diseases associated with Keratoconus

The following are diseases associated with Keratoconus. Leber congenital amaurosis, anterior polar cataract, brittle cornea syndrome, Down's Syndrome and connective tissue disorders such as Ehlers Danlos Syndrome. A thorough eye exam should be performed in all patients of KC to detect other abnormalities.

Basic principles of Collagen Corneal Cross-linking (CXL)

The main aim of corneal crosslinking is to: Halt increase in the bulging of the cornea and make the cornea stronger and resistant to pressure of the eye. Secondary Aim: Flatten the cornea and improve the vision.

How does CXL work?

The standard Dresden protocol requires epithelial removal, the instillation of 0.1 % riboflavin solution for 30 minutes to soak the cornea. This is followed by 30 minutes of UVA irradiation with a wavelength of 370 nm and power of 3 mW/cm2 (5.4 J/cm2). There are two phases of the irradiation process. An early aerobic phase and later anaerobic one. In the oxygen dependent aerobic phase molecules of

riboflavin are excited to a single or triplet state. Reactive free oxygen radicals are liberated. These interact with collagen in the later anaerobic phase when oxygen is depleted. As a result, corneal rigidity is increased, collagen fiber become thicker and more resistant to enzymatic degradation. There is decreased permeability and swelling of the cornea, especially in the anterior stroma. Youngs modulus or stress strain ratio is increased with cornea cross linking and is the hallmark to demonstrate the effectiveness in the lab.

Indications for collagen corneal cross linking

Progressive Keratoconus is indicated when there is an increase Kmax of 1 diopter (D) in 1 year, an increase in nearsightedness and/or astigmatism ≥3 D in 6 months, a mean central K-reading change ≥1.5 D observed in three consecutive topographies in 6 months, or if there is a decrease ≥5 % in mean central corneal thickness in three consecutive tomographies in the last 6 months.

Other indications for CXL are Lasik Ectasia getting worse and Pellucid Marginal Degeneration that is progressively worsening.

Contraindications to undergoing standard CXL treatment

Corneal thickness of less than 400 microns.
Previous herpetic infection.
Immunological disease.
Severe scarring or haziness of cornea.
Epithelial wound healing problems.
Severe dry eye or surface disorders.

Procedure

The FDA has only approved the Avedro Photrexa epithelium off procedure. The Dresden protocol, mentioned above, is

employed. The procedure lasts around an hour and half. It starts with 30 min of soaking the cornea with the Photrexa riboflavin. Corneal thickness and the penetration of the riboflavin into the anterior chamber is confirmed. This is followed by 30 minutes of UV radiation well centered on the cornea. Even though the procedure is so lengthy, it is very well tolerated by patients. Even children have comfortably undergone the intervention.

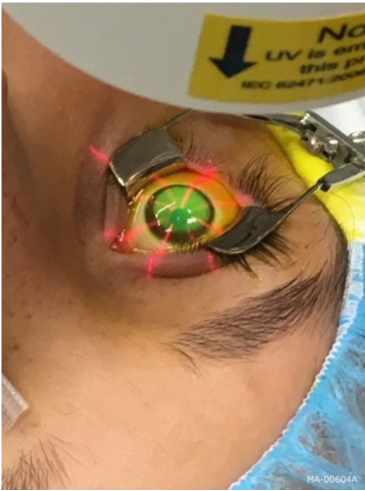


Figure 9.2 UV radiation on a cornea soaked with Riboflavin.

Results

Follow ups ranging from 6 months to 6 years all showed stabilization of Keratoconus with flattening of the central cornea and an improvement in vision.

Side Effects

In around 8.1–33.3 % of patients CXL may not be beneficial. The central cornea continues to steepen more than 1 D in a year or vision continues to deteriorate further.

Infection remains the main problem. Bacteria, fungus, herpes and acantamoeba can all invade the denuded cornea. Clinicians and patient have to be vigilant against this threat. Corneal haze is quite common and occurs three weeks to three months later. The good news is that corneal haze resolves on its own. It may be related to keratocyte activation.

Corneal edema may occur. Watery eyes, tearing and pain is frequently benign.

What are Intacs and how is Intacs surgery performed?

Intacs are FDA approved cornea ring segments made from PMMA, a specialized type of plastic which is very friendly to the eye. Intacs surgery is performed to improve the vision in patients suffering from Keratoconus eye disorder. A mechanical instrument, or the more accurate femtosecond laser, is employed to make an intracorneal channel at a precise depth. This depth is calculated based on the pachymetry map and the refraction.

The intacs are microscopic and cannot be seen with the naked eye. They are smaller than a dime. The doctor has to use a slit lamp microscope to visualize them.

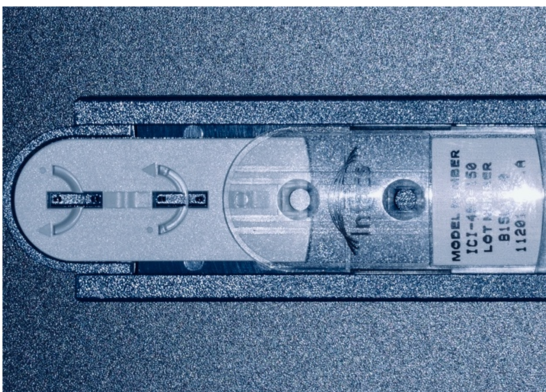


Figure 9.3 Intac ring segments in the sterile box.

Indications of Intacs surgery

Keratoconus or pellucid margin degeneration.
Higher order aberration.
Desire to see better.
Intolerant to contact lenses.

Contraindications of Intacs procedure

Central corneal scar.
Cornea thickness less than 450 microns at insertion.

Recovery after Intacs surgery is quick and patient can return to work in a few days. Some cornea discomfort may be expected.

PIE in Keratoconus patients

The main challenge is to determine the true curvature of the cornea. Multiple instruments are used to detect the high astigmatism which is usually present. Patients should remove their hard contact lenses for few weeks before the measurements and the procedure. Many times, patients are not able to see well with glasses. In these instances, soft lenses may be temporarily tried. Sometimes irregular refraction, fluctuating shape or inability to be off hard lenses more than a few days requires an educated guess by an experienced Keratoconus and PIE surgeon.

In view of the irregular refraction, Crystalens is the best option. If significant astigmatism is present, then Trulign aligned at the correct axis would be nice as well. Trifocal and multifocal lenses should not be used. PIE can still be performed, even if the eye has undergone cornea crosslinking.

Lazy eye or Amblyopia

This is what gives us real happiness. Helping convert a one-eyed patient to a binocular and enjoying the joy on their face.

"By age 52 I am resigned to function with one eye. My left eye is lazy. Seven doctors over 40 years have said nothing can be done about it. Can you help my right eye see at near? What? You want to wake my lazy eye and want to make it active again?"

Lazy eye is an eye which is not working to its full potential. This is caused when an eye has a higher degree of prescription compared to the other eye. This may be because the eye is smaller, causing farsightedness, or it is longer, leading to nearsightedness. An asymmetric eye will result in a person having an astigmatism. The image from this eye is not sharp and therefore the brain suppresses it. You may ask, "what if the patient wore glasses or contact lenses?" That's a great question. The refractive defect is usually so much that with correction the image shape and/or size is markedly different leading to dissimilar images which cannot be superimposed by the brain.

This is different than a sleeping eye. In such circumstances, the optic (vision) nerve or other components of the neuro visual pathway are not developed. Current technology cannot fix these problems, but we hope that future generations will be able to cure these issues.

We will restrict our discussion to lazy eyes caused by refractory errors. Let's turn our attention to what has been the treatment modality for the last hundred years, followed by looking at the application of modern technology to fix this ailment. Traditionally, the most common intervention has been to prescribe glasses and patch the "good eye" so the weak eye is forced to see. Kids hate it and get scared when they cannot see well out of the lazy eye. It is illogical to resort to patching without fixing the underlying problem. It's like forcing a person to walk on a broken leg to make it stronger. We don't do this

do we? Instead, we set the fracture and then start the rehabilitation.

We first perform a very detailed eye exam to determine the refractive state of the eye. We do scans of the cornea, nerve and macula to confirm they are normal. The treatment varies based on age but kids as young as eleven can have laser vision correction in a normal laser suite. Younger kids may need an anesthetist. If the prescription is too high for laser vision correction, then an implantable collamer lens may be employed. In patients older than forty-five, PIE, or presbyopic implant in eye is used.

The sooner the eye is corrected the better the chances of equalizing the both eyes. Interestingly, older textbooks taught there is no cut off age to restore lazy eyes, however patients in their seventies have had lazy eye improved by our interventions. Once in a while we are even amazed to see the lazy eye overtake the good eye and become the stronger one.

If we do not intervene, the lazy eye can deviate out or in, leading to squinting or strabismus. Before any squinting surgery is undertaken, the lazy eye should be fixed. Otherwise, the eye may again move away.

Curing lazy eyes is possible in expert surgical hands. Education about lazy eyes is important as it can cause learning disabilities in children.

Strabismus or squint

There are multiple options when dealing with a person who has a wandering eye.

Macular Degeneration

This is one of the most common causes of vision loss in the developed world. As the name describes, it is the degeneration of the macula. Macula is that part of the retina which is very important for central vision. The three layers of the eye, the

retina, choroid and sclera are present here. The retina is adjacent to the choroid and obtains its nutrition through the choroid. Bruch's membrane is the inner most layer of the choroid. In genetically predisposed people at around 50 years of age, Bruch's membrane layer accumulates yellow degenerative material. This affects the nutrition supply to the retina, leading to the death of the rods and cones. On fundus examination, yellow spots called Drusen may be seen at the macula.

On OCT, Drusen may be visualized as thickened projections from the choroid. This stage is termed as Dry AMD, or Age-related Macular Degeneration. This stage is further divided in to Early, Intermediate and Advanced.

In the earliest form, which is most prevalent, there are few Drusen with no visual loss. The disease progresses to loss of retinal pigment epithelium (RPE) and the atrophy of overlying retinal layers manifesting as concomitant loss of contrast sensitivity, as well as speed of reading with difficulty in adapting to changing light conditions. This is the intermediate stage. In the late stage there is further destruction, leading to loss in central vision presenting as a dark hole. Even though the disease may be present in both eyes, it may be at different stages in the two eyes. It's important to remember this is a very slowly progressing disease. It may take decades for vision loss to occur.

In a small subset of people, around ten percent, the blood vessels of the choroid generate new vessels to supply nutrients to the retina. These new abnormal blood vessels leak, causing swelling and further vision loss. This is called Wet Macular Degeneration.

Good nutrition with a lot of green, leafy vegetables has been shown to be beneficial. This intake needs to start at as early an age as possible. Protection from UV light also prevents progression.

Age Related Eye Disease Studies (AREDS) have shown beneficial effects of Lutein and Zeaxanthin, as well as Vitamin

C and E, in specific doses to decrease the progression in 40 % of patients.

Considering PIE in patients of ARMD

When we are approached by people for consideration of PIE, they may be already be aware they have macular degeneration. In others, we detect ARMD through detailed fundus OCT exams. The first step is documenting the stage of the disease. That will determine appropriate discussion and implant selection. Sometimes a consultation with a retina specialist, OCT angiography or Fluorescein angiography might be required.

Early Dry ARMD: This is the most frequent stage seen. Proper education and counselling regarding progression is important. Family history may help predict future events. Clear UV protective lenses with good distance vision like Tecnis Multifocal, Symfony and Crystalens can be chosen. One eye can have a different lens than the other depending on the stage of the disease.

Intermediate ARMD: PIE should be considered only if patients have strong motivation. Symfony and Crystalens would be the implant of choice. Patients could be made a little nearsighted so that the effect of magnifying glasses is increased.

Advanced Dry and Wet ARMD: We do not recommend PIE in these situations. We dissuade patients in this subset from having this procedure, as there is a high chance of progression and little possibility of the implants working well.

It is important to remember that PIE does not influence the progress of macular degeneration. That means it does not speed up, nor prevent the progression of the disease. After presbyopic implants are inserted, the degeneration may still

continue. Experience has shown us that the deterioration is so subtle patients do not notice it. They are able to adapt and still enjoy the benefits of the implanted lenses decades later.

54-year-old contact lens wearer using monovision:

In this scenario the person is already used to clear monovision at all distances. It is appropriate to replicate similar but better vision with Crystalens.

Sometimes, a patient may have already had cataract surgery on one eye, done either before the modern presbyopic implants were available, or with a doctor who does not do PIE. The question asked is, "should the second eye have the modern advanced implant? And what, if anything, should be done with the first eye?"

The simplest plan is to have an extensive discussion regarding monofocal lenses, accommodative lenses and types of multifocal lenses. Once that is done, then proceed with making a decision about which type of presbyopic implant would be best. This would still free them from the constant dependence of glasses. Nearly all patients we did in this scenario were happy with their choice. It does take time to adapt to the different visions in the two eyes. If the patient is happy and able to adjust, then nothing more need be done. If they are happy and want a similar lens in the other eye, it needs to be considered on a case by case basis. If the first surgery has been recently performed and the eye has not undergone a YAG procedure, the exchange may be possible. On the other hand, if the procedure had been performed many years ago and had already undergone a large capsulotomy and the patient is happy with vision in that eye then it is safer to leave the eye alone.

One-eyed patient

This is both a philosophical and technical challenge. Many patients who have lost one eye also don't want to be dependent

on glasses. Most surgeons are cautious and will ask the patient to reconsider. You may wonder why the hesitation if the risks are so low and each eye is important. It arises from a philosophical viewpoint.

Patients who have cataracts are more likely to explore this opportunity. Many surgeons do not operate on one eyed patient. Our thinking is to only offer it if the present vision is affecting their work. It may be reasonable to take a second consultation with another eye surgeon for a second opinion, especially a retina doctor. A 70-year-old who lost her left eye to pressure complications of an eye stroke attributes her continued independence to Restor implanted into her right eye 5 years ago. Recently, a schoolteacher who had no vision in her right eye since childhood underwent successful Tecnis Multifocal lens implant in her left eye. This helped her to increase her confidence as the vision in her left eye became more superior than it's ever been.

Can the implants move?

Implants can rotate in the early postoperative period. This affects only the toric implants. Proper wound closure and maintaining the pressure of the eye is very important. Therefore, eye rubbing and lifting heavy weights is strongly discouraged. After a few weeks, as the lens sticks to the capsule, rotational movement is unlikely.

Should I wait for newer technology?

Technology is always on the move. We need to acquire what is best at the time we need it. It's like waiting for the newest iPhone or car. There will be always a newer one, but the current one could last a lifetime if they continue to improve functionality while in our possession. The basic principles will remain the same.

Chapter 10 Neuroadaptation and Fine Tuning

We live in an age where we demand instant results, such as instant coffee, instant messaging and so on. Sometimes instant is not always memorable. Has any instant message ever had a major effect on you compared to a well written book? PIE is like old wine and whiskey, as time passes, vision gets better. Two factors account for this: **fine tunings** and **neuroadaptation**. Crucial to both is a fundamental understanding of the way presbyopic implants work and the factors which influence the optimum result.

Neuroadaptation

It is the process by which the brain modifies its sensory input in response to external stimuli. For example, if one keeps poking oneself with a pin, after a few pricks the pain is not felt. If a person has knee joint pain and an irritant cream is rubbed on the skin, the joint pain gets masked.

Visual neuroadaptation is not a new phenomenon. A person who wears glasses for the first time, or tries progressive glasses, must neuro adapt to the different way the image is presented to the brain. Neuroadaptation in the visual system can occur with monocular or binocular disturbance. The blurriness, or other undesirable patterns, are negated over

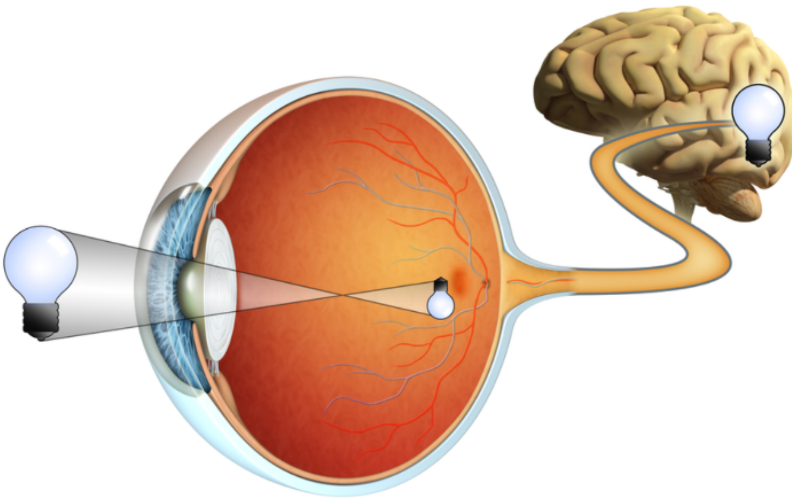


Figure 10.1 Pathway required for neuroadaptation.

time. If similar patterns are generated from both eyes, negation is faster. If the patterns are different, but fusion is allowed, such inconvenient patterns can be obscured.

Psychophysics is the interaction of the brain and optics phenomenon. It deals with the binocular rivalry and visual crowding; two phenomena at work helping to adapt to the presbyopic implants. Having a working plan and knowledge about the timeline for adaptation, coupled with exercises, helps increase the assimilation of the new vision.

When a baby is born, its vision is not 20/20. In fact, it takes up to 7 years to reach that target. PIE is akin to rebirth; an accelerated development re-birth. Even though you may see 20/20 in a few days to weeks, the quality of vision keeps improving in the ensuing months and years. Studies have shown that vision at one year is better than at one week, and wait for this…vision at seven years becomes even better than

Figure 10.2 Left side focused on distance makes the thumb blurry. Right side focus shifted to the thumb to make it clear causes distance details to become blurry.

at one year! Have you ever heard of a product that improves with time? Computers and cars wear out with time. This seems like an investment which can pass the test of the legendary Warren Buffett. How is this possible? Let us refer back to the first chapter of the book. We said eyes focus the incoming light signal and transmit them to the brain. The brain subtracts the noise from signals and creates a map of the world. From birth onward, it learns what is true information and what may be discarded as aberrations. Stationary fixed objects are also eliminated from perceived reality. That is why we do not see our cornea nor the blood vessels.

When PIE procedure is performed, the brain must then re-learn how to sift the data. The new implants create their own unique noise. Visual areas of the brain adapt to the fixed noise and drop it. Fixed constant noise is the key to eliminations. The same concept fails in contact lenses and the contact lenses are often removed. Contacts also move with every blink. Therefore, adaptation is very difficult in such instances.

The brain must adapt to the new paradigm. When a person is aware of this concept before the procedure, the brain is more

receptive to the change. It is looking forward to obtaining new data. If people are unaware of this, information is likely to shock the brain. That results in the classical fight or flight response. The brain is more likely to become fearful and reject the change. This will lead to increasing interpretation of the noise as data. Clinically, this means a person is likely to suffer from ghosting images, glare and halos. In simple words, it means such a person may see shadows or may possibly even experience double vision. While driving at night they may be plagued by glare and halos.

Forewarned is forearmed. Well informed and adaptable neurons will use their plasticity to adapt to changing times. We can also help in this reshaping and learning process. Holding objects at proper distances avoids the brain needing to use energy unnecessarily. Holding a book at a fixed distance creates static noise which can be eliminated faster. Performing PIE on both eyes within a few weeks feeds the brain with similar data, avoiding confusion. In fact, summation of the electric signals decreases the ratio of the noise. We can also do some training exercises to help jumpstart the learning process of the neurons. These can be simple exercises you can perform in your home or office. There are also apps available and for the connoisseur there are structured, computerized training sessions. To make it simple, and to follow the applicable ones, after your procedure we will divide them based on zones of vision.

Adapting for Distance: Daytime and nighttime adaptation is required.

Adjusting for Intermediate: This involves working on computers, seeing the smart and not so smart phones. Cooking, cutting vegetables and fruits.

Training for Near: Reading, sewing and handling small screws.

Visual exercises for aiding neuroadaptation

Occasionally, the optimal results may take a few months after both eyes have had implants inserted. Performing certain visual tasks or exercises can hasten this process. These include watching TV, working on iPads, cell phones and learning to avoid looking at bright lights. Finding the best distance to read requires patience and effort. Modulating room light and adjusting the distance between the computer and oneself are all helpful. There are computer-based exercises to enhance neuroadaptation. It seems tedious but is very gratifying. That is why vision after seven years is even better than six months after the PIE procedure.

Adjusting to reading after PIE surgery

One of the reasons people desire PIE is because their arms are not long enough. As one grows more presbyopic, one tries to hold books and newspapers away from their eyes. Once the presbyopic implant is in the eye, there is no need to do this, but people are creatures of habit. Though they have been cured and can read at a normal distance, breaking the subconscious distance set by the brain takes time. This is truer when only one eye has been cured. An active conscious input is therefore required. The best way to achieve this is as follows. Hold a book in one hand and close the unoperated eye. This is to prevent the two eyes fighting each other. Move the book back and forth until it is clear. Stretch out the other hand and measure the distance at which the vision is most clear. Is it near the elbow, biceps, or forearm? Memorize the spot and next time hold the book around there. Now open the unoperated eye. After both eyes are done, the first eye could be closed, and the exercise repeated. Usually after both eyes have been treated it is easier to find the optimum distance.

Fine Tuning - modifying the vision by the surgeon

Dry Eye

This is the most common pre-existing eye condition. That is why Lasik is not a good choice, as it induces more dryness. Even though PIE does not induce dryness, the cornea needs to be kept polished by the tear film for optimum vision; like a mirror, the more polished it is the better we can see. This can be achieved by a dry eye treatment regimen including preservative free artificial tears, lid scrubs, warm compresses, room humidifiers, and if required, medicated cyclosporine drops. We will discuss this in depth in the next chapter.

YAG Procedure

The lens is implanted in the bag in which the natural human lens existed. This bag still has living cells, which replicate and drift behind the lens in the line of sight. These cells, and the wrinkles in the bag, prevent clear vision. After at least 12 weeks have passed, a non- contact, painless laser beam (different than the one used in Lasik) can blast an opening in this capsule. The 12-week wait allows the lens to form a bond and become attached to the eye. Increasing the duration between the lens implant and the YAG procedure increases the safety.

Correcting Astigmatism

This can be achieved at the time of the PIE procedure by placing an incision on the steep axis or performing Limbal Relaxing Incisions (LRI). AK incisions are not used as they are unstable. LRI can also be performed in the office after the procedure. Even laser vision correction in the form of Lasik (for the younger with less dry eye) or Lasek / Superlasik can be deployed to correct astigmatism.

Correcting Refractive Error

Presbyopic implants require great optics for optimum functioning. Any residual astigmatism, nearsightedness or farsightedness can affect the functioning. These need to be fixed before neuroadaptation can begin. The patient and the doctor may have to wait for the fluctuations in vision to settle down. YAG may change the final position of the lens, effectively changing the refractive power. Hence, Lasik or Lasek to correct refractive error is best performed a few weeks after YAG. Once both eyes have undergone the above procedures, neuroadaptation can truly begin. Therefore, tunings can be considered as an investment for lifelong improved vision. Confident surgeons tend to include these fine-tuning procedures in the original cost, but it is necessary to check with your surgeon to avoid any unforeseen costs.

Fighting CME

CME stands for Cystoid Macular Edema, or fluid in the back of the macula, which is essential for seeing. This occurs in most patients as a result of upsetting the equilibrium of the eye but is clinically significant in only a few patients. Nonsteroidal and steroidal drops are routinely prescribed for 4-6 weeks after PIE to prevent its onset. If it does occur, prompt diagnosis with ophthalmoscopy or ocular coherence tomography (OCT) is important. Treatment options available include increasing the frequency of the drops and in extreme cases, steroid delivery inside the eye.

Glare and halos

Initially, the new implants may cause some glare and halos. Please avoid searching for haloes. When driving at night, refrain from looking at the oncoming headlights. It is better not to drive in the lane closest to opposing traffic. Though the

taillights in the cars in front may appear bigger, do not stare at them. These side effects decrease as the eye heals and astigmatism and spherical imperfections are treated. They disappear in a few months as the brain adapts and subtracts the aberrations in the images. Hardly anyone notices them a year from the procedure.

Chapter 11 Astigmatism Management

The clear, front part of the eye called the cornea is normally shaped like a basketball. This shape allows the incoming light to come to focus at a single point on the retina. If it is shaped like a football or an egg, it causes the light to become distorted and forms a blur on the retina. To understand this disease, let us take the example of the game of darts. A normal eye is like an ace shooter, with all the darts hitting the bull's eye. Whereas an eye with astigmatism is like a novice, with the darts scattered all over the board, some in the center and some out. Further, let's say you try to pluck and reinsert the darts in the inner circle. The novice keeps pushing out some that were already there. This prevents all the darts from being in the inner circle at the same time.

The brain also tries to achieve accumulation of all the data on the macula. It sends signals to the inner muscles of the eye to change the shape of the lens to achieve this goal. It's a futile exercise leading to fatigue of the muscle, in addition, nutrition is rushed through blood vessels, which are red in color. Finally, the brain is exhausted. Therefore, people with astigmatism experience headache, redness and generally feel their eyes are tired.

Figure 11.1 Astigmatism vs Normal Vision.

Now that you have understood what astigmatism really is, let's discuss the less common causes of astigmatism. The natural lens, retina, and rarely, the vitreous jelly can also cause astigmatism. Spoke shaped cataracts called cortical cataracts can cause astigmatism. The combination of all these generates the total astigmatism of the eye.

We are fortunate enough to finally have technologies which can detect and eliminate this condition. The most precise way to detect and document changes in astigmatism is by a machine called color corneal topographer. This sends beams of light to be reflected off the front surface of the eye. It detects and color-codes the results for easier interpretation. This yields the astigmatism on the cornea on the front part of the eye. OCT based devices like IOL Master 700, and others like Pentacam, can analyze astigmatism on the posterior corneal surface. Finally, autorefractors and wavefront devices can detect the total astigmatism of the eye. They do so by sending beams to the retina and back.

The twentieth century way to counter the effects of astigmatism has been wearing glasses or contact lenses, but they are an addiction if you will, as they do not cure the condition. They are themselves shaped like a football and placed perpendicular to the direction of astigmatism of the eye. So now you have two football shaped objects perpendicular to each other. Light passing through these arrangements of eye

and contact lenses develops various aberrations or defects preventing perfect vision. This leads to distortions and color changes of objects in the field of vision. If you wear glasses and rotate them in front of your eyes, you will see the world move in an opposite direction.

Contact lenses can also counteract the effect of astigmatism. Hard lenses and soft lenses employ different methods. Hard lenses accumulate tear film between itself and the cornea. This tear film acts as a lens of opposite power and negates astigmatism. This method can also treat irregular refraction. Soft lenses, on the other hand, have the power ground on the cornea in a particular axis. It is marked and weighted at the six o'clock position to prevent contact lens rotation.

Why not just eliminate the football shape of the eye? The good news is that in this century astigmatism can be permanently cured.

For younger people between 18 and 45 years of age, Wavefront astigmatism Lasik is the best option. The Wavefront device uses principles of astrophysics to calculate the imperfections of the eye. Iris registration allows very precise placement of the laser beam. The result is the shape of the eye being changed to spherical. The vision, especially night vision, improves. The halos and glare at night decrease. Further, the redness and fatigue are eliminated.

If you are above 45 years of age, we have to determine the quality of tear film, thickness of the cornea, presence of cataracts, and desire to be free from glasses. If you have a cornea with normal thickness, with good tear film and the absence of cataracts, thin flap Lasik can get rid of the astigmatism. If you have dry eye or a thin cornea, Superlasik or Epilasik is a better choice. It is a superficial type of Lasik. There is no cutting into the cornea to make a flap.

If cataracts are present, the scenario changes. First, we have to study the technical output from our various machines to determine whether the astigmatism is arising from the cornea, the cataract or the retina. If it is from the cataract, then

eliminating it should solve the problem. If it is from the retina then it is imperative that the health of the retina be confirmed before progressing further.

The treatment options for corneal astigmatism include limbal relaxing incision, Toric IOL, multifocal IOL or Toric multifocal IOL. Limbal relaxing incisions are derived from RK, or radial keratotomy techniques. Incisions in the cornea are made dependent on the amount of astigmatism. The number, length, depth and the distance from the center of the incisions vary depending on the amount of astigmatism which has to be treated. Metal or diamond blades have been used since the last century. Today, femtosecond lasers can perform this function more accurately. These lasers are different from the one used for Lasik. Now, the fun part is that these lasers can also perform the cataract surgery. They can make openings in the lens and reduce the lens into small cubes.

The drawback of LRI is that it can treat only a small amount of astigmatism. The effect also may fade away with time. A permanent way of correcting astigmatism is the use of a Toric implantable lens. The lenses are inserted when the cataracts are removed. They are of different powers and must be accurately aligned for best results. If they rotate, the astigmatism correction can be affected. That is why the more stable Tecnis and Acrysof Toric are popular. The Tecnis Toric is white and allows maximum light to pass through. The yellow Toric IOL absorbs the blue light. A person would need more light to read in a dim room.

Despite the monofocal Toric lenses, a person would still need reading glasses. This problem has been solved by merging the benefits of accommodating lenses and multifocal lenses with Toric lenses. The current FDA approved lenses are, Trulign (Crystalens Toric), Symfony Toric, Panoptix Toric and Tecnis Multifocal Toric. Theses lenses will counteract the astigmatism of the eye and will allow you to see sharply at all distances.

Eliminating Astigmatism with PIE

PIE has an arch enemy, it is astigmatism. It is imperative to correct even small amounts of astigmatism to get the best vision after implanting presbyopic implants. When we open the lens bag during PIE or cataract surgery, it resolves the lenticular astigmatism. We then need a strategy for the residual corneal astigmatism. It is logical to treat astigmatism at its source. Therefore, a procedure on the cornea is the best option.

Limbal Relaxing Incisions (LRI) – Manual or Femtosecond laser. Vertical incisions up to 90% depth of the cornea near the junction of the clear cornea and the opaque sclera. The number (one or two) and the length of each determine the final effectiveness of LRI. These incisions have minimal side effects as they are far from the pupil. They have less effect than AK and also effectiveness decreases as the incisions heal by vascularization.

Astigmatic Keratotomy (AK) - Diamond Blade or Femtosecond laser. These are made on 90 % clear cornea. Being closer to the center of the cornea they are more effective. The final effect is dependent on the number, distance and length of each AK incision. The femtosecond laser can make hidden AK. These are ones which do not come to the surface but stop short at the epithelium. These can be opened later to further titrate the final effect. AK can cause progressive effects over years. If the incisions are too close to the pupil, they can cause glare at night.

Operating on Steep Axis - When an incision is made on the steep axis it flattens that axis, decreasing the astigmatism. The length of the incision is directly correlated to the effect. Corneal incisions are more effective than scleral incisions.

Wound suturing on flat axis - When a suture is applied to a corneal wound it causes flattening around the suture but steepens the central cornea.

Lasik/ Lasek - The best and precise way to treat astigmatism is by laser vision correction. Either Lasik or Lasek may be performed. When performing Lasik and creating a flap it is necessary to wait at least three months after lens implantation to avoid destabilizing the lens. Where the surgeon is anticipating Lasik after PIE, he can choose to make a flap before PIE. Then a few weeks after lens implantation, the flap can be lifted, and laser vision correction be performed. With femtosecond lasers a flap can be performed at the time of the laser cataract surgery.

Toric Lens - A lens with built in astigmatism can counter the corneal astigmatism. Special vector-based nomograms are required to predict the exact power and orientation of the Toric lens. A Toric lens will not give the ability to read. It may be an option where laser vision cannot be performed.

Toric Multifocal Lens - A combination of Toric and multifocal lenses can treat astigmatism and yield vision at all distances.

When should astigmatism be corrected?

Before PIE: We could correct and document the correction before the presbyopic implant insertion procedure. This would allow us to document the change. The con of this road is that the procedure itself could induce or alter astigmatism. It could affect the calculated power of the implant. An option is to make the Lasik flap before the procedure. A few weeks after the presbyopic implant is inserted, the flap could be lifted, and residual refractive error could be simultaneously treated with astigmatism. This method is really helpful when the patient has

a lot of astigmatism and wants a permanent quick cure; understanding the flap can be lifted around a year or two for final touch up.

During PIE: This is a preferred method of intervention for many surgeons. Patients perceive the many components as one procedure. They can be wowed by the outcomes. This option is preferred by cataract surgeons who have evolved into PIE masters. LRI, AK, Laser LRI and toricity of implants are options when selecting to treat astigmatism at the start or end of the main procedure. Toric implants – Sympfony, Restor, Trulign, Panoptix

After PIE: Let everything settle down is an approach used by refractive surgeons who are guaranteeing lifelong outcomes. Once effective lens position is achieved there is more likelihood of stability of vision for the rest of life. Many cataract surgeons may not have the experience, nor access to excimer lasers, to fix residual numbers. That is why they tend to refer to Lasik surgeons for the necessary adjustments.

Chapter 12 Dry Eyes

Introduction

Dry eye is a very common condition afflicting more than five million Americans. A lot of people suffer from dry eyes without realizing it. For many decades it was neglected and was sort of a trash bin diagnosis. Even medical doctors were not comfortable handling it. Most just prescribed over-the-counter drops which gave temporary relief but did not relieve the condition. Short term measures, like taking the redness out, propagated a whole industry without alleviating the condition. It's only in the last decade there has been an advancement in the management of dry eyes. Technological advancements have generated new diagnostic and treatment modalities. Today, the management of dry eyes is a multibillion-dollar industry. To tell you the truth, dry eye is not one condition, but many different diseases put together under one terminology, as there was no real treatment until around few years ago.

The reason dry eyes have taken on such a big interest by the industry is because of the realization of importance of tears. The tears are important in the functioning and health of the eye. Lasik causes dry eye and therefore patients, especially above forty, may notice a progression of dry eye. Tears are essential for crisp and clear vision This has been brought to the forefront with presbyopic implants, where dry eyes can play

havoc with the outcome. That is why people with severe dry eyes, like those suffering from Sjogren's Syndrome, are not good candidates for presbyopic implants. Tears also carry lysozymes which fight bugs, so a decrease in tears can lead to susceptibility to infections.

Importance of Tears

Nutrition: The tears bathe the cornea and the conjunctiva cells lining the eye and the lids. In the rest of the body, blood vessels and cells provide nutrition and protection. Tears take up that role in the eyes as the presence of blood vessels would obscure vision.

Vision: The air tear interface is where the tears coating the cornea come in contact with the air in the atmosphere. At this juxtaposition the light changes direction so that it can be further focused by the natural lens.

Lubrication: The tears form a thin interface between the cornea and the lids to prevent injury to the cornea.

Protection: The lysozymes attack organisms which might try to enter the body through the eyes.

Allergen removal: Everyday a lot of dust and allergens reach our eyes. The tear film entraps them and sends them down the drain into the nose and beyond.

Composition of Tears

The three main components of tear film are Lipid (the fatty part), Aqueous (the watery part) and Mucin (the rubbery component). These three components interact with each other in a complex, physical interaction to produce the tear film. The ratio is as important as the quantity.

The watery component is produced by the main lacrimal gland and some helper or accessory lacrimal glands found in the lids. The lipid component is from the meibomian glands which are located in the cartilage of the lid and open up near the root of the lashes. Mucin is secreted by the small glands called goblet cells, found in the conjunctiva, cornea and the lacrimal gland. Oil floats on water and therefore the lipid and aqueous layer cannot mix. The mucin layer helps the oily layer to mix with the watery layer. Each part plays a specific role and combined their effectiveness is exponential.

There are also minerals, lysozymes and antibodies. Minerals are important for the nutrition of the cornea. Lysozymes and antibodies are the natural defense mechanism of the eye. The proportion and interaction of these three components are as important as the total volume.

The tears are spread across the front surface of the eye by the blinking action of the lids. The eyelids blink around 16 times per minute. The lower lid holds the tear lake and with each blink the lid muscles pump fluid out of various glands, help mix them and produce flow. The upper lid coats the cornea with a thin layer of tear film by its windshield wiper action. In a few seconds this film breaks up, to be restored with the next blink.

Production and drainage

The tears are produced by the lacrimal gland located on the upper outer part of the upper lid. They flow across the eyeball to the minute openings in the inner part of the lids. They are joined on this journey by other components secreted from the glands in the lid margin. The direction of tear flow is due to gravity and the shape of eye. It is aided by the pumping force generated when lids blink. Tears then flow down the special tubes to the nose. That is why when you put drops in the eye you may get an odd taste in your mouth.

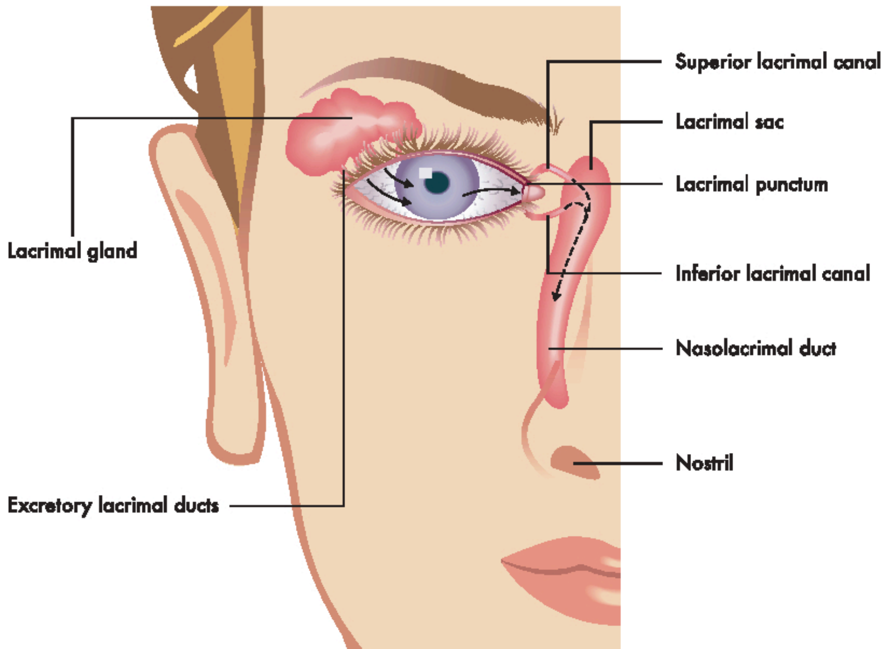


Figure 12.1 Tear production and drainage.

Definition of Dry Eye

According to the Definition and Classification Subcommittee of the International Dry Eye Workshop, "Dry eye is a multifactorial disease of the ocular surface characterized by a loss of homeostasis of the tear film, and accompanied by ocular symptoms, in which tear film instability and hyperosmolarity, ocular surface inflammation and damage, and neurosensory abnormalities play etiological roles." In simpler terms, dry eye can be defined as when the volume of tears in the eye are not sufficient to carry out the functions attributed to tears. Vision is affected because light is not able to refract at the tear cornea junction. There is a delicate balance between the volume of tears produced, the amount which evaporates into the atmosphere and the amount which is drained through special tubes into the nose. Whenever there is decreased

production of tears, an increased evaporation or drainage, or a combination of this, the balance is upset and results in dry eyes.

Symptoms of Dry Eyes

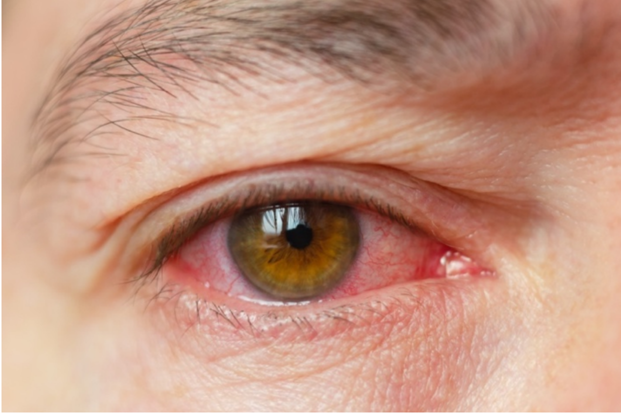


Figure 12.2 Example of a red eye.

Common symptoms of dry eyes can be easily understood once we have realized the importance of tear film. Tears play the role of blood vessels and blood components, as well as much more. If tears are deficient, the lubrication effect is lost. With each blink, the lids scrape the cornea and conjunctiva damaging the top cells. These cells are cast off and rub against the membranes producing the feeling of grittiness. There is also liberation of histamines which causes burning, itching, stinging and light sensitivity. Air and atmospheric temperature stimulate the exposed corneal nerves, producing reflex tearing or watering and pain. Many people wonder how they can have dry eyes if their eyes are watering. There are two kinds of tearing - basal and reflex. Basal tearing is the constant tear production, irrespective of the weather conditions. This production is what's really essential for the nutrition and functioning of the eyes. Reflex tearing is produced in response to external stimuli and is more to wash away allergens.

The lids try to revert the situation by blinking frequently. This can manifest as heavy eyelids and lead to fatigue. As you may have surmised, poor tear film can lead to imperfections in vision, such as blurry or fluctuating vision, interfering with reading, computer vision, watching television, driving, or playing video games. When tears decrease, nutrition to the cornea and conjunctiva is compromised, triggering response mechanisms. Blood vessels dilate and grow larger to bring nutrition and therefore redness is produced from the red blood in the vessels.

When a person dreams, there is rapid eye movement, hence that stage of sleep is termed as REM sleep. In a person with dry eyes, that implies there is more friction between cornea, conjunctiva and the lids. The resultant excess watering overnight can dry up to lead to discharge or even matting of the lids.

Questionnaires

History taking is an art. In the developing field of dry eye management, it is crucial to detect the correct symptoms. To alleviate confusion in terminology and overcome memory lapses, various questionnaires have been developed. They document a patient's subjective dry eye experiences and symptoms to convert them to a more objective and reproducible data set, which can be compared with others or oneself over time. There are numerous questionnaires to assess dry eye patients, but the most popular are the National Eye Institute Visual Function Questionnaire-25 and the Ocular Surface Disease Index.

National Eye Institute Visual Function Questionnaire-25 (NEI-VFQ25)

National Eye Institute came up with this 25-item questionnaire to analyze the irritation from dry eyes and

document their effect on activities of daily living and health-related quality of life. The questionnaire analyzes overall health, overall vision, difficulty with near vision, difficulty with distance vision, limitations in social functioning due to vision, role limitations due to vision, dependency on others due to vision, mental health symptoms due to vision, future expectations for vision, driving difficulties, and pain and discomfort around the eyes. Zero is the lowest score while one hundred is the highest.

Figure 12.3 Exposure to breeze can cause dryness.

Ocular Surface Disease Index (OSDI)

Outcomes Research Group at Allergan Inc created a 12-item questionnaire. It quickly assesses dry eye disease and symptoms of ocular irritation with their effect on visual functioning in the past week of the patient's life.

Diagnostic testing

We have seen in the definition that the various causes of dry eye disease result in tear film instability, hyperosmolarity, ocular

surface inflammation and damage. It would be prudent to measure these various components to diagnose dry eye disease.

Tear Film Stability is determined by following methods:

Fluorescein TBUT, or Tear Break Up Time: Fluorescein dye is instilled in the eye and the patient is seated at the slit lamp. The patient is asked to blink, and the cornea is observed under the cobalt blue light. The time from when the patient blinks until seeing a spot of the cornea that is no longer covered with fluorescein stained tears is counted in seconds. This is the tear break up time. A TBUT greater than 8-10 seconds is usually considered normal, whereas under 5 seconds points to dry eyes.

Non-Invasive TBUT (NITBUT): An image is projected on the cornea. Computer software measures the time to distortion in specific segments of the image.

Ocular Surface Staining

The same fluorescein dye used for TBUT is most commonly applied to detect abnormal or missing epithelial cells. Under the cobalt blue light, gaps in epithelium appear bright green. Lissamine green and rose bengal are two other dyes which detect damaged cells on the conjunctiva. Lissamine green is less toxic and better tolerated than rose bengal.

Tear Volume Assessment

Schirmer's Test: This uncomfortable test is not much used nowadays. A small paper strip is placed over the temporal one-third of the lower lid margin before any drops are instilled. After 5 minutes the length of the strip that is wet is measured. This gives reflex tearing. The test is again performed with anesthetic drops having numbed the eye. This is the basal

secretion. Less than 10mm of tear production in 5 minutes, or marked difference between two eyes, is suggestive of dry eye.

Tear Meniscus Assessment: Fluorescein dye under the cobalt blue filter can also detect the tear meniscus. The height above the lower lid can be measured. Anterior segment OCT can also be used to measure the tear meniscus height.

Tear Osmolarity: The painless test utilizes a card mounted on a device and placed over the lower tear meniscus. It can even be used in severe dry eyes as it requires less than 100 nanolitres of tears. Normal osmolarity < 300 mOsm/L in both eyes and a difference between eyes of < 8 mOsm/L.

Matrix Metalloproteinase-9 Test: The tears of patients with dry eyes, where their ocular surface barrier function has been compromised, have elevated matrix metalloproteinases (MMP). This indicates anti-inflammatory therapy may be beneficial. Allergic conjunctivitis and infection may yield a false positive.

Lactoferrin Test: The protein lactoferrin, produced by the acinar cells of the lacrimal gland, has antimicrobial and anti-inflammatory properties. Dry eye due to decreased aqueous tear production has lower concentrations of lactoferrin.

Meibography: Computerized imaging using black-and-white photography, infrared camera, or near-infrared charge-coupled device (CCD) video camera of an illuminated everted eyelid can outline the silhouette of the meibomian gland. Computer software can do a quantitative analysis of the morphology and structure of meibomian glands.

Interferometry: Lipiview uses interferometry and can be utilized to measure the thickness of the lipid layer.

The Sjo Test: In the Sjo test, performed to diagnose Sjogren's syndrome, a finger prick sample of blood saturates a specimen filter paper to detect four SS antibodies (anti-SS-A/Ro, anti-SS-B/La, rheumatoid factor [RF], and antinuclear antibody [ANA]) along with three novel, proprietary early biomarkers, antibodies to SP-1, PSP, and CA-6. Anti-SSA antibody is the only serological marker for Sjogren's Syndrome.

Causes of dry eyes

Let us consider an example of a swimming pool, where we want an optimum level of water to be always present so we can swim properly. The inlet tap supplies water at a predetermined rate and the drainage regulates the exit of water from the pool. Also, there is evaporation from the surface of the pool. In hot, dry weather, there will be increased evaporation. Whereas on rainy days the water dissipating into the atmosphere will be markedly less. The level of water may decrease in times of drought when there is a restriction on water supply. Finally, if there is a leak in the pool there will be excessive loss leading to lower water level.

Classification of Etiology of Dry Eye Disease

Decreased Production:

- Atrophy of tear producing cells
- Hormone imbalance associated with aging
- Pregnancy
- Thyroid eye conditions
- Diabetes
- Vitamin A deficiency (rare in US)

- Inflammation - Allergies, eyelid inflammation (blepharitis), inflammatory eye conditions including Herpes virus infections and uveitis / iritis
- Suppression by drugs - Medication/supplement use, including psychiatric medicines, OTC cold medicines, antihistamines, beta-blockers, pain relievers, sleeping pills, diuretics, hormones replacement, and oral contraceptives
- Congenital absence of lacrimal gland
- Tumors
- Surgical excision of tear producing glands
- Post refractive surgery (LASIK or PRK) – dry eye may generally last three to six months, or longer
- Eye surgery, especially lid surgery such as chalazion removal
- Contact lens use
- Sjogren's syndrome (dry mucous membranes throughout body)
- Other autoimmune disorders including Lupus and/or Rheumatoid Arthritis
- Chemical splashes / injuries to the eyes

Increased Evaporation:

- Air conditioning
- Heat in cold climate
- Outdoor exposure to sun
- Environmental (dusty, windy, hot/dry)
- Infrequent blinking or poor blinking associated with staring at computer or video screens
- Lid tumors
- Exposure keratitis, in which the eyelids do not close completely during sleep, such as lagophthalmos

- Neurologic conditions, including stroke, Bell's palsy, Parkinson's, trigeminal nerve problem

Increased Drainage:

If the tear punctum is too big then tears may flow down too fast. Rarely there can be an anatomic variation and the tear duct is duplicated. This can again lead to an increased flow.

Incorrect Composition:

The volume is good but there is a mismatch between the oily and water layers. This is the most difficult problem to solve.

Treatment of dry eyes

Once a clinician knows the cause of the dry eyes, it becomes relatively easier to treat the dryness. The older shotgun approach of throwing artificial tears at everyone benefited some, but did not treat the cause, and even caused harm in a few. Since we have been so diligent in classifying dry eye disease, our treatment modalities will be based on that.

There are some general lifestyle adjustments all people can make before resorting to medications. Eating healthy green vegetables with plenty of water intake is a good first step. Protecting eyes from smoke, dust, wind and sun with a good pair of sunglasses, especially a wraparound type is another easy choice. A wide brimmed cap or hat can increase the protection from these elements.

Exercising regularly, especially in fresh air and decreasing stress through meditation will help reduce systemic diseases and medicines needed to control them. Proper sleeping habits, as well as limiting screen time on computers, tv and phones will also help. Follow the 20/20/2 rule – every 20 minutes look

away from your book or screen for 20 seconds and blink 2 times.

Avoid sitting in front of a fan or air conditioner. While driving, have the windows up and point the air conditioning vents away from your eyes. A humidifier at work and while sleeping will moisten the air. Simple humidifiers increase the moisture in dry places and are a more natural and functional way to keep eyes moist. Get enough sleep — about 7 to 8 hours a night.

Figure 12.4 Humidifier while sleeping.

Increase Production

Foods rich in omega-3 fatty acids have been shown to be of value in improving tear film. Flaxseeds or flaxseed oil, salmon and sardines have high omega 3 content. They are also available as supplements, as well as in artificial tears.

Blepharitis, or lid margin inflammation, which progresses to non-infectious inflammation of the lid called chalazion, or even infection of the lid called hordeolum, can be treated by a simple warm compress and lid scrubs. A clean washcloth soaked in warm (not hot) water is applied over the closed eyelids for a few minutes. This may be repeated 2 or 3 times.

The warmth allows the oily gland secretions to melt. A thermal pulsation device is an expensive method to accomplish the same goal. Lid scrubs, which are designed for eyes can then be gently rubbed along the base of the eyelashes and lid margin itself to loosen any debris and open the pores.

Lid scrubs are also available as foam which can be applied at the time of shower. Lid scrubs are superior to another method where baby shampoo is rubbed with fingers or Q tips on the base of the lashes.

Drops to reduce eyelid inflammation. Antibiotics may be used alone to tackle any infection present. They are usually combined with steroids for a short time to reduce inflammation which may be preventing various glands from executing their job.

Systemic antibiotics to improve the quality of tears. An antibiotic known as Doxycycline works with a dual mechanism. It fights any infection present, as well as makes gland secretions more liquid. It is administered in a low dose over many weeks. It may cause some bowel disturbances; however, it is otherwise well-tolerated. It should not be given to pregnant women nor teenagers as it can cause discoloration of teeth and bones.

Eyedrops to control inflammation of lacrimal glands. In the last decade there has been commercial development of an immune-suppressing medication cyclosporine (Restasis or Xiidra). This reduces the inflammatory cells in tear glands, especially the lacrimal gland. The suppression of inflammatory cells kickstarts the lacrimal gland again.

Eye drops made from your own blood. They are a last resort when other therapies fail. To generate these eye drops, blood is drawn and centrifuged to remove red blood cells. The remaining liquid is mixed with a salt solution.

Using light therapy and eyelid massage. A technique called intense-pulsed light therapy followed by massage of the eyelids has proven to help people with severe dry eyes.

Acupuncture. Some therapists claim acupuncture therapy can increase tear production.

Decrease Evaporation

Artificial tears - These drops are available with preservatives or without preservatives. Preservatives are added to prevent detonation from external stimuli. They can therefore be packaged in multi-use bottles which can last weeks. These drops can be used one to four times a day. Preservatives are toxic to the epithelium and any further increase in frequency can harm the epithelial cells. Non preservative eye drops on the other hand, have no preservatives and have a limited shelf life. They are packaged as single-use clear vials. They can be put as frequently as every half hour.

Figure 12.5 Correct way of instilling eye drops.

Drops vs. Ointments - Lubricating eye ointments are far superior to drops. They adhere and coat the surface of the eyes and provide longer relief from dry eyes. The eye ointment is thicker and can make vision blurry, therefore they are best used in a small quantity at bedtime. In the morning, water from the shower can be allowed to fall on the closed eyes to wash away excess ointment. Ointments are a good alternative for those who are too busy to put in eye drops. Eye drops can be used at any time and won't interfere with your vision. This is especially

useful for patients who have had recent eye surgery, whose lids open during sleep, or people using C-pap machines.

There is an intermediary product available called gel drops. These are thicker eye drops which last longer.

Figure 12.6 Inserting ointment by pulling the lower lid down.

Eye inserts that work like artificial tears - These inserts, made from hydroxypropyl cellulose (Lacrisert), are inserted daily between the lower eyelid and the eyeball. As they dissolve, they release components similar to eye drops.

Drops that take the red out - These temporary solutions work by constricting the small blood vessels on the surface of the eye. As we have discussed, the blood vessels provide nutrition for the eyes and body. By cutting off this source of nutrition there is more stimulus for blood vessel production. That means over time these very drops cause increased redness. There are some sunglasses which spray moisture at regular intervals. These eyeglasses also block wind or dust from reaching the eye. Eye covers for sleeping which prevent exposure and evaporation without touching the eye itself. Using special contact lenses called scleral contact lenses protect the surface of the eyes by trapping moisture between the cornea and the lens. They keep the severe dry eye bathed in liquid.

Castor oil eye drops may improve symptoms by reducing tear evaporation. This is not a recommended option at present.

Increase Production	**Addition**	**Prevent Evaporation**	**Decreased Drainage**
Oral vitamins	Artificial tears	Sunglasses	Temporary Punctal occluders
Warm compresses	Lubricating eye ointment	Wide brim hats	Permananet Punctal occluders
Lid scrubs	Humidifiers	Sleeping eye covers	Cautery closure of punctum
Drink flax seed oil	Drink water		Surgical closure of punctum
Restasis or Xiidra	Moisture glasses		
Doxycycline	Scleral contact lens		
Autologous serum			

Figure 12.7 Treatment of dry eyes.

Decrease Drainage

Punctal Occluders - This is an elementary and painless, simple office-based procedure. The method to decrease the drainage is akin to putting a stopper in the drainage pipe of a spa or a pool. It is customary to start with a temporary punctal occluder in the lower lid. If both eyes are dry it is best to start with only one lid at a time. The other lid will serve as the control. If there is documented benefit the test can be

expanded to the other lid. In the next stage intermediate duration plugs can be inserted. If there is only partial improvement and more is desired the upper punctum can be also occluded. Occluding the upper punctum requires more skill and experience, as gravity tends to pull the occlude out. Everting the upper lid may help in insertion. Similar to the lower lid it is good science to work on one lid at a time, starting with a temporary occluder. The reason to start with temporary occluders is that patient can get used to them and if for any reason there is overflow of tears it will resolve quickly. Once mutual satisfaction is established between doctor and patient progression can be made to intermediary or even permanent plugs. We use permanent plugs as a last resort, as they are difficult to remove and may serve as a nidus for infection.

Don't worry, in experienced hands this is a quick and pain free procedure requiring only topical anesthesia. The procedure takes a few seconds and can be easily repeated.

Type	Temporary	Intermediate	Permanent
Material	Collagen	Synthetic Polymer	Silicone or Acrylic
Duration	2-4 weeks	3 -6 months	Lasts for years
Usage	Diagnostic	Lasik/ Therapeutic	Therapeutic
Dissolution	Dissolves in few weeks	Slowly dissolves over months	Inert

Figure 12.8 Comparison of punctal occluders.

Punctum occluders have recently been used to serve as a drug delivery vehicle for medications such as Dextenza.

Heat Cautery Closure

Heat is applied with a ball cautery. This special instrument has a ball which concentrates heat and transmits to a projection which is inserted into the punctum. Yes, this procedure is only performed under local anesthesia. Radiofrequency controlled needles may also be used.

Surgical Closure

The final option is to do traditional surgery. The patient is put under anesthesia and a regional, non-absorbable suture is used to hold the punctum in place.

Surgery

If the lids are everted, paralyzed or have a tumor, surgical solutions with an oculoplastic surgeon may be considered.

Am I at risk for dry eyes?

You might be more likely to have dry eye if you:
-Are age 50 or older
-Are female
-Wear contact lenses
-Don't get enough Vitamin A (found in foods like carrots, broccoli, and liver) or Omega-3 fatty acids (found in fish, walnuts, and vegetable oils)
-Have certain autoimmune conditions, like Lupus or Sjögren Syndrome
-Live in an arid region like Southern California or Arizona

If you have a combination of the above factors, you may be more likely to suffer from dry eyes.

Chapter 13. Risks & Complications

Worst case scenarios?

Early in my career in Santa Monica, California, a patient asked me what the chances of complications of cataract eye surgery were. Fresh from training, I rattled off the numbers. She retorted that she would rather choose another surgeon who claimed that he never had any complications. I patiently replied that there were only two kinds of surgeons who never had any complications - the ones who never operated and the ones who lied. She did not believe me. She investigated and approached the head of the department of the hospital where we operated. She found out that the "no complication surgeon" did in fact have complications but he did not believe them to be complications. That was a new one for me. Needless to say, the patient trusted me to operate on her and she had a great outcome.

It may surprise you to learn that cataract eye surgery is one of the safest eye surgeries. PIE is performed on patients younger than those who have cataract surgery; therefore, PIE has an even better safety profile. Patients undergoing PIE usually are in better physical health. They are free from systemic diseases like diabetes or hypertension. They are less likely to suffer from eye diseases like blepharitis. PIE is akin to Lasik eye surgery for many patients.

Yet sometimes there may be an undesirable result. Our whole focus is to prevent such an occurrence. In the remote chance if a complication does occur it is in everyone's interest to detect it as soon as possible, discuss the options and work as a team. The information should be shared and a treatment plan instituted right away. There should be no embarrassment on the surgeon's part if he needs the expertise of another surgeon to resolve the situation.

Our approach to risks and complications has been to devise a strategy how to avoid them. To achieve this goal, we like to classify them based on how they can be prevented. Some may have more than one source of origin and they require an advanced strategy.

We will classify on how complications can be prevented by interventions, before PIE, during PIE, after PIE and those related to implants.

Before the PIE Procedure

Under and overcorrection of vision: Anomalies in axial length of the eye measurement can account for this. Older methods of eye length measurements like contact ultrasound or older models of IOL master and similar machines are a leading cause. Failure to recognize previous eye surgery especially, Lasik and PRK can contribute to errors. Utilizing the correct formula and cross checking various IOL generation formulae is also important. Cornea curvature has a greater influence on the final power of the implant generated. Poor surface tear film can play havoc with cornea curvature data. Cross checking these on multiple instruments and repeating them another day prevent these mishaps.

Residual or induced astigmatism: Failure to obtain spectacular corneal shape measurements can rear its ugly head as residual astigmatism. Poor topography can miss keratoconus, keratoglobus, or pellucid marginal degeneration

too. A plan to treat astigmatism must be developed as discussed in a previous chapter.

Corneal edema or decompensation: The inner lining of the cornea is a pump that actively removes water out of the cornea to keep it clear. Increased corneal thickness can be detected by pachymetry and is indicative of poor endothelium function. In such cases and those with known endothelium abnormalities, like Fuchs cell count, should be obtained.

During the PIE Procedure

Corneal edema or hazy cornea: Modern surgeons use cohesive viscoelastic to coat and protect the cornea, especially in a compromised cornea. The fluid used in the surgery may enter into the clear cornea, making it milky and causing blurry vision. The inner lining of the cornea is a pump that actively removes water out of the cornea to keep it clear. The use of excessive energy or ultrasound in the eye can cause reversible or irreversible shock to these cells. Touching the inner surface of the cornea can permanently damage the cells. Cornea, edema usually resolves with time, aided by the use of hypertonic saline.

Inflammation or Uveitis: The entire body responds to any insult or trauma. The eye also considers a surgery as a violation. It releases white blood cells from the blood vessels supplying it into the anterior chamber. Pigment released from the colored iris and blood cells add to this mixture. This inflammation or anterior uveitis is usually minimal and quickly resolves. Excessive uveitis causes blurred vision, redness and pain. The surgeon should do gentle surgery and avoid traumatizing the iris. Nonsteroidal anti-inflammatory and steroid drops aid in the resolution. People with a deeply pigmented iris may take longer to resolve.

Zonular Dialysis/Implant shift: This condition is more common in people with Marfans Syndrome and Homocystinuria. It can also express in Pseudoexfoliation. The fibers supporting the lens bag are loose and weak It can be exacerbated by increased pressure on the lens and zonules during the surgery. Therefore, the natural lens and the implanted lens can move in anterior posterior direction. In this case, Crystalens should not be implanted. A 3-piece presbyopic implant is a better option.

Capsular Tear or Rupture: The integrity of the lens bag is very important for ideal outcomes with PIE procedure. We can still get great outcomes if we follow certain principles. If there is a tear in the front or anterior capsule then Crystalens cannot be implanted; however, other presbyopic implants could still be safely positioned. If there is a tear or hole in the posterior capsule, that is the capsule which is behind the implant, then the strategy is different. If there is vitreous jelly protruding through the hole, then an anterior or pars plana vitrectomy with high speed cutter needs to be done. Preservative free steroid solution like Triamcinolone can improve the visualization of this colorless jelly. A proper assessment of the anatomy is necessary A Crystalens insertion would not be possible after a rupture, but a single piece or three-piece lens may still be safely implanted in the capsular bag. Only a three-piece implant should be inserted over the anterior capsule.

***Blood in the Anterior Chamber*:** Trauma to conjunctiva or the iris allows blood to seep into the anterior chamber. This is augmented in patients on blood thinners, like aspirin, or anticoagulants like Warfarin. Minor amounts obscure vision. The blood clears with time. Sometimes, larger amounts of blood can accumulate after the surgery and form a clot, especially if stents are inserted in the trabecular meshwork. Intraocular pressure has to be monitored. The clot may require aspiration.

Wound Leak and Iris Prolapse: An improperly constructed wound may allow the iris to bulge forward and through the wound. Predisposing factors are small eyes, patient squeezing due to anxiety and high vitreous pressure. Switching to a properly constructed wound or intravenous mannitol can counteract this problem. It can also be circumvented by constricting the pupil with Miochol or Miostat. Protrusion of the iris after the procedure can cause inflammation and provide a channel for microorganisms to enter the eye. In cases that are detected approximately within 48 hours the eye pressure can be lowered and the iris pushed back. If the pressure is not detected until later, then the protruding iris may need to be excised.

Seidel's test is a good way to detect a leak. Colored dye is instilled on the eye and blue light is shone onto the eye. Colorless fluid escaping the eye is detected against the blue background.

After the PIE Procedure

Regular follow up visits with the operating surgeon is very important. A well performed procedure can still face unexpected problems.

Increased Intraocular Pressure: Residual viscoelastic jelly clogging the drainage channels is the usual cause of the rise in eye pressure. That is why it is good to check the eye pressure at the end of the procedure, as well as between four to thirty-six hours after the procedure. After the procedure, the drainage channels may also become compromised by trauma, inflammation, and mechanical blockage by red blood cells. Mild increase in eye pressure can resolve on its own or with drops. Eye pressure twice the normal amount requires burping the wound to allow the viscoelastic to escape. This is done under an antibiotic cover at a slit lamp.

Cystoid Macular Edema: The procedure and the thinner implant may allow vitreous to move around tugging on the macula and its blood vessels. Leakage of vessels can occur. This can be detected early on OCT and monitored. Steroid drops, steroid pill or intravitreal steroid resolve the problem. Hypertension, diabetes, posterior capsule tear, vitreous loss and vitritis predispose to this situation.

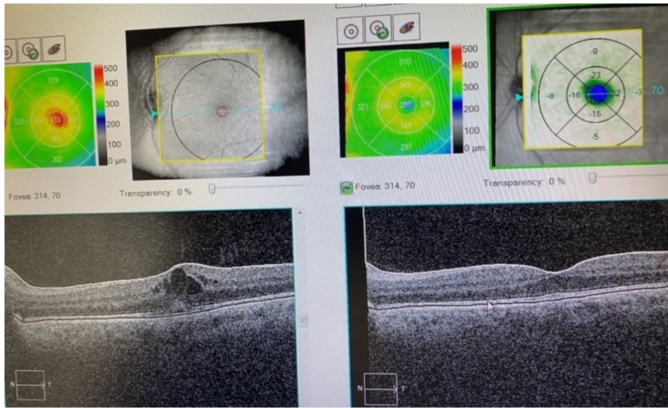


Figure 13.1 On left OCT shows elevation of macula due to fluid. On right side resolution after steroid treatment.

Vitritis: As a result of trauma to vitreous, cells from blood may invade the vitreous chamber. It is seen with posterior capsular rupture, prolonged surgery, lens pieces in the vitreous jelly, injecting vitreous with medicines with preservatives and systematic diseases. Early onset can distinguish it from infection and amenable to treatment with steroidal and non-steroidal drops. Vitrectomy may be rarely required in extreme cases that affect transmission of light and hence vision.

Retinal Detachment: It is the separation of the neurosensory retinal layer from the retinal pigmented epithelium due to entry of fluid to through a retinal hole or tear. High myopia posterior capsule tear, vitreous traction, vitreous inflammation, excessive exercise or lifting heavy weights are predisposing factors. Early

detection and intervention with pneumoretixopexy or injection of gas with laser helps. May require further surgery.

Endophthalmitis: This is the most rare but dreaded complication. An infection of the eye manifesting three to ten days after surgery (versus immediate onset of inflammation). We focus on preventive steps including preoperative and postoperative antibiotic drops, betadine (povidone-iodine) scrub of the eye prior to and at end of the procedure, attention to detail in draping, and sterile conditions during surgery. People with low immunity, diabetes, wound leaks, complicated surgery, exposure to germs in hospitals and who touch their eyes have a higher chance of this condition.

It manifests with severe pain, redness, and decreased vision. The anterior chamber and vitreous cavity appear hazy with cells. Treatment requires a vitreous sample for cultures, injecting steroids and antibiotics in the vitreous. Vitreous debulking or vitrectomy with further intra-vitreal drugs may rarely be required.

Side Effects Related to Presbyopic Implants

G*lare and Haloes:* This may be considered a side effect of the way presbyopic implants function. Rings around lights are a common early feature of the implants and is directly correlated to the number of rings. Crystalens has the least and Tecnis the greatest amount. Symfony displays instead as a spider web.
Most people adapt very quickly. Some require yellow tinted, or blue blocking glasses. A good strategy is to avoid driving in the fast lane, avoid looking at headlights from oncoming traffic and to look above taillights. By focusing on halos or glare, they can become imprinted on the brain. It's reassuring to remember these symptoms eventually go away.

Figure 13.2 Extreme glare and haloes

Shadows: Instead of glare, a person sees shadows. This is more likely to occur at edge of optic zone. The solution is to avoid looking for it and instead ignore it so that neuroadaptation can suppress it.

Flexed Lens or Z Syndrome: This is unique to plate haptic accommodative lenses which are larger than the bag and require posterior bowing. As cells invade from the periphery, they can cause shrinkage of the lens bag with an arm of the lens getting flexed anteriorly. Early laser YAG capsular opening helps prevent and treat.

In and Out Lens: As you may recall, the presbyopic implant has a central optic which is involved in sight and two haptics to position it in the lens bag. When one haptic is in the bag and the other is accidentally placed or migrates outside over the anterior capsule this can cause tilting, leading to imperfections like induced astigmatism, glare and halos. The lens needs to be implanted symmetrically in the capsular bag. After implantation all implants should be rotated to confirm their position. When the lens is place in the bag it rotates smoothly. If one haptic is outside there is hindrance to rotation. In doubtful cases the lens may be rocked to confirm position. When detected the lens

should be rotated back in either in the office or in the surgical suite.

Glistening and Scratches: Glistening was more common in Restor due to the manufacturing process, which has been abandoned. Scratches can rarely be found in any lens due to manufacturing or poor handling. They rarely have visual consequences, but they could cause glare or halos.

Above mentioned risks may appear very scary but remember, they are very uncommon and even if they do occur, most resolve quickly with intervention.

Conclusion

An unbiased account has been presented of the latest methods in vision correction surgery. Utilizing Presbyopic Implants in Eye (PIE) is beneficial for people above 45 and the advantages increase with age. This procedure is a lifelong investment. I hope this book has given you scientific information that will help you make intelligent decisions to improve your lifestyle.

About the Author

Rajesh Khanna grew up in India surrounded by poverty. As a young man, he remembers vividly seeing a vendor on the corner selling balloons. The man had only one functioning eye and he thought to himself, "how can people have an opportunity to support their families when they have to struggle with sight?"

That started his journey down the path to eradicate visual deficiencies. Many years later, and with much schooling under his belt, he found that balloon vendor and performed his first charitable corneal transplant. That passion has driven him to be the visual pioneer and leader in his field that he is today.

Dr. Khanna completed his internship at Graduate Hospital in Pennsylvania and performed his residency at Suny Downstate in New York. His fellowship training in Corneal and Refractive surgery was done at the University of Cincinnati in Ohio.

Currently he lectures to the medical community on various ophthalmological topics, as well as appearing on many television and radio shows. He is a syndicated columnist and author. He has been featured in various magazines and newspapers for his contribution to the medical communities and well as his charitable endeavors.

He practices in Beverly Hills and other locations in Southern California, where he lives with his wife. He leads an active lifestyle, regularly playing field hockey and swimming. He enjoys gardening and hiking with his German Shepherd. His patients include other surgeons, various celebrities, as well as the rich and poor alike. His philosophy is that regardless of riches or poverty, each requires the same attention and care.

Glossary

20/20 vision: normal vision acuity

AAAHC: Accreditation Association for Ambulatory Health Care. An organization that promotes patient safety and quality health care.

Ablate: To remove, or vaporize, tissue, using laser energy.

Ablation zone: The area of tissue removed by the laser. Also called the treatment zone.

Accommodation: The ability of the eye's lens to fine-tune focus by flexing-becoming more or less convex-as needed. Accommodation can compensate for minor focusing problems in younger people whose lens and surrounding muscles are still limber and pliable.

All laser Lasik: This term has been used to describe both the Femtosecond laser assisted Lasik.

Ambulatory Surgery Centers (ASC): An outpatient operating room where PIE can be performed. No admission is required. Independent of hospitals.

Anterior ciliary sclerotomy (ACS): A surgical procedure intended to relieve presbyopia. Several small incisions are made in the sclera directly over the muscle that controls the lens. The results of the procedure are poor, and very few doctors perform it.

Antibiotic drops: Eye drops containing medicine that prevents infection by killing or inhibiting harmful bacteria.

Anti-inflammatory drops: Eye drops containing medicine that counteracts inflammation, usually a steroid or a nonsteroidal medicine similar to ibuprofen.

Artificial tears: Sterile eye drops used to lubricate the eyes the same way natural tears do.

Astigmatism: A refractive error caused by an asymmetrically shaped cornea. Rather than being round in shape like a basketball, an astigmatic cornea is shaped like a football, causing light to come to several points of focus instead of meeting at a single point of focus. People with astigmatism experience blurred images or double vision.

Axis: A measurement of the direction of astigmatism. The astigmatic cornea is oval in shape, and axis is the angle of the long direction of the oval against a horizontal line.

Benchmarking: The process of tracking statistical outcomes for the purpose of predicting future outcomes. With PIE, statistics from 1,000 or more procedures can provide a good basis for benchmarking.

Best corrected vision: The best possible vision achieved with corrective eyeglass lenses.

Blended vision: The surgeon sets one eye for distance and the other eye for intermediate vision. The brain is able to retain binocularity.

Board certified: A credential awarded to physicians who have undergone the additional training and proved proficiency in an area by passing a rigorous examination. Ninety percent of ophthalmologists are board certified. If a surgeon is not board certified in ophthalmology, BEWARE!

Cataract: Clouding of the natural lens within the eye, causing blurry vision.

Choroid: Middle layer of the eye containing pigment and blood vessels that provide oxygen and nutrients for the retina

Constrict: To become smaller.

Cornea: The outer, dome-shaped, transparent part of the eye that bulges out at the front of the eyeball and covers the iris and pupil. Its curvature causes light to bend. The cornea provides most of the eye's focusing power. It is the only part of the eye on which LASIK is performed.

Corneal topographer: An instrument that creates a three-dimensional map of the cornea, using computerized analysis.

Crystalline lens: See lens.

Cylinder: One of three measures in an eyeglass prescription. It indicates whether astigmatism is present, and to what degree.

Dextenza: A corticosteroid indicated for the treatment of ocular inflammation and pain following ophthalmic surgery

Dilate: To become larger, as when the pupil enlarges in very dim light conditions.

Diopter: A measurement of how strong a lens is. One diopter lens is one that will bring light from very far to focus at one meter. Thicker lenses have a higher number of diopters. In eye care, it is used to measure your refractive error, or what eyeglass lens is needed to correct your vision. Hyperopia is measured in terms of positive diopters whereas myopia in terms of negative diopters.

Dry eye: A condition characterized by corneal dryness due to inadequate tear production.

Endothelium: The innermost layer of the cornea, a single cell thick, that helps regulate the cornea's hydration.

Enhancement procedure: A secondary treatment with the excimer laser to fine-tune one's visual acuity after the initial PIE procedure. Enhancements take place after vision has stabilized, usually three to six months after PIE.

Epilasik: A variant of PRK in which the epithelium (the clear skin that covers the eye) is peeled off by an automated machine called an epikeratome.

Epithelium: The thin, protective outermost surface of the cornea. It is made up of the same kind of cells as the skin. It also grows rapidly and continually regenerates.

Excimer laser: The type of laser used in refractive surgery to remove corneal tissue. It emits highly precise pulses of ultraviolet light to break up tissue one molecular layer at a time, vaporizing it without generating heat that could damage surrounding tissue.

Eyelid Speculum: A device placed between the upper and lower eyelids to keep the patient from blinking during surgery. It is painless, because the eye is anesthetized.

Farsightedness: See hyperopia.

Femtosecond laser: An ultra-short pulse of light, used to make bladeless incisions on the cornea, make opening in the lens capsule and cuts in the lens in PIE or cataract surgery. It is also used to make flaps for Lasik.

Floaters: Deposits of various size, shape, consistency, refractive index, and motility within the eye's vitreous humor, which is normally transparent. Usually result of posterior vitreous detachment

Food and Drug Administration (FDA): The federal agency that regulates the manufacturers and distributors of drugs and devices.

Ghosting: The appearance of double images or shadows around images. Ghosting is sometimes experienced by people with astigmatism and can also result from irregular healing of the corneal surface after LASIK.

Glaucoma: A disorder of the eye characterized by an increase of pressure within the eyeball.

Halo: A side effect of Lasik and presbyopia implants in which the patient sees a glow around lights at night. Halos usually decrease over time.

Haze: Scarring of the corneal stroma, or corneal bed.
Significant haze occurs rarely after PRK and does not occur after Lasik.

Higher-order aberration: Irregularity of vision that cannot be corrected by glasses or contact lenses.

Hyperopia: Also known as farsightedness, hyperopia occurs when the eyeball is too short from front to back or when the eye's focusing mechanism is too weak, causing light rays to be focused behind, rather than on the retina. People with hyperopia see objects at a distance more clearly than close up but usually have difficulty with both distance and near vision.

Induced astigmatism: A rare complication of PIE in which astigmatism develops after the initial surgery. Most people can tolerate a small degree of astigmatism. In more serious cases, induced astigmatism can be treated with LRI.

Inflammation: A localized response to an injury that results in redness, heat, pain, and swelling and that can result in tissue damage if left untreated.

Informed consent: A legal form a patient is asked to sign that thoroughly discusses the risks, benefits, alternative options, and possible complications of PIE.

Intralase: A femtosecond laser that helps the surgeon create the flap by creating thousands of tiny explosions in the cornea. The surgeon then dissects the flap free with a blunt separator. Some surgeons prefer Intralase, while others prefer the newer automated microkeratome that does not require manual dissection of the flap.

Intraocular pressure: The pressure exerted by the fluid within the eye that gives it its firmness and round shape.

Iris: The colored ring of tissue in the eye that is behind the cornea and in front of the lens. The muscles of the iris can adjust the size of the eye's opening, or pupil, to allow for larger or smaller amounts of light to enter the eye.

Keratectomy: Surgical removal of any part of the cornea.
In the context of Lasik, keratectomy is the flap- making part of the procedure.

Keratomileusis: Any process of carving, or reshaping, the cornea.

Lamellar: An adjective meaning "layered." Lamellar corneal surgery corrects focusing errors by removing or reshaping some of the corneal layers.

Laser thermal keratoplasty (LTK): A technique that uses heat energy to change the shape of the cornea and that is designed
correct only low amounts of farsightedness. A special laser is used to deliver laser energy to the peripheral cornea to slightly tighten the fibers and thereby steepen its curvature. The LTK procedure may also be useful for treating occasional overcorrection from Lasik procedures. It is similar to conductive keratoplasty (see chapter 9) but has largely been abandoned, because it was found that the effect wore off too quickly.

Lasek: A variant of PRK in which the epithelium (the clear skin that covers the eye) is removed by loosening it with an alcohol solution. The results are the same as those of PRK.

Lasik: An acronym for laser in-situ Keratomileusis. In Lasik, a miniature-automated instrument called a microkeratome creates an extremely thin, hinged flap on the surface of the cornea. After the flap is gently lifted back, the surgeon reshapes the corneal stroma, using an excimer laser. The corneal flap is then replaced, and it quickly adheres. Lasik is a safe and pain-free form of refractive eye surgery that has proven to be highly successful and popular.

Lens: The globe-shaped natural lens of the eye, located behind the iris, that helps fine-tune the angle of light to bring it to a point of focus on the retina. As the lens becomes less flexible with age, its ability to adapt its focus for reading gradually decreases.

Lensx: A femtosecond laser approved by FDA to be used in cataract procedure. It can make precise cuts in cornea and lens.

Limbal Relaxing Incision (LRI): Peripheral corneal arcuate incisions made to decrease astigmatism.

Microkeratome: The instrument a surgeon uses to create the corneal flap in the uppermost layer of the cornea during the Lasik procedure.

Monovision: A process by which a doctor corrects one eye for seeing at a distance and the other eye for seeing objects close up.

Myopia: Also known as nearsightedness, myopia is due to a cornea that has too much curvature or to an eyeball that is too long, causing light to be focused in front of, rather than on, the retina. People with myopia have difficulty seeing objects at a distance.

Nearsightedness: See myopia.

Nomogram: The surgeon's formula that is entered into computer software calculation to further refine the manufacturer's recommended settings.

Ophthalmologist: A medical doctor specializing in the diagnosis and medical or surgical treatment of eye diseases.

Ophthalmology: The field of medicine dealing with diseases and conditions of the eye.

Optic nerve: A bundle of nerve fibers, about the diameter of a pencil, that connect to the nerve fiber layer of the retina and terminate in the brain. The optic nerve carries the visual

messages from the photoreceptors of the retina to the brain, where images are created and processed.

Optometrist: An eye-care professional specializing in the examination, diagnosis, treatment, management, and prevention of diseases and disorders of the eye. Optometrists do not perform surgery, but otherwise perform many of the functions that ophthalmologists do. Optometrists are often general eye-care providers and can provide preoperative and postoperative care for Lasik and other refractive surgery patients.

Overcorrection: A complication of PIE when the amount of correction resulting from the procedure is more than intended.

Peripheral vision: The ability to see objects and movement outside of, or on the periphery of, one's direct line of vision.

Photoablation: The process of removing, or vaporizing, tissue by means of laser energy.

Photorefractive keratectomy (PRK): A type of laser vision correction that removes the outer epithelial layer of the cornea and reshapes it by ablating, or vaporizing, the corneal tissue one microscopic layer at a time, using an excimer laser. Unlike with Lasik, in which a hinged corneal flap is first made and lifted back to expose the corneal bed, with PRK the sculpting process is on surface of the cornea.

PI: Presbyopic Implant, an implant designed to correct presbyopia. Synthetic inert artificial lens which when implanted into the eye allows one to see at all distances

PIE: Presbyopic Implant in Eye, a procedure which reverses presbyopia

Presbyopia: Often confused with farsightedness, presbyopia (literally, "old eyes") is the age-dependent need for reading glasses or bifocals, caused by the decreasing ability of the eye's lens and surrounding muscles to fine-tune focus.

Posterior Vitreous Detachment (PVD): When the vitreous jelly liquefies and separates from the neurosensory retina. May lead to retinal detachment.

Prescription: A series of numbers that instruct someone how to provide a patient with the proper eyeglass or contact lens (see also refractive error).

Punctum plugs: Used in the treatment of dry eye, this tiny collagen, plastic or silicone plugs are inserted into the tear-drainage openings of the eyelid to delay the drainage of natural tears so the eyes will stay moist.

Pupil: The small black dot, or opening, in the center of the iris. The pupil changes its diameter in response to changes in lighting.

Radial keratotomy (RK): A form of refractive surgery in which the surgeon alters the shape of the cornea by making thin incisions around it in a spoke like pattern. The incisions cause the central portion of the cornea to flatten, treating myopia and astigmatism. RK is not performed anymore.

Refract: To bend, as when light passes through a curved shape such as a cornea or lens.

Refraction: The art of measuring the refractive error of the eye. Also, a synonym for refractive error.

Refractive error: The eyeglass prescription needed to correct your vision. Refractive error has three parts: sphere (how

nearsighted or farsighted you are), cylinder (how much astigmatism you have), and axis (the angle of your astigmatism).

Refractive surgery: Any type of surgery that changes the focusing power of the eye in order to correct a refractive error. PIE is a type of refractive surgery that corrects the eye's focusing ability by exchanging the lens of the eye.

Regression: A potential complication of Lasik in which the vision tends to drift back, or regress, toward its original refractive error.

Retina: The light-sensitive layer of cells on the inner back surface of the eye that processes light and functions much like film in a camera. The retina converts light into electrical impulses, which are transmitted along the optic nerve to the brain, which in turn interprets the impulses as images.

Secondary membrane: Haze forms in the lens capsule after removal of natural lens. Develops months to years after PIE.

Sclera: The tough "white" of the eye that makes up five- sixths of the outer layer of the eyeball. Along with the cornea, it protects the eyeball.

Scleral expansion bands (SEBs): Used in surgical reversal of presbyopia, these thin silicon bands are implanted in the sclera to expand the equator of the eye. The theory behind SEB is that expansion of the eye will allow increased room for the lens to move normally, enabling the eye to see nearby objects again. A number of studies now suggest that this procedure is ineffective.

Snellen eye chart: The standard eye chart used by eye doctors to determine visual acuity.

Sphere: One of three measurements taken during an eye examination to arrive at one's eyeglass prescription. The sphere measures where the eye focuses light on the retina (normal vision), in front of the retina (myopia), or behind the retina (hyperopia).

Starburst: A visual aberration in which the patient sees rays radiating from lights viewed at night. Sometimes experienced by patients who have undergone RK and Lasik.

Stroma: The strong, fibrous layer that makes up 90 % of the cornea's thickness and provides the cornea with its structure and shape. Also called the stromal bed, this is the part of the cornea sculpted with the laser in Lasik surgery.

Surgical Reversal of Presbyopia (SRP): See scleral expansion bands.

Tonometry: The measure of intraocular pressure, or the pressure inside the eye.

Topical Corticosteroid: A medicated eye drop that prevents inflammation of the eye tissue after surgery.

Under correction: A complication of PIE; results when the amount of correction resulting from the PIE procedure is less than intended. Most under corrections can be treated with an enhancement procedure.

Visual acuity: The sharpness or clarity of vision that enables one to distinguish fine details and shapes.

Vitreous humor: The gel-like substance composed of about 99 percent water, which fills the main cavity of the eye between the lens and the retinal wall.

YAG laser: Yttrium aluminum garnet laser, which produces a short pulse, high energy beam of light that removes or cuts tissue.

Wavefront analysis: A measurement of irregularities of the eye performed with light rays.