Eximer Laser Photorefractive Keratectomy

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Forward

Photorefractive surgery has been developing rapidly in recent years, and the laser photorefractive keratectomy (PRK) has been one of the most popular technology of the 21st century. The effectiveness of PRK has made many oculists to believe it as the "savior" of the field. With a comparatively short history, photorefractive keratectomy has been documented to be with great precision, relatively simple procedures, fewer complications and excellent predictability. The new technology has been widely adopted in China, even in hospitals of primary levels.

It is found that few reference books are available on the field. Relevant findings are scattered in documentation. In order to systematically introduce eximer laster photorefractive keratectomy, we compile the book based on the documentation and clinical practices both home and abroad. Due the advancing technology and our limited expertise, the book may have errors. We are looking forward to your comments.

Writers

June 1, 2000

Preface

After graduation from the Department of Medical of Kaoshiung Medical University, Taiwan, I decided to take further study of ophthalmology, my favorite subject, and become an ophthalmologist as my career. After completing the training of resident ophthalmologists and taking the jobs as a doctor in charge and chief physician, I went to the USA in 1994 to take further study at Harvard University, USA. After I gained yhr master degree of public health in 1996, Imet Dr. Dimitri Azar, Chief Professor of laser refractive ophthalmology of Harvard University. With his recommendation, Ihad the opportunity to act as a researcher of laser refractive ophthalmology at Massachusetts EYE and EAR Infirmary of the Harvard University. It was thisopportunity that helped me to lay the foundation for my career in the field of professional laser refractive surgery. I stayed in the USA for about one and a half year. In addition to professional knowledge and technique in ophthalmology, I learned much about Western language and culture. When coming back to Taiwan in the autumn of 1997, I worked as a teacher of health care management and clinician at Taipei Medical University, Taipei Clooege of Nursing, the National Oper University, Taipei Pojen General Hospital, Honyen General Hospital, Sheher Clinic, and LaserOne Clinic. In 2001, Iand my friends created Nobel Eye Serrice Group in Taipei with laser refractive surgery as the major service. Since then, more than 20,000 patients have been serviced by outstanding ophthalmologists of our clinic. In the future, I hope that we can share experience with our colleagues and patients at everyphase of our career.

To inprove the technique and promote exchange of academic experience, I ofter take part in conference or workshops of laser refractive surgery. Especially, I am much interested in the academic conference in China. I am invited ot give speeches in China very often and surprised about the vast territory, abundant resources, and rich cultural heritages of China. The professional knowledge and technique of ophthalmologists inChina are so amazing that I deeply recognize their achievement in the field of laser refractive surgery. I knew Dr. Xu Shen and Dr. Fan Yu-Xiang, authors of this book, when I was invited for the Cross-Strait Ophthalmologic Clinical Conference, held in Cangzhou

City of Hebei Province, in 2001. Dr. Xu Shen and Dr. Fan Yu-Xiang were, respectively, the chief physician and doctor in charge of the ophthalmologic department of Cangzhou Central Hospital. Since this book has rich contents and complete structures, both the authors agree with the publisher and me during the 2002 Chinese Ophthalmologic Conference in Taipei to modify part of its contents and translate it to traditional Chinese. The new versions are printed at the end of 2004 and Taiwan is the location where this book is first published outside China. I am so proud of this achievement.

The book is eivided into nine chapters: Chapter One Anatomy and Histology of Cornea; Chapter Two Development of Surgical Treatment of Refraction Error; Chapter Three Principles of Eximer Laser Photorefractive Keratectomy; Chapter Four Preoperative Screening of PRK Cases; Chapter Five Basic Procedures and Postoperative Treatment of Eximer Laser Keratectomy; Chapter Six Complications of Eximer Laser Keratectomy; Chapter Seren Eximer Laser In-situ Keratomileursis; Chapter Eight Repeat Photorefractive keratectomy; and Chapter Nine Eximer laser Phototherapeutic keratectomy. The book also has two appendixes: Appendix I Technical Guidelines for PRK, ALK, and LASIK Treatment of Amertropia Stipulated by the Keratopathy Group of the Ophthalmology Society under China Medical Association in December of 1995; and Appendix II Outline of Examination for National Large Facilitates Operators (Eximer Laser Equipment Doctor).

I would like to show my appreciation to Dr. Xu Shen, Dr. Fan Yu-Xiang, and Tainjin Science & Technology Publisher, and Mr. Chou Hwa Yue, President of Taiwan Hongshin Culture Business. I also want to show my appreciation to all my friends ho have taken care of me when I was in Chine for academic conferences. No matter whether in China or Taiwan, this book would not be published on time without their endeavor and assistance Thank you!

Editor

Chaokai Chang M.D. M.P.H

Taipei Nobel Eye Cliuic, Taiwan

January 15, 2005

Contents

Chapter One

Anatomy and Histology of Cornea

The smooth and transparent cornea which covers the front of the eye and shares a sixth of the fibrous membrane, protects the eye and plays a vital role in the refractive system.

Section One Applied Anatomy of Cornea

I. Shape of cornea

The cornea which appears as a circle when looking from inside of the eye and an ellipse when looking from the outside, is slightly convex with spike-shaped edge and embedded in the corneoscleral. As the iris covers both the upper and lower parts of the cornea, the cornea looks like an ellipse in the front. The 4-mm area at the center of the cornea, known as the optical area or visual area, is almost spherical and gradually flattens as it reaches the surrounding area. The average front surface area of adult cornea is 194 mm^2, approximately 144.8 mm^3 in volume and 170mg to 190 mg in weight.

II. Diameter of cornea

The diameter of newborn cornea is 9 to 10 mm. In the first few years, the cornea grows rapidly that a 3-year-old child has a cornea as large as that of an adult. For male adults, the horizontal diameter of the cornea is 11.5mm to 12 mm, and the perpendicular diameter is 10.5mm to 11 mm; while that of female adults is 0.1 mm smaller than the male adults in average.

If the transverse diameter is over 13 mm, the patient has morbid macrocornea. If it is under 9 mm, the patient has microcornea

III. Thickness of cornea

The thickness of cornea varies with different measuring methods. When measuring with corpses, the central thickness is about 0.8 mm and the surrounding thickness is about 1.0 mm for adult cornea; with slit lamp microscope, the central thickness is 0.583mm to 0.641 mm; with ultrasonic pachymeter, the average central thickness is 0.5mm to 0.57 mm. The thickness increases from 30° and the edge thickness can reach to 1 mm.

For the elders, the edge of cornea tends to be thinner, even as thin as 0.5 mm. For those who have moderate or severe myopia, the edge of cornea also tends to be thinner. The newborns have thicker corneas when compared with the elders. According to Zhang Sufang and Ma Saifeng, the average corneal thickness is 515±4 μm for the adult, 547 μm for children between the age of 6 to 10 and 588 μm for the newborn.

IV. Corneal curvature

The curvature varies at different parts of the cornea. At the central visual area, the curvature remains almost the same while at the center and edge, the cornea tends to be flatter. Any points other than the central area do not have the same curvature radius. It is found that the curvature radius is 7.7mm to 8.4 mm (7.85 mm in average) for the front surface and 7.7mm to 7.8 mm in average for central visual area; the curvature radius is 6.22 to 6.8 mm for the back surface and 6.6 mm in average for the central visual area. The diopter of the front surface is +48.8 m^{-1} (48.8D; 1D=1m^{-1}) while that of the back surface is –5.8D. The absolute diopter of the cornea is +43D, or 70% of the total diopter of the eye.

In theory, diopters are identical on different meridians of the cornea. In reality, the curvature radius of the transverse meridian is 7.8 mm and that of the peripheral meridian is 7.7 mm, indicating a difference of diopter. Clinically, it leads to astigmatism of different degrees.

Section Two Histology of Cornea

Histologically, the cornea is divided from outside to inside as the epithelial cell layer, the front elastic membrane layer, the stroma layer, the back elastic membrane layer and the endothelial cell layer (see fig. 1).

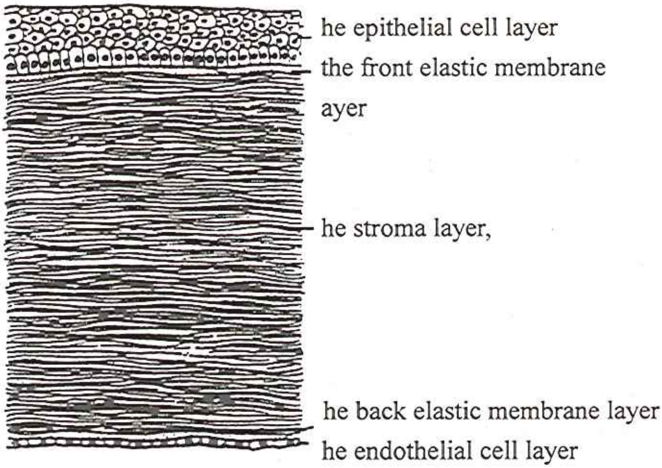


fig. 1 A cross-section of corneal tissue

I. The epithelial cell layer

The epithelial cell is composed of pavement epithelial cells and basal membrane. The newborns have four layers of cells for while anyone over 6 months has six layers. The epithelial cell layer, 50μm to 90 μm in thickness, is an extension of the bulbar conjunctiva. The layer consists of three types of cells—the upper pinacocyte (flattened cell), the middle pterygoid cell (winged cell) and the lower columnar cell. Under normal physiological conditions, the lower cell will continuously reproduce and move towards the surface; meanwhile the cell will become more flattened. The upper flattened cell will degenerate and fall off from the surface. The life of the epithelial cell is about 7 days to 19 days.

1. **The upper layer:** consist of 2 to 3 layers of polygon pinacocytes (flattened cells); it has tiny villi and creases with functions ① to keep the integrity of tear film and ② to facilitate absorption and exchange of nutritions and waste in the tear.

   Superficial cells are connected with zonula occludens and desmosomes while mosaicism cells at the deeper level further strengthen the upper layer's function as a barrier.

2. **The middle layer**: consist of 3 layers of polygon middle pterygoid cells (winged cells); it is located below the upper layer. With larger level area, the cell looks like a wing thus named as winged cell. Lower columnar cells will move into the middle layer as they reproduce.

3. **The lower layer:** consist of a single layer of columnar cells which are regularly arranged like a fence. The level bottom of the lower layer is closely linked to the basal membrane. The layer is the center of mitosis, with vigorous reproduction of epithelial cells.

4. **The basal membrane**: produced by epithelial cells and located between the epithelial basal cell in the cornea and the front elastic membrane layer. 30μm to 60 μm in thickness, the membrane consists of irregular collagen

fibers without cellular structure. The deeper fibers of the basal membrane are embedded in the front elastic membrane and they are linked together. When the corneal epithelial cell is removed, the hemidesmosome structure of the basal columnar cell and the basal membrane may be left to repair the damaged epithelium.

Corneal epithelial cells are highly reproductive. One to five days after the removal of most epithelial cells, they will reproduce rapidly to cover the whole surface. However, when the basal membrane is damaged, it takes months to re-establish the anatomic structure between the basal membrane and the front elastic layer. The epithelium without a basal membrane, though appears intact, falls off easily.

II. The front elastic membrane layer

The front elastic layer which is a collagen fiber membrane located below the basal membrane is composed of a very thin and irregular collagen fibers. The even and transparent layer does not have a cellular structure. In fact, it is not a real elastic membrane but part of the upper stroma layer.

The front elastic membrane layer is a littler thicker than the back elastic membrane layer (about 10μm to 13 μm) and the thickness remains the same throughout its life. The smooth surface of the front elastic membrane layer makes the epithelial cell layer separate easily. Many arch-shaped fibers are embedded in the stroma layer; so the front elastic membrane layer is adhered to the stroma layer.

There are many tiny holes or vessels in the collagen fibers of the front elastic membrane that function as a passage for nerve fibers to grow from the stroma layer to the epithelial cell layer. When the cornea is infected, swollen nerve fibers will be found here.

The collagen fibers of the front elastic membrane layer are produced by epithelial cells during the embryo period; thus, it is unable to reproduce when damaged.

III. The stroma layer

The stroma layer, also called the substantial layer, is a vital part of the cornea. As thick as 90% of the cornea, it is composed of collagen fibers, corneal cells and extracellular sticky materials.

1. **Collagen fibers:** The stroma layer consists of 200 to 250 collagen masonites (fibrous layers) which are interlocked. Each fibrous layer, approximately 1.5μm to 2.5 μm in thickness, consists of parallel layers of collagen fibers which are about 30 nm in diameter (300 Å; 10 Å =1nm). Mucopolysaccharides are widely found among collagen fibers which are closely linked and interlocked. Adjacent fibrous layers are also interlocked at a certain angle or right angle.

The upper one third of the stroma layer is the superficial layer in which fibrous layers are arranged randomly. There are tilting fibers that reach the bottom of the epithelial layer. The tilting fibers and the level fibers are interlocked and form a perpendicular fibrous fence. An interlocking network is formed as a result of tilting fibers, which is 15μm to 20 μm beneath the epithelial cell layer. The histological structure explains why it is difficult to remove the superficial layer and why edema is seldom found in the superficial layer alone.

The other two third of the stroma layer is the deeper layer in which collage fibers are typically fascicularly arranged. The fibrous bands, arranged in the same direction, are completely parallel to the corneal surface; a fibrous band may even extend from one side of the cornea to the other side. Some fibrous bands are split into two or three branches, mixed with the scleral fibers in a sector manner. Many circular fibers are found in the corneal limbus of the deep stroma layer, which maintains a specific curvature of the cornea and a constant diopter at the central area of the cornea.

2. **Corneal cells**: corneal cells are scattered in the space among corneal fibrous layers, including fixed cells, wandering cells and histocytes.

Fixed cells: the major part of corneal cells. In fact, fixed cells are fibrocytes in the connective tissue and main ingredient forming collagen fibers. When the cornea is damaged or infected, fixed cells will change into fibroblasts to produce connective tissue fibers to repair. Fixed cells can last for at least one year.

Wandering cells: come from blood vessels of the corneal limbus and originate from nerve-like tunica vaginalis cells. The amounts of wandering cells are normally few but they will increase and spread to infected areas in case of inflammation or damage. Lymphocytes and plasmacytes may emerge in the late phase of inflammation.

Histocytes: derived from the reticuloendothelial system (RES) and located near the corneal limbus.

IV. The back elastic membrane layer

Produced by epithelial cells of cornea, the back elastic membrane layer is located between the stroma layer and the endothelial cell layer. The layer gets thicker as one grows older—5 μm for children, 8μm to 10 μm for grown-ups and 20μm to 30 μm for the elders. The central part is thinner than its edge which is as thick as the whole cornea. The back elastic membrane ends at the Schwalbe line of the angle. Partial back elastic membrane enters the pectinate ligament of iris.

The back elastic membrane is composed of collagen fibers,

Section Three   Corneal Limbus and Tear Film

I. Corneal limbus

Corneal limbus refers to the transitional area between the transparent cornea and the opaque sclera. With an average width of 1.0 mm, the round-shaped corneal limbus surrounds the transparent cornea. It is widest at the top (1.7 mm) and0.64 mm in average on each side.

1. Difference between corneal limbus, cornea and sclera

Anatomically and histologically, the corneal limbus, cornea and sclera are different.

(1) The corneal limbus is semi-transparent while the cornea is transparent and the sclera is opaque.

(2) The corneal limbus contains plenty of blood vessels and lymphatic vessels while the cornea does not have blood vessels.

(3) The corneal limbus has over ten layers of epithelial cells which are irregularly arranged. Its stroma is thin with pigment. The basal membrane beneath the epithelial cell layer appears wavy, which turns thinner irregularly and passes onto the extremely thin epithelial basal membrane of the conjunctiva.

(4) The front elastic membrane disappears at the corneal

limbus. Its arch-shaped end stops inside the corneal limbus while the extension is replaced by connective tissue fibers.

(5) The stroma loses its transparency at the corneal limbus and passes onto the sclera; and collagen fibers change into irregularity and unevenness.

(6) The back elastic membrane thickens, protrudes towards the angle of anterior chamber, and ends at the schwalbe line of the corneal limbus. Partial fibers turn slimmer and extend to the trabecular meshwork.

(7) Epithelial cells cover the internal surface of the corneal limbus and connect with the trabecular meshwork.

2. The stem cell of corneal limbus and its clinical significance

Researchers have proven that reproduction of epithelial cells and tissues of cornea lies in stem cells of corneal limbus. Stem cells which mostly distribut at the upper and lower part of the corneal limbus and less on the sides play an important role in maintenance of the corneal epithelium and repair of damage. When the corneal limbus is injured or dysfunctional, the corneal epithelium will not heal properly e.g. chemical injury of the eye, cornea diseases caused by extensive wear of contact lenses or pterygium. Deficiency or malfunction of the corneal limbus will affect the change of conjunctiva and turn the cornea conjunctiva-like which leads to newborn blood vessels in the cornea, damage to the basal membrane, infiltrating inflamed cells, etc.

II. Tear film

Tear film, a lay of tear covering the front surface of cornea, is divided into three layers from front to behind—the lipid layer, the tear layer and the mucoprotein layer. Tear film lubricates and protects the corneal epithelia to make the cornea smoother and luster so as to promot the cornea's transparency.

1. **The lipid layer:** excreted by the gland of upper and lower eyelids and composed of fat, triacylglycerol, free sterol, cholesterol-ester and fatty acid. The approximately 0.1-μm-thick layer mainly prevents evaporation of tears.

2. **The tear layer:** excreted by the main and accessory lacrimal glands and mainly composed of water. The about 7-μm-thick layer is the most important part of tear film. Continuous production and removal of tears keeps the corneal epithelium moist and functions as a conveyer of nutrients to epithelial cells.

3. **The mucoprotein layer:** excreted mainly by goblet cells of the conjunctiva and partially by the main lacrimal gland

that is composed of mucopolysaccharides and glycoproteins. The layer with a thickness at 0.02μm to 0.05μm functions as a corneal epithelium cover and to moisten the cornea.

Section Four Blood Vessel, Lymph and Nerve of Cornea

I. Blood vessel of cornea

The cornea does not have any blood vessel, making it possible to keep it transparent. Corneal limbus has plenty of blood vessels that are arranged in the shape of triangle with the pointed top linking the end of the front elastic layer of corneal limbus and the bottom connecting blood vessels of conjunctiva and superficial sclera. Blood vessels in corneal limbus form a series of arch-shaped bands.

The cornea-conjunctiva blood vessel network branches from the anterior ciliary arteries which come from the ophthalmic artery. The seven branches of the arteries reach 4mm to 8 mm away from cornea limbus through four rectus muscles; there the arteries enter the sclera and the ciliary body through behind the venous sinus of sclera (Schlemm's canal). The branched arteries connect the iris arteries to form greater arterial circle of iris. The anterior ciliary arteries which do not penetrate the iris still travel in the anterior layer of iris and branch to be anterior conjunctival arteries. The anterior conjunctival arteries connect braches of posterior conjunctival arteries, forming the cornea-conjunctiva blood vessel network.

Oxygen needed by metabolism of cornea is supplied through air (80%), blood vessels of corneal limbus (15%) and aqueous humor (5%).

II. Lymph of cornea

No real lymphatic vessels are found in the corneal tissue except in where there are blood vessels of corneal limbus.

Lymphatic vessels of corneal limbus are divided into three parts:①. lymphatic vessels parallel to surrounding arteries and veins of corneal limbus; ②. lymphatic vessels not accompanied by blood vessels—above, below or among arched blood vessels of corneal limbus. Some form blind tracts and some are anastomotic; and ③. lymphatic vessels of conjunctiva. Superficially distributed, they often form larger anastomotic braches and even enter the corneal tissue.

III. Nerve of cornea

The cornea has a very dense network of nerve fibers, mainly coming from the ophthalmic division of trigeminal nerve and traveling to the cornea through anterior ciliary nerve. The long ciliary nerve travels to the superficial layer of sclera through around the choroid membrane a few millimeters behind the corneal limbus, extends to the corneal area and connect with the nose ciliary nerve and the lacrimal nerve, forming the nerve plexus of the corneal limbus.

The nerve plexus of corneal limbus sends out 60 to 80 nerve fibers arriving at the superficial layer of the corneal stroma via the corneal limbus. The nerve fibers enter the cornea by 0.3mm to 0.5 mm, where most nerve myelin sheaths change into transparent axis-cylinder fibers to extend into the deep part. The axis-cylinder may split into three principal nerve plexuses—stroma nerve plexus, subepithelial nerve plexus and intraepithelial nerve plexus. Most nerve plexuses split into two or three branches, or T-shaped branches or interlocked branches to form a network.

Subepitherlial nerve plexuses and intraepithelial nerve plexuses (about 30 to 50 branches) form the nerve plexus of superficial cornea. Traveling through the stroma, the nerve fibers are interlocked to form subepithelial nerve plexuses in the front elastic membrane. Some nerve fibers travel through the front elastic membrane, forming intraepithelial nerve plexuses around or inside epithelia.

The nerve fibers in the stroma layer of cornea form deep nerve plexuses (about 40 to 50 branches, distributed in the stroma layer of the cornea). The nerve fiber network is less dense among the deep nerve plexuses. The deeper the nerve plexuses, the denser the nerve fiber network. Generally, there are five layers of nerve fiber networks of various densities which are connected with perpendicular fibers. No nerve fibers are found in the deeper stroma, the back elastic membrane layer and the endothelial cell layer.

Chapter Two

Development of Surgical Treatment of Refraction Error

Refraction error (ametropia) refers to the condition that parallel light is unable to precisely focus on the retina through the refractive system when the eye is at rest. For those with stronger refractive power, the focus is located in the vitreous body in front of the retina, leading to myopia (nearsightedness). For those with weaker refractive power, the focus is located behind the retina, leading to hypermetropia (farsightedness). When the exterior light is unable to focus at one point, astigmatism occurs. Statistics both at home and abroad indicate that myopia is the dominant of refraction error cases, which has a tendency to increase. In the latest century, various surgeries have been devised to correct myopia but there is no permanent, safe and effective cure yet. On the basis of surgical technology, surgery for myopia treatment is divided into photorefractive surgery not involving the cornea and photorefractive surgery of the cornea.

Section One Photorefractive Surgery not Involving Cornea

I. Intraocular photorefractive surgery involving the lens

Intraocular photorefractive surgery involving the lens is divided into extraction of transparent lens, combination of extraction of transparent lens and implant of posterior chamber intraocular lens, implant of anterior chamber intraocular lens into lens eyes.

1. **Extraction of transparent lens.** In 1708, Hermann Boerhaave put forward the idea of treating nearsightedness by removing the transparent lens. In 1894, Fukala reported for the first time that extraction of transparent lens was used to treat severe myopia. However, high incidence of complicated retinal detachment prevented its application. In recent years, the operation is reconsidered as the development of modern extracapsular extraction of cataract and phacoemulsification. In theory, extraction of transparent lens is able to correct severe myopia.

   In practice, severe myopia is often accompanied by vitreous liquifaction, condensation and posterior detachment and peripheral retinal disorder. In addition, when the lens is removed, its support to the vitreous body disappears. As a result, retinal detachment and cystoid macular edema easily occur following the operation. The higher degree, the higher incidence.

What's more, the patient may suffer from posterior membrane opacity due to surgical irritation, residual cortex and epitheliogenesis of posterior membrane. Incision of posterior membrane might lead to other complications.

2. **Combination of extraction of transparent lens and implant of posterior chamber intraocular lens.** In the early 1990s, extraction of transparent lens and implant of intraocular lens has been used to treat severe myopia both at home and abroad. Take the SRK II formula for example, those with positive SRK value will be implanted with convex lenses of proper diopter (increased by 1 to 2D for those working at desk); those with negative SRK value will be implanted with plane lenses. Compared with the extraction of transparent lens, this treatment promotes stability of anterior part of the eye and enlarges diopter range. Unfortunately, specific high-quality lenses and precise ultrasound measurement of eyeball axis are required. Once the retinal detachment occurs after the operation, it is more difficult to search for the retinal hole and to conduct the operation.

3. **Implant of anterior chamber intraocular lens into lens**

eyes. Soon after the implant of intraocular lens was used to treat non-lens eyes, researches were conducted upon the implant of intracular concave lens into lens eyes to treat myopia. In 1953, Strampelli conducted such operation for the first time. Barraquer reported 239 cases in 1959 and Choyce reported 12 cases in 1964. However, the surgery had to be given up due to severe complications such as chronic iridocyclitis, bleeding of anterior chamber and corneal dystrophy. Many years passed which were characterized by fast developing ophthalmologic microsurgery and perfected production of intraocular lenses.

In 1989, Fechner and Worst reported that instead of removing the lens, they implanted intraocular concave lens into anterior chamber of the eye to treat myopia. Eight-four eyes were treated with serious complications. Fechner and Worst devised the intraocular lens that was used to treat lens eyes, or Fechner-Worst double concave intraocular lens. Anterior chamber intraocular lens consists of the chamber corner fixing type and the iris supporting type.

Implant of anterior chamber intraocular lens into lens eyes is found to be simple procedures, stable effectiveness and regulating function. However, it is still to be observed whether the operation will affect the iris, the cornea or the lens.

In short, extraction of transparent lens to treat severe myopia has the advantage of greatly improved sight at early times; but the complications may lead to permanent damage to the eyesight. Implant of posterior chamber intraocular lens with extraction of transparent lens and implant of anterior chamber intraocular lens into eyes with lenses will result in improved eyesight; but complications still exist. Most researchers propose cautious applications.

II. Posterior reinforcement

Posterior reinforcement treats prolonged eye axis and posterior scleral staphyloma of the severe myopia patient. Advanced by Borley and improved by Curtin, Thompson and Nesterov, posterior reinforcement, which has been applied to thousands of patients, is believed to be a relatively safe and effective treatment of severe myopia. In the operation, collagen or other reinforcing material is used to reinforce where the iris is thin, especially the area with posterior scleral staphyloma. Inhibition of posterior scleral staphyloma will stabilize the eyesight and the degree of myopia, prevent development of complications and recovery partial eyesight of severe myopia patients.

Materials for posterior reinforcement can be divided into the self material, the allogeneic material, the heterologous material and the synthetic material.

1. **Self material.** Self fascia lata and tendon is relatively ideal. Clinical observations have found self material to be of good biological compatibility and flexibility and of certain tensile strength. After the operation, surrounding connective tissue is closely connected to the iris, preventing any mobility. No atrophy or absorption is found in the following 3 to 6 months.

2. **Allogeneic material.** The most common materials are allogeic iris, fascia lata, tendon, dura mater, etc. Such material is found to have good biological compatibility and tensile strength. After the operation, surrounding connective tissue may be formed, which is closely connected to the iris, forming blood vessels and slight infiltration. There exist blood vessels and nerves between the implant and the iris, preventing any mobility. Absorption of various degree is observed.

3. **Heterologous iris.** In 1988, Wang Yingfeng applied pig iris to rabbit eyes; the result was observed to be similar to that of the allogeneic material. It is proven that the heterologous iris does not lead to immunological rejection and thus can be used to substitute allogeneic iris.

4. **Synthetic material.** Non-living material is used to reinforce the iris instead of living material, the most popular are polymers. In 1988, Abe-ТИСОВ instilled 0.5 ml polymers into the fascial sac in the upper quadrant of

the eyeball and reported that 95% of the 500 cases, myopia was controlled without side effects. It is believed that the material promotes formation of connective tissue on the surface of the iris and reinforces the eyeball. In 1989, СВИРИИ used hemostatic gel to treat 84 cases among which 84% were relieved. Three years later, it was found that myopia did not worsen. Recently, silicon gel is reported to be used as reinforcement material.

The most common complications of posterior reinforcement include uveitis, vitreous hemorrhage, retinal detachment, atrophy of optic nerve and eyeball movement disorder.

Pathological changes of severe myopia and its damages to eyeball tissues indicate that the disease is not a simple refractive disorder. Morphologically, there exist various severe damages. Considering the longtime effectiveness, treatment of severe myopia with posterior reinforcement has the disadvantages of instability, imprecision and limitation. Thus, its practicability is still controversial.

Section Two Photorefractive Corneal Surgery

I. Radial keratotomy

Radial keratotomy (RK) opens the front surface of the retained corneal visual area in a non-penetrating and radial manner in order to correct eyesight. In the surgery, the front surface outside the visual area is broadened by cutting open in a radial manner so that the visual area becomes flatter, thus reducing corneal diopter and correcting eyesight.

RK started in Japan when Sato cut open the back surface of cornea in 1930. Between 1951 to 1959, sixty-eight RK cases were treated by cutting open the front surface and the back surface of cornea. Bullous keratopathy caused by damage to endothelia prevents its wide application.

In 1972, former Soviet researcher, Fyodorov, summarized Sato's experiences and conducted researches upon cutting open the front surface of cornea. He found that the operation could reduce the diopter of the central cornea by 2-3D. The therapy was put into clinical application in 1974. In order to evaluate the efficacy, safety, stability and predictability of the RK, the US National Health Institute established a research center to conduct prospective evaluation upon RK in 1980. RK had been observed for five years in the United States while Russian researchers carried out similar studies. It is found that the RK is a good treatment for non-developing myopia of lower and medium degrees. However, problems still exist in terms of its predictability and stability as well as safety.

In terms of its stability, it is generally reported that effectiveness remains stable in 3 to 6 months. However, change of diopter lasts for 3.5 years after the operation.

Unpredictability is believed to be the major problem of the RK. Many factors may interfere with the result of surgery, such as biomutation of different patients, expertise of different surgeons, inability to keep all the cuts identical and imperfection of corneal biomechanics.

In terms of its safety, it is reported that there exist over seventy RK complications, which are classified as organic and functional. The organic complications include diffuse superficial keratitis, recurrent erosion of corneal epithelia, corneal opacity, corneal perforation, new blood vessels, hyphema during operation, cataract, interstitial keratitis, degeneration of epithelium basement membrane, star-like siderosis of epithelia, traumatic inclusion cysts of epithelia, ptosis of eyelids, endophthalmitis, contusive wound dehiscence, retinal detachment, etc. The functional complications include unstable eyesight and diopter (daytime eyesight fluctuation and far eyesight fluctuation), night dizziness, postoperative astigmatism (residual astigmatism, irregular astigmatism, postoperative astigmatism), progressive farsightedness, changes of contrast sensitivity, etc.

Potential blindness-causing complications, though rarely reported, are likely to occur. Interstitial keratitis caused by corneal perforation, epithelial hyperplasia, traumatic cataract, late keratitis and progressive farsightedness are troublesome.

II. Keratomileusis

Barraquer first advanced keratomileusis (KM) in 1965 to treat severe nearsightedness, severe farsightedness and non-lens eyes. In the operation, the front layer of the corneal stroma is cut off with the mini-keratome (0.2 to 0.3 mm in thickness and 8.5 mm in diameter). The layer is frozen in the freezer, cut and polished according to computer-determined data and restored to the original place. The method is not effective to non-lens eyes and it can not correct farsightedness over 10 to 12 D. The best treatment range is 5 to 18 D of nearsightedness.

The operation is difficult to conduct and the equipment is expensive, additionally, precise calculation and excellent expertise are required. Moreover, it is risky to obtain material from the cornea and to cut the material under frozen condition. When any error occurs, penetrating corneal implant needs to be conducted immediately.

III. Epikeratophakia

Epikeratophakia (EP) is to cut the donor's cornea into corneal sheets of various diopter which are implanted to the patient's cornea with no epithelia.

In 1977, Kaufman advanced EP, which was to treat non-lens eyes at that time. With more and more researches, epikeratophakia has been used in wider fields and developed into the only photorefractive surgery that is changeable and does not damage the central visual area of cornea. In 1986, researches in the field started to treat non-lens eyes, severe myopia, keratoconus, unilateral non-lens eyes and patients who are unsuitable to have a second intraocular lens implant or willing to wear spectacles. The major disadvantage of the therapy is that the patient recovers slowly, the result is hard to predict, the cutting is not precise and deformation appears when suturing the cornea. The most common complications are excessive or insufficient correction, abnormal epithelization, epithelial implant, dot-like to wave-like opacity, aseptic ulcer and improper match between lens and cornea.

In treatment of severe myopia, epikeratophakia is effective immediately after the operation but unstable in the long run. Degree of myopia tends to rise. Thus, precision and predictability is relatively poor so that its application has been terminated in the United States.

IV. Intrastromal corneal ring implantation

In 1987, Fleming conducted intrastromal corneal ring implantation (ICRI) when he made the PMMA into corneal rings of various diameters and implanted them into the corneal stroma of rabbits. The intrastromal corneal ring (ICR), which is cone-shaped, makes the surrounding area steep, leading to increased curvature in the surrounding area and reduced curvature in the corneal center. In the operation, a radial or oblique cut (about 2/3 of the depth of cornea) is made above where the ICR is to be implanted; a ring-shaped stromal tunnel is made in the stroma of the same depth with a special spiral tunnel knife; and the ICR is implanted. If nearsightedness is to be corrected, the ICR diameter will be increased so that the angle of anterior chamber is increased, the central depth of anterior chamber is reduced, the central curvature of cornea is reduced and the anteroposterior diameter of eyeball is shortened. If farsightedness is to be corrected, reduce the ICR diameter so that the angle of anterior chamber is decreased, the central depth of anterior chamber is increased, the central curvature of cornea is increased and the anteroposterior diameter of eyeball is extended.

In 1995, Kerry reported that computer-assisted video cornea photography, keratoscopy, keratometry and corooscopy revealed that all patients had flattened central area of the cornea and indicated improvement of the eyesight. It was also true with Zadnik and Renato's researches. It was believed that the ICRI had good reversibility, relatively good predictability and wide correction range. However, it was found after the operation that the ICR moved into corneal stroma, corneal tissues changed with the passage of time, implant depth and corneal cut depth interfered with effectiveness. In addition, opacity of corneal ring, deposit inside tunnel and growth of new blood vessels were observed.

V. Kerato epithlil mileusis

In 1990, Krasnov advanced a new type of photorefractive keratectomy—kerato epithlil mileusis (KEM). Between 1990 and 1992, 11 KEM cases were treated, 12 eyes, aged between 21 and 42 years, with diopter range between 7.5D and 22.0D. The implanted corneal ring was made with freezing machine of fresh human cornea from those who died within 12 to 24 hours. The stroma surface of corneal ring was parallel to Bowman's membrane. Computer was used to calculate the size of implanted corneal rings. In order to facilitate epithelial growth of the donor, any point of the ring was made the same thickness except that the brim was becoming thinner. The outside diameter was 7mm to 8 mm, the inside diameter 4mm to 5 mm and the thickness was 0.1mm to 0.25 mm under freezing condition. In the operation, mark on corneal surface the optical axis and central area of the ring; the latter must be identical to the implanted corneal ring. Remove the epithelium and Bowman's membrane without affecting the cornea of the central visual area. Place the prepared corneal ring into ring-shaped cut of the patient's cornea and fix with 10/0 nylon suture. Three to five days later, epithelia fully grew on the implanted corneal ring. The newborn epithelia reached the visual center and gradually the normal depth was restored. The epithelial formation in the surrounding area was not as thick as in the central area, forming biological negative diopter lens. The power of the lens was determined by the size of the implanted ring.

In the operation, the optical axis is not affected, the corneal stroma is hardly injured, the cut on cornea is quite small and no perceptual dysfunction occurs. As the central area is not affected, there is no possibility of dizziness, glucose deficiency in epithelium, anterior stroma ulcer and late disruption of wound. Unfortunately, as the therapy is restricted to animals and eyes of the dead and the follow-up is not sufficient, it is impossible to rule out possibility of complications found in other photorefractive keratectomy such as loss of epithelial cells in cornea, keratitis, eyesight and diopter fluctuation, corneal macula and ocular hypertension.

VI. Eximer laser photorefractive keratectomy

Problems of predictability and complications are widely found in the above-mentioned photorefractive keratectomy. In order to solve the problems as well as to promote accuracy and stability, eximer laser photorefractive keratectomy (PRK) has been put into use with satisfactory results. Eximer laser cuts corneal epithelium and anterior stroma, and corneal epithelium grows again to cover the residual stroma. Thus the shape of cornea is changed to correct refractive errors. In the latest decade, oculists both at home and abroad have been making intensive study of eximer laser photorefractive keratectomy with encouraging achievements. With the development of eximer laser technology, advanced optical system and computerization, operation is simplified and structure of beam is directly observed, so as to guarantee the evenness of the cut area. Eximer laser photorefractive keratectomy is viewed as a safe, effective, predictable, stable and simple way to treat diopter.

Chapter Three

Principles of Eximer Laser Photorefractive Keratectomy

Eximer laser or stimulated eximer laser is a stimulated dimer laser whose active medium is a very unstable compound formed by stimulated combination of inert gases and halogen molecules—*dimer*. The laser is called the "eximer laser" because the medium molecules are extremely unstable whose life is as short as a few nanoseconds. Different inert gas combines with different halogen molecule to form eximer laser of different wavelength in the ultraviolet spectrum (see the following table).

Comparison of eximer laser of various media

Medium	Wave Length (nm)	Peak Value (MW)	Efficiency (%)	Pulse Time (ns)	Size of Light Spot (mm)
Fluorine	157	1	0.1	4.5 ± 0.5	18 × 4
Argon Fluoride	193	5	0.5	4.5 ± 0.5	18 × 4
Krypton Fluoride	248	20	2	4.5 ± 0.5	18 × 4
Krypton Fluoride	223	3	0.25	4.5 ± 0.5	18 × 4
Xenon Bromide	282	2	0.2	4.5 ± 0.5	18 × 4
Chlorine Fluoride	285	1	0.1	4.5 ± 0.5	18 × 4
Xenon Fluoride	308	10	1	4.5 ± 0.5	18 × 4
Nitrogen	337	1	0.05	4.5 ± 0.5	18 × 4
Xenon Fluoride	353	5	0.5	4.5 ± 0.5	18 × 4

Eximer laser of 193-nm argon fluoride has the advantages of short wavelength, high energy, short pulse width, high concentration of light beam, high precision, good repetitiveness and small damages, making it most popular in eximer laser photorefractive keratectomy. At present, the eximer laser is used to: 1. remove the cornea linearly (for radial keratotomy and astigmatism keratotomy); 2. process self and allogeic corneal lenses (for lens cutting and grounding); and 3. cut the central area of the cornea (for photorefractive keratectomy, or PRK). Where the PRK is the most common in the three fields.

PRK refers to the reshaping of the cornea by laser cutting the optical area of the cornea to correct refractive errors. Eximer laser of argon fluoride is used for the longest time and for the most PRK cases. In the book, PRK refers to argon fluoride eximer laser RPK unless otherwise specified.

Section One History of PRK

I. History

Eximer laser is a new type of laser developed in the 1970s and applied to ocular treatment in the early 1980s.

In 1981, Toboada first reported argon fluoride eximer laser's influence upon corneal epithelia.

In 1983, Stephen and Trokel began researches upon eximer laser RPK. Argon fluoride eximer laser was used to cut the cornea of the calf whose eyeball was just removed, with energy density at 1 J/cm^2, the cut depth at 1 μm. It was found that corneal curvature was changed. Pathological section revealed that the cut was level and the surrounding tissue was not damaged. It was believed that laser directly broke molecular bonds. The research laid the foundation of eximer laser RPK.

In 1985, Cotliar conducted radial cutting of various depths upon the corneas of the dead with argon fluoride eximer laser. He observed that the central curve and tissue of cornea was changed and concluded that laser energy was related to the flattened central part of the cornea. The cut of cornea deepened as laser energy increased. Microscopic studies found that the laser cut was quite smooth.

Marshall and Mcdonald cut monkey corneas (3mm to 7 mm in diameter and 40μm to 130 μm in depth) and observed corneal opacity and reversion of correction degrees as well as the relationship among cut depth, cut diameter and correction diopter.

In the same year, Daniele reported that he carried out argon fluoride eximer laser PRK. He believed that histologically, eximer laser cut at the molecular level and removed cut tissues; it should be considered whether photon energy matched molecular bonds. In 1987, Pullafito studied 193-nm and 248-nm eximer laser's influence upon rabbit corneal epithelia. It was observed that 193-nm laser did not cause visible loss of epithelial cells while 248-nm laser did.

Based on the studies of animals' and dead people's eyes and of the development of eximer laser devices, Daniele conducted the first in vivo argon fluoride eximer laser keratectomy. Healing of the cut was observed. On the first day following the operation, slip lamp examination revealed that the cut formed by laser with original width at 70 μm was reduced to 75μm to 80 μm. At the postoperative 48 hours, the cornea remained transparent with slight edema around. On the fourth day, the epithelia fully reproduced. On the fourteenth day, no cut was observed in slit lamp examination. Unfortunately, the subject's eye had to be removed on the fourteenth day as neoplasm was found in the eye.

In 1988, L' Esperance, a French researcher, reported on the American Annual Meeting of Ophthalmology that six cases of in vivo eximer laser PRK were successfully conducted. The central area of cornea was removed by 35 μm on the 600-μm-thick cornea with the result that myopia was corrected by 2.5 to 3.0 D. The corneal epithelia were healed within 64 hours and the whole cornea was transparent without any opacity. In 1989, Taylor conducted the PRK upon 10 blind eyes, among which 7 cases were followed up. Observation with naked eye found that all the cut area was transparent for all eyes. Slit lamp examination of the flattened cut area observed slight opacity between the epithelium and the stroma, which did not affect eyesight. Examination with ultrasonic corneal pachymeter, keratometer and mathematical keratoscope revealed that the cut area was progressively filled in by two thirds. However, the original correction diopter was only reduced by one third. Examination of three eyes on the third to twelfth day revealed that 40-μm-thick corneal tissue was cut off on the elastic lay and the stroma, surrounding tissue was hardly damaged, no inflammatory cells were observed and the epithelia, which were closely connected to the stroma, were 50% thicker. In the fourth month following the operation, active corneal cells were found in a sample, which were accompanied by protein formations (possibly collagen and substrate).

Satisfactory cases of eximer laser PRK were reported by Seiler in 1990 and by Gurry in 1992, in which the best correction diopter was over 1.0. PRK has been widely used in many industrialized countries.

II. FDA verification

With the guidance of Food and Drug Administration (FDA), researches upon PRK were divided into three phases—phase I, **II** (**II**$_A$, **II**$_B$) and **III**.

Phase I: blind eye test. In June 1988, McDonald conducted the PRK upon 9 blind eyes. As the clinical trial was effective, it was agreed that 10 subjects with partial eyesight were treated. The best correction eyesight was up to 20/50.

Phase II:

II_A: began in March of 1989, by McDonald in the Center of Ophthalmology, Louisiana State University and by Michael R. Deitz and Larry W. Pledenga in Missouri University. Forty patients were treated and the best correction eyesight was 20/50 or better.

II_B: clinical trial. Since September 1990, 80 non-blind patients were treated with the PRK with satisfactory results.

Phase III: began in the spring of 1991, 700 patients and 10 subsidiaries of three American ophthalmologic laser corporations were involved. 2100 PRK cases were treated with a follow-up of 2 years.

Section Two Biological Features of Eximer Laser

Eximer laser is characterized by cutting tissues with the following features.

I. Extremely weak penetration

With extremely weak penetration, only superficial tissues absorb the eximer laser beam. Each pulse cuts the tissue by about 0.25 μm. As the threshold value of the laser is 10 ml/cm^2, 50 pulses of 4 ml/cm^2 leave no trace on tissue surface while pulses of 16 ml/cm^2 leave visible trace on the reflection area of the exposed tissue. The eximer laser has the advantage of cut evenness, slight damage to surrounding tissue, small distance between damaged area and cut area (less than 0.2 μm) and no damage to the intraocular tissues.

In large numbers of experimental operations, the treatment only slightly reduces the number of corneal epithelial cells. Clinical observations reveal that the change of average density and coefficient of variation of corneal epithelial cells is not statistically significant, indicating that eximer laser does not harm the corneal epithelia. Feates proves that 193-nm laser is not received at the retinal level for both lens eyes and non-lens eyes, indicating that laser of such wavelength does not penetrate the cornea.

II. Little damage to surrounding tissue

Eximer laser functions through high-energy photons. Theoretically, the shorter the wavelength, the higher the photon energy, and the less damage to the surrounding area. On the other hand, the longer the wavelength, the lower the photon energy, the more damage to the surrounding area. 193-nm argon fluoride eximer laser is closest to the maximum absorption peak of corneal and sclera tissues (190 nm). Laser to which corneal and sclera tissues are exposed is mostly absorbed in a tiny distance of 5 μm while the adjacent area is hardly damaged. The damaged area is restricted in 0.2 μm and heat injury is scarcely observed. Generally, eximer laser of wavelength of 193 nm does far less harm compared with laser of longer wavelength, so much as that there is hardly any heat injury.

III. Beam even and cut smooth

High precision and predictability characterizes eximer laser. Early laser devices often cause irregular astigmatism of cornea as large-diameter beam travels irregularly, energy density distributes unevenly and healed surface is not smooth. Later, the evenness of energy density and the smoothness of cut surface are bettered through improvement of laser devices.

The tissue surface cut by eximer laser turns out to be fairly smooth and even. With the help of light microscope and scanning electron microscope, tissues cut with metal knife, diamond knife and eximer laser are compared. The metal knife, sharp and at least 1.5 μm wide, tears the collagen fibers. The diamond knife, up to 0.1 μm in width, separates the collagen fibers; its degree of smoothness is about 10 μm.

The degree of smoothness of eximer laser is 1 μm or below.

IV. Shape and variety of tissue cut controllable

Based on energy pattern, the laser release system effectively cuts corneal surface. If nearsightedness is to be corrected, the central part of cornea is cut deepest; the farther from the center, the thinner the cut. If farsightedness is to be corrected, cut from the central part of cornea; the farther from the center, the thicker the cut. If the cut is oval, astigmatism is corrected.

Section Three Basic Principles of PRK

I. Mechanism of the eximer laser device

The eximer laser device is a new instrument to process substances, which Srinivasan called an instrument to controllably cut substances. In eximer laser PRK, scattering rays are converted into laser beam through a set of controllable diaphragms. The controllable diaphragms with computer-controlled diameter and frequency are placed between the light source and the cornea. Thus, diaphragms control the energy of laser beam entering the corneal tissue.

Laser energy, transmission frequency (pulses per second) and diaphragm are adjusted according to the depth and area to be cut so as to attain the goal of precise cut, smooth surface and no heat injury to surrounding tissues. The correction diopter can be adjusted via pulse frequency and controllable diaphragms. The depth on corneal tissue cut by one pulse (certain energy strength) is fixed and released energy varies little from one pulse to another. Therefore, the cut depth can be controlled with strict control of pulse frequency.

II. Histological principle of PRK

Eximer laser, a kind of ultraviolet laser, is a high-energy photon beam produced by stimulated dimers. Each photon contains the energy of 6.4 eV, much higher than the maintenance energy between peptide chain and carbon chain in the corneal tissue (3.4 eV). The laser will break up molecular bonds in the target tissue and evaporate the corneal tissue. The process is referred to as photochemical tissue decomposition or photochemical decomposition by cauterization (the photochemical effect). Eximer laser cutting is divided into four parts—transmission, tissue absorption, bond break in tissue molecules and removal of tissue. Experiments have proven that the cutting depth is positively correlated to the logarithm of energy density (also called fluence) , or 1 J/cm^2 energy cuts 1-μm-deep corneal tissue.

III. Optical principle of PRK

To correct myopia, the corneal diopter needs to be reduced or increase the curvature radius. When corneal epithelium and partial stroma are removed with eximer laser, the epithelium will reproduce itself evenly, leading to re-establishment of new stroma curvature or new corneal curvature.

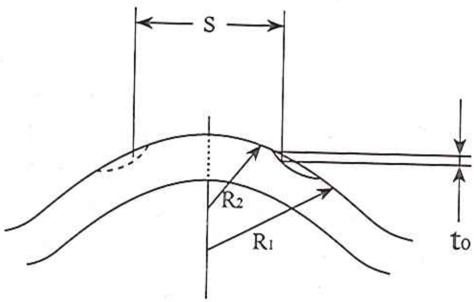


Fig.2 PRK-myopia

In Fig. 2, R_1 is the curvature radius of the cross section of a spherical surface, R_2 is the post-operative curvature radius, t_0 is the maximum distance on the optical axis (that is, the maximum depth to be cut), S is the diameter of the cut area (diameter of optical area). The stuff between R_1 and R_2 is equivalent to a thin lens, removal of the stuff is equivalent to addition of a negative lens whose diopter is

$$D=(n-1)(1/R_1-1/R_2) \quad (1)$$

The refractive index of cornea: n=1.377; signs of all values are uniform, length unit is meter.

As shown from equation (1) and figure 2, Y represents the cut thickness of the cornea, or the distance to the optical axis. When D, S, R and n are known,

$$t(Y)=(R_1^2-Y^2)^{1/2}-\left[\left(\frac{R_1(n-1)}{n-1+R_1D}\right)^2-Y^2\right]^{1/2} \quad (2)$$

$$-(R_1^2-S^2/4)^{1/2}+\left[\left(\frac{R_{1(n-1)}}{n-1+R_1D}\right)^2-S^2/4\right]^{1/2}$$

As the tissue to be cut is located on the optical axis, Y=0, so $t_0 = t(0)$

$$to=(R_1-\frac{R_1(n-1)}{n-1+R_1D}-(R_1^2-S^2/4)^{1/2} \quad (3)$$

$$+\left[\left(\frac{R_1(n-1)}{n-1+R_1D}\right)^2-S^2/4\right]^{1/2}$$

Expand the binomial, equation 3 is simplified as

$$to \approx -S^2D/8(n-1) \quad (4)$$

As shown in equation (4), when the cut diameter is 3 mm, the cut thickness is 3.0 μm per D; when the cut diameter is 4 mm, the cut thickness is 5.3 μm per D; and when the cut diameter is 5 mm, the cut thickness is 8.3 μm per D.

To correct farsightedness, the corneal curvature is to be increased as shown in fig. 3.

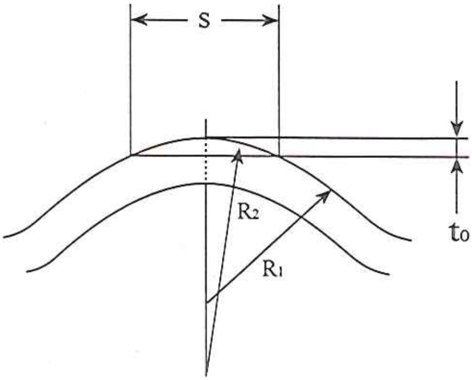


Fig.3 PRK-nearsightedness

Suppose t' (Y) is the cut thickness, Y is the distance to the optical axis, D is positive.

$$t'(Y) = R_1 - \frac{R_1(n-1)}{n-1+R_1 D} - (R_1^2 - Y^2)^{1/2} \quad (5)$$

$$+\left[\left(\frac{R_1(n-1)}{n-1+R_1 D}\right)^2 - Y^2\right]^{1/2}$$

No tissue on the axis is to be cut, the cut depth of the edge $t_0' = t'$ (S/2). The final result is similar for that of myopia.

To correct nearsightedness, the central part of cornea is cut off to flatten the cornea, increasing the corneal radius and reducing the diopter of the cornea. Reflected light of any object is refracted by the cornea, making the focus move back onto the retina. Removal of the central part of cornea is equivalent to the placement of a concave lens.

To correct farsightedness, the paracentral tissue is cut off to steep the cornea, reducing the corneal radius and increasing the diopter of cornea. Reflected light is refracted by the cornea, making the focus move forward onto the cornea.

Astigmatism may be corrected to some degree by cutting down or cutting off with eximer laser. The former refers to cutting the corneal surface in an oval manner so as to correct astigmatism; the latter refers to making a long and narrow cut so as to correct astigmatism.

Section Four Pathophysiology of PRK-treated Cornea

I. Eximer laser's biological effect upon the corneal tissue

1. **Effect upon corneal epithelium.** Eximer laser is a kind of ultraviolet light. Amund Ringvold (1983) found that

ultraviolet light might cause the loss of corneal epithelial cells, separation of nuclei and damaged or dead cells.

2. **Effect upon corneal endothelium.** In 1986, Dehm found in animal researches that damage to endothelial cells was uniform when 193-μm eximer laser was used to cut off 50% or 90% of rabbit corneal thickness. Edema of endothelial cells, loosen connection of cells and line-like crease parallel to the cut were observed but no loss of endothelial cells was detected.

   In earlier researches, it was found that high-speed impact caused loss of endothelial cells of cornea. Thus, it was thought that eximer laser might harm the corneal endothelium. It is later reported that the loss of endothelial cells is only found when the eximer laser reaches 40 μm in front of the back elastic membrane layer. Damage to epithelial cells might be caused by the split material is rushing out at 2 to 10 times of the speed of sound and meanwhile exerting a pressure over 130 times of atmospheric pressure. Amund Ringvold thinks that the PRK does not have visible influence upon the density of epithelial cells, indicating that the PRK is associated with the corneal surface.

3. **Effect upon corneal stroma.** Amund Rigvold (1985) and Pitts (1987) find that the ultraviolet light may result in edema and the death of the front quarter of cornea and

nucleus break and abnormal inclusion of the remaining cornea.

4. **Effect upon cell cycle, chromosome and DNA.** Cells of different stages have different sensitivity towards the eximer laser, as shown below:

$$M < G_1 < S \; G_2$$

Effects upon chromosome include the alteration of chromosome number, chromosome interchain adhesion and alteration of chromosome structure, as well as chromosome break and in-situ joint following injury and chromosome loss following partial break.

Effect upon DNA include base break, base damage, formation of pyrimidine dimer, damage to deoxyribose, single-chain break, double-chain break, cross-linking or interchain cross-linking of DNA chains, cross-linking of DNA and protein; the most popular is the formation of pyrimidine dimer.

II. Pathophysiology of PRK cut

Fundamental researches have proven that in the early period of PRK (0 to 7 days after the operation), the epithelium covers the cut (45μm to 70 μm in thickness), fibroblasts appear in the anterior stroma and cytoplasmic vacuoles and enlarged rough endoplasmic reticulum turn up. Fibrinogen deposits partially, basal collagen breaks and VII type collagen staining is negative.

Three weeks after the operation, the epithelium is nearly restored to normal, the number of fibroblasts obviously rises in the anterior 40μm to 60 μm of the stroma, the hierarchical structure of the anterior stroma is somewhat deranged, and fibrocytes are active which indicates active composition.

Ten to twelve weeks after the operation, if relatively large foggy haze is still found in the corneal epithelium, more black basal cells will be observed as well as more vacuoles (where the epithelium and the base meet), more fragments (in the newly formed basal membrane) and more active fibrocytes (in the anterior stroma).

Six months after the operation, the epithelium is restored to normal. If the cornea is clear, then the basal membrane is normal and normal hierarchical pattern of the anterior stroma is observed; otherwise, active fibrocytes are observed in the basal membrane.

Nine months after the operation, the structure of cornea is nearly restored to normal, the epithelium is mature, the anterior stroma is normal, no scar is observed, the posterior stroma, Descemet membrane and endothelium are all restored to normal.

Pathologically, postoperative proliferation of corneal epithelium changes refractive pattern of tear film, often leading to insufficient correction. Active cells and collagen fibers produced by active cells are highly associated with the regression of refraction and subepithelial opacity of the cornea. Some researchers believe that fibroblasts and corneal epithelial cells that appear after PRK can produce much hyalidase which regulates hydration, thickness and refractive power of the cornea. Lohmann believes that hyalidase leads to the reproduction of corneal cells, disturbance of the stroma layer and vacuolation in the cytoplasm, changing the water balance of the cornea, causing disturbance of surrounding hierarchical structure or altering focus of refractive index; thus the regression of refraction and subepithelial opacity (haze) of the cornea occurs. Tsubota thinks that although PRK produces less heat during the operation, the temperature of surrounding tissue reaches as high as 53.3℃. Clinical data also indicates that local temperature is positively correlated to the degree of postoperative foggy haze. Irrigation of the cornea with freezing liquid reduces local temperature of the cornea and significantly relieves subepithelial opacity of the cornea.

Chapter Four

Preoperative Screening of PRK Cases

Section One Indications and Contraindications

Ever since the first PRK case in 1987, it has been widely spread and developed. However, indications of the treatment shall be strictly controlled, as it is highly selective.

I. Criteria established by the Food and Drug Administration (FDA)

(1) Age over 21;

(2) Myopia degree between 2.00D to 8.00D;

(3) Corrected eyesight shall be no less than 20/50 and impossible to wear contact lenses;

(4) Corneal astigmatism shall be less than 1.50;

(5) No corneal diseases,scars, severe ophthalmoxerosis, blepharitis nor lagophthalmos shall be allowed;

(6) Wound-affecting systematic diseases shall be exempted.

II. Absolute contraindications

1.Progressive myopia

2. Diseases and pathological changes of the eyeball: blepharitis, dacryocystisis, ophthalmoxerosis, lagophthalmos, degeneration of corneal endothelium, keratoconus, keratitis, corneal opacity, corneal scar; glaucoma, cataract, uveitis; ocular injury, Fuchs syndrome, case history of retina and optic nerve.

3. Systematic disease: scar constitution, rheumatism, auto-immune diseases, diabetes, mental illness, abnormal personality, mental retardation and collagenosis, etc.

III. Domestic criteria for subject selection

(1) Demand for operation to get rid of spectacles;

(2) Age between 18 and 45;

(3) Diopter is relatively stable for at least 2 years, annual development of myopia less than 0.5D;

(4) Regular contact lens users shall stop wearing soft corneal contact lenses for at least 2 weeks or hard corneal contact lenses for at least 4 weeks;

(5) Suggested best range of correction: between –6.00 to –8.00D and preferably below –4.00D;

(6) Interval with other keratorefractive surgery: over 1 to 2 years; preferably over 2 years after an RK; and

(7) Interval for another surgery of the same eye: over 1 year.

Section Two Preoperative Examination of PRK

I. General ophthalmologic examination

1. **Eyesight examination:** examination of naked and corrected eyesight under standard visual testing chart, standard light and standard distance.

2. **Slit-lamp examination:** examination of the eyelid, conjunctiva, cornea, anterior chamber, lens and vitreous.

3. **Ocular fundus examination:** careful examination of the optic papilla, retina, blood vessels and macula. And mydriasis test with three mirror for severe myopia patients to find degeneration and holes.

4. **Refraction examination:** subjective examination, mydriasis eyesight examination and computerized eyesight examination; determination of diopter with subjechive refrachon.

5. **Ocular pressure examination:** preoperative examination with press-fall tonometer, applanation tonometer or non-contact tonometer and postoperative examination

with non-contact tonometer.

6. **Corneal thickness measure:** an indispensable item for the PRK.

7. **Corneal topography:** surface diopter examination and morphologic examination.

8. **Corneal perception examination and contrast sensitivity examination:** for comparison before and after surgery.

9. **Corneal endothelial cell count:** no longtime findings are available at present as for whether eximer laser harms the corneal endothelial cells. Use endothelial cell microscope (specular microscope) to determine cellular area and cell count in a given area with images or photos and observe the form of cells.

10. **Ocular A/B ultrasonic examination:** to observe anterior chamber depth and to rule out organic diseases.

11. **EOG examination:** to observe optic nerves and retinal functions.

II. Case history inquiry

1. **History of refractive error:** inquire in detail case history and development of refractive error.

2. **History of systematic diseases:** systematic immune

diseases, diabetes and scar constitution, etc.

3. **History of familial diseases:** family history of refractive error.

Section Three Application of Corneal Topography in PRK

The corneal power accounts for 3/4 of the total power of the eye, so that change of corneal surface shape often leads to change of refraction and visual function. Objective and precise analysis of corneal form and refractive distribution as well as their minute changes helps to improve predictability, monitoring and evaluation of photorefractive treatment. Computer-aided analysis system of corneal topography provides us with an accurate and reliable quantitative method to monitor corneal form and refractive distribution as well as their minute changes.

I. Make-up and work principle

Computer-aided analysis system of corneal topography, a corneal modeling system based on keratoscope, is made up of three parts:

1. **Placido disk projection system:** 16 to 34 concentric circles are evenly projected to the corneal plane from the center to the edge. The central circle is as short as 0.4 mm in diameter and the concentric circles almost cover the

whole cornea; thus the whole cornea is under projection and analysis.

2. **Real-time image monitor and video system:** the projected circular image can be real time observed, monitored and regulated with a real-time image monitor and video system, so as to keep the corneal image under optical state. The image is taken by a digital camera and saved on a computer.

3. **Computer video processing system:** the computer digitalizes the saved image. As thousands of measurements of refractive power or curvature radius are widely distributed on all circles and meridians, almost the whole cornea is under analysis. Analyze with established formula and program and display on the screen colorful images (corneal topography), tables and diagrams and output with color printer.

In the topography, red or near-red colors indicate higher refractive power and blue or near-blue colors indicate lower refractive power. Absolute grading or gradual grading are often used to describe the color change of corneal topography. In the absolute grading system, 26 colors have been used to indicate the different power between 9D to 100D and each color represents a fixed power range. Between 35D to 50D, a specific color represents 1.5D while each color stands for 5D outside of this range.

II. Terms related to corneal topography

1. **Division of cornea:** no standard is available for division of cornea at present. Some researchers divide the cornea into the central area, the peripheral area and the limbus area. Others divide the cornea into four areas as follows:

   The central area: Mandell (1961) defines the central area of cornea as the largest area with uniform curvature. Located in the center or the slightly deviated area, the area is 4 mm in diameter. Change of maximum curvature of the main meridian is most significant in the area, which is of great optic importance.

   The paracentral area: a 4mm to 7 mm ring-shaped area surrounding the central area and a transitional ring between the central area and the peripheral area. The area, which shifts from the central spherical area to the peripheral aspheric area, has reduced curvature.

   The peripheral area: a ring-shaped area with 7 to 11 mm in diameter. It has a curvature significantly lower than the central area, characterized by visibly aspheric shape. The area is connected with the corneal limbus area.

   The corneal limbus area: a corneal edge to connect with sclera or a transitional area between the cornea and the sclera. The 0.5-mm-wide area is often covered with corneal limbus blood vessels.

2. **Surface asymmetry index (SAI):** a measure of the corneal central whirlpool's radiating symmetry. SAI is determined by measuring refractive powers of opposite points (180 degrees) with the same distance to the center on 128 meridians and summing up all the differences of respective powers. The more symmetric the corneal area, the lower the SAI. Normal corneal central area is characterized by high symmetry. Theoretically, the value of SAI is zero (0) for a perfect spherical surface, a flat spherical area with perfect regular astigmatism and a radial symmetric surface. The normal SAI is 0.12 ± 0.01 for foreigners and 0.3 ± 0.1 for Chinese.

3. **Surface regularity index (SRI):** a measure of irregularity of the central area and the paracentral area.

   SRI is determined by summing up power fluctuation of half meridians of concentric circles of the central whirlpool. Select 10 rings in the central area; if the corneal power of three adjacent rings is irregular (that is, other than regular increasing, decreasing or constant), the value is included in the addition. The more regular the front surface of corneal center, the lower the SRI value. SRI approaches zero (0) for a perfectly smooth surface. The normal SRI is 0.05 ± 0.03 for foreigners and 0.2 ± 0.2 for Chinese. SRI is highly associated with the best corrected eyesight.

III. Normal corneal topography

Corneal topography of non-diseased emmetropia appears as concentric circles of Placido rings with smooth and complete edges and with no aberration while the distance between adjacent rings is roughly the same. The central area of cornea is positioned on the optic axis (towards the temple-side). The corneal curvature decreases from the central area to the paracentral area. The change is more significant on the nose than the temple. As seen from the values of power, the power is strongest in the center while the curvature remains roughly unchanged from the paracentral area to the peripheral area.

Bogan divides the normal cornea into five types:

1. **Round:** 22.6% of all corneas, indicating uniform curvature or more or less spherical shape.

2. **Oval:** 20.8% of all corneas, indicating uneven curvature distribution or astigmatism in the peripheral area, which can not be detected with routine examination.

3. **Symmetric bow-tie:** 17.5% of all corneas, indicating symmetric astigmatism of the cornea. The corneal power is strongest on the bow-tie meridian.

4. **Asymmetric blow-tie:** 32.1% of all corneas, indicating asymmetric astigmatism of the cornea.

5. Irregular: 7.1% of all corneas.

Liu Zhuguo reported that the power of normal corneal center is 43.3 ± 1.4D, reading of analog device (Simk) is about 43.2 ± 1.3D, the difference of average powers is 0.6 ± 0.3D between the first ring and the fifteenth ring and 1.8 ± 1.4D between the first ring and the twenty-fifth ring. Rabinowitz reported that the power of normal corneal center is 43.7 ± 1.4D, the difference of average power between the lower cornea and the upper cornea (I-S) is –0.3 ± 0.8D and the power difference of the two eyes of the same patient is 0.5 ± 0.2D.

IV. Clinical application of eximer laser PRK

(1) Preoperative application

1. Preoperative screening of keratoconus. Keratoconus is a non-infectious disease characterized by progressive thinning of the cornea. In most cases, both eyes will suffer from the disease one after another. The incidence of the disease is 54.5/100,000 and most victims are the young and the middle-aged. Among the PRK patients, as many as 5.7% patients are diagnosed with keratoconus in preoperative examination.

Vogt line, Fleischer ring and corneal scar are typically detected in slit lamp examination. Diagnosis is relatively easy if the typical signs are detected. However, it is difficult to detect keratoconus at the early stage; corneal topography is required for the detection.

Typical kerotoconus: in the absolute grading system, the typical topography of kerotoconus is shown as the steepness of local area, which forms a local cone. Mostly, the top of cone is not at the center of the optic axis and the steep area is at the lower side or at the side below the temple. Typical kerotoconus is mainly divided into the peripheral type (the cone is steeper towards the corneal limbus) and the central type (the central part of the cornea becomes steeper). Or it is divided into the round type, the oval type and the 8-shaped type according to the shape of cone.

Pseudo-kerotoconus: external pressure or artificial factor leading to something similar to kerotoconus in corneal topography. Wearing corneal contact lenses (especially hard contact lenses) is the most common cause—contact lenses directly press the cornea so that corneal curvature is changed. Another cause is metabolic factors. General consequences include irregular astigmatism of the corneal center, change of astigmatism axis, radial asymmetry, flattened corneal center, flattened site of contact lens (especially when the contact lens is deviated) and steep site outside the contact lens. Those who wear soft contact lenses may recover a few days after removal. Those who wear hard contact lenses may recover one to two weeks after removal. However, the time varies from one person to another.

Subclinical kerotoconus: in the absolute grading system, it is round, oval and 8-shaped in corneal topography. However, it is different from normal cornea in that the steep conical area is more localized and the eight (8) shape is mostly asymmetric (the shape is symmetric for normal cornea). Rabinowitz suggests the following screening criteria for subclinical kerotoconus: 1. power of the corneal center > 46.5D; 2. difference of power between 3-mm below corneal center and 3-mm over corneal center (i.e., I - S) > 0.92D; and 3. power difference of two eyes of the same patient > 0.92D. However, the power of the corneal center is not a very sensitive endpoint as it may be as high as or over 50.0D for normal eyes. Therefore, Maeda puts forward the following five criteria: 1. different sector index (DSI): mainly refers to the difference of average sector between maximum diopter and minimum diopter; 2. opposite sector index (OSI): mainly refers to the maximum power difference between two opposite 45° sectors; 3. central surrounding index: mainly refers to the difference of average power between 3-mm-diameter central area and its surrounding area. Among the three indexes, DSI and OSI is more sensitive to abnormal steepness of the corneal surrounding area and CSI is more sensitive to the abnormal steepness of the corneal central area; 4. irregular astigmatism index; and 5. analysis area (AA): they reflect irregularity of the corneal diopter distribution, used to analysis and diagnosis of medium and severe kerotoconus.

2. **Design of surgical regimen.** Surgical regimen is designed based on the corneal pattern as shown in corneal topography.

(II) Postoperative application

1. Evaluation of surgical efficacy

(1) Evenness of cutting or corneal topography and PRK effect: PRK breaks the molecular bonds between the corneal central tissue with laser, so as to increase the curvature radius, reduce the degree of bent and lower the diopter (refractive power). Observation of postoperative corneal topography will reveal evenness of cutting. Postoperative corneal topography is divided into five types:

The evenly-cut type: the cut area appears as concentric circles with flatter center and step-like edge. The type produces the best naked vision and with the best satisfactory.

The semi-circle type: the cut area appears as a semi-circle with a range below 180 degrees. Its power is at least 1D lower than other areas.

The key-hole type: the cut area appears as a key hole with a range over 180 degrees.

The central-island type: the center of the cut area appears as an island with power that is at least 1D greater than other cut area and with a range over 1 mm. It is believed that the central island is associated with postoperative insufficient correction as well as subjective symptoms such as flashing, iridization and monocular diplopia.

(2) Cut position, eccentric cut and PRK effect: Eccentric cut is quite common in PRK treatment while the corneal topography helps the oculist to have a precise idea of the degree of decentralization. Generally, if the degree of eccentricity is below 0.51, post-PRK visual function is hardly affected. If the pupillary diameter and cut diameter are both 4.50 mm, then 14% of the pupillary area will be located outside the laser cut area and cause dizziness and interfering with visual function.

2. **Types of post-PRK corneal healing**: with the help of slit lamp, Durrie believes that post-PRK corneal healing is divided into three types:

Type I healing: corneal foggy haze develops normally and reaches the peak in about three months before starting to vanish. Corneal topography indicates that mild farsightedness is observed in the first month following the surgery and stable expected diopter is attained in 3 to 6 months following the surgery. The efficacy is well predictable.

Type II healing: corneal foggy haze does not appear after the surgery. In the postoperative period, the cornea remains relatively transparent. Corneal topography indicates that farsightedness is observed in the first month following the surgery, and lasts for a long time with slow recovery. In 6 months, over-correction is still observed.

Type III healing: postoperative corneal reaction is severe and corneal foggy haze is very significant, often leads to subepithelial fibrosis. Corneal topography indicates obvious reversion of efficacy and eventually regression of vision.

In short, corneal topography changes with the diopter and visual function, which makes it possible to provide more information for clinical application.

Section Four Ultrasonic Measurement of Corneal Thickness

Measurement of the corneal thickness is essential to PRK and Lasik, which offers more accurate data for surgery.

I. Ultrasonic measurement of corneal thickness

Ultrasonic pulses are used to measure corneal thickness. Generally, the detecting velocity is 1640 M/s, which might be higher for severe myopia. Operating procedures, though with variations, are generally described as follows:

(1) The patient lies down; apply local anesthetic to the conjunctival sac and the cornea for three times (once every three minutes).

(2) Adjust the device and test its function.

(3) Input the patient's name and age as well as date.

(4) Examine the quality of the probe; qualified if it is over 85%.

(5) Ten minutes after the anesthesia is applied, ask the patient to look straight upward. Measure the corneal thickness at different spots with the probe. Generally, eight lines are measured, each having four points—1 paracentral point, 1 corneal limbus point and 2 middle points. The temple side and the lower side are thinner.

(6) Save the result.

(7) Print the result.

(8) Measure the following patient or shut down the machine: the working conditions for the ultrasonic corneal pachymeter must be kept relatively constant. Excessively high or low temperature will interfere

with the result. The probe must be kept perpendicular to the corneal surface used with proper pressure, so as to avoid influence upon the result. Excessively high pressure will lead to a measured thickness smaller than it is. Excessively low pressure will lead to no result. Wash the conjunctival sac and cornea with antibiotics when the examination is over; instruct the patient not to rub the eye. Clean and store the probe to prolong its service life.

II. Corneal thickness of normal eyes

Many researches upon the corneal thickness of normal eyes have proven that it varies from one person to another, the difference between the maximum and the minimum is as high as 0.18 mm and the corneal thickness of most eyes ranges from 0.48 mm to 0.54 mm. Zhang Sufang reports that the age group between 6 and 10 is significantly thicker than other groups and there is no significant difference among other groups. Hansen reports that there is no significant difference among different groups. It is believed that measured corneal thickness is influenced by the corneal curvature except for keratoglobus and keratoconus; but the influence is slight. According to the regression analysis, the thickness of the corneal center does not interfere with the anterior corneal curvature. It is observed that the peripheral cornea is thicker than the central cornea for normal human eyes. The peripheral cornea thickness is 0.66 ± 0.076 mm and decreases as one gets older.

Chapter Five

Basic Procedures and Postoperative Treatment of Eximer Laser Keratectomy

Section One Basic Procedures

Eximer laser photorefractive keratectomy (PRK) refers to precise removing of corneal tissue with eximer laser to reshape the central cornea and correct refractive error.

Eximer laser PRK is divided into two parts—to remove cornea epithelium and to cut off corneal stroma. In addition, irrigation of conjunctival sac and surface anesthesia shall be conducted before operation. The main procedures are as follows:

I. Miosis

Apply 1% pilocarpine eye drop for miosis (pupil constriction) half an hour before the operation. At present, most researchers do not support miosis as they believe that it makes the pupil slightly move downward and leads to imprecise cut.

II. Anesthesia

In most cases surface anesthesia is applied to the pupil, with 0.5% to 1% cinchucainium chloride and 0.5% alcaina. Three times and once every three minutes.

III. Irrigation of conjunctival sac

Irrigate conjunctival sac with saline + gntamicin (1000IU/L) or 0.33g•H betaiodine.

IV. Removal of corneal epithelium

1.The mechanic method: remove the corneal epithelium within the operation area with operative tools such as Patin iris spatula, round and blunt scraper and round blade knife.

The mechanic method has the advantages of complete removal, reduced possibility of excessive-laser-causing heat damage to the cornea and laser-causing vitreous stirring and retinal commotion. The method is safer for those who suffer from severe myopia, visible myopia-causing retinal disorder, history of macular bleeding, retinal degeneration and hole-producing argon laser photocoagulation, and surgery for retinal detachment.

However, the mechanic method has the following disadvantages: 1. more time is required to remove the corneal epithelium which makes the corner drier and thinner and causes over correction; 2. the cornea is slightly opaque during or after the cut, which makes it difficult to see the cornea clearly and determine its center; and 3. slow recovery. Therefore, gentleness and evenness of manipulation and properness of cut depth and area are required for the mechanic method.

2. **The chemical method:** 18% to 20% alcohol and 4% cocaine hythochloride are often used. Different from the mechanic method, the corneal epithelium is removed faster, the wound is small and the edge is regular with the chemical method, so that the epithelium recovers faster and eyesight is restored faster.

3. **The laser method:** to remover corneal epithelium with laser. The method is characterized by simplicity and swiftness. A clear and round mark is left, serving as a good marker for determination of the center of PRK treatment. Even if the corneal opacity makes it impossible to see the cornea clearly during the cut procedure, the cut will not be significantly deviated.

The laser method has the advantages of slight reaction and fast epithelium recovery. However, uneven distribution of corneal surface water, rolling of the eye, instability of laser energy, corneal edema caused by surface anesthesia (leading to the increase of corneal thickness) and individual difference of corneal thickness may result in incomplete removal of epithelium (leading to over correction) or formation of corneal epithelial islands (leading to postoperative formation of central islands).

4. **The laser with mechanic method:** The method is believed to be the best choice for the removal of epithelium during photorefractive keratectomy, which have advantages of both the laser method and the mechanic method without their disadvantages.

V. Centralization of cornea and fixation of eyeball

The patient lies down with eyes opened with the eye speculum. Ask the patient to fix his eyes on the light before regulating the focus and fixing the corneal center.

1. **Centralization of cornea:** the right corneal center is a point on the axis directly aiming at the center of pupil. Generally, the patient is asked to fix his eyes upon the red helium-neon laser focus which is positioned straightforward. The projection point located in the center of pupil is the corneal center.

2. **Determination of the reference object for PRK cut center:** opinions vary as to the selection of the reference object for PRK cut center. Zhang Xiaohui thinks that ideally, the cut center shall be the same as the pupil center. For easy focusing and intraocular tissue protection, PRK treatment shall be conducted under miosis. The cut center

is the pupil center under miosis.

Qi Yanhui thinks that the following four points may be used as reference: 1. the central point of cornea; 2. the pupil center during eye fixation; 3. visual axis' intercept point on the cornea; and 4. visual axis' reflecting point on the cornea during eye fixation.

Milind proves that visual axis' reflecting point on the cornea during eye fixation leads to the minimum postoperative decentralization of visual axis.

3. Fixation of eyeball

As cutting the cornea with eximer laser takes only dozens of seconds, most patients do not have to have their eyeballs fixed. Instead, they are required to fix their eyes upon a point which is used to locate the corneal center. However, some patients tend to roll, sway or drift their eyes which makes it necessary to fix their eyeballs. For eyeball fixation, a negative pressure system is used to hold the eyeball; or an improved Short-tooth Thorton fixing ring is used to apply pressure to the eyeball. The fixing position of the ring must be carefully checked so that the ring is parallel to the plane of iris and perpendicular to the path of laser.

VI. Cut of cornea

The parameters and the regulating system must be well mastered as they vary from one equipment to another. When the eyeball of a patient is corrected, the PMMA membrane must be used as a sample to check the correction efficacy of the equipment and the working conditions of the eximer laser system. Only when all the parameters are proven stable shall the treatment be carried out.

Input and check with the patient his name, sex, age, address, telephone, type of eye, type of surgery, etc. Then input the power to be corrected, corneal curvature radius, etc. The laser cut starts with a preset program after the technician and the oculist have examined all the data.

Fibrous sponge may be used to gently remove tissue fragments on the path of laser or accumulated water during the cut.

Section Two Postoperative Treatment

Apply antibiotic eye-ointment to the treated eye before having it wrapped for three successive days following the operation. Change the ointment each day. Generally, the corneal epithelium will recover in 72 hours after the operation. Soft contact lens or collagen film may be used to protect the wound instead of dressing it. Once the corneal epithelium heals, routine corticosteroid eyedrops such as Flumetholon, and FML are often prescribed at the following dosages: q.i.d for months 1&2; t.i.d. for months 3&4; b.i.d. for month 5 and o.d. for month 6. For mild myopia, the dosage for the first 4 months is q.i.d., t.i.d., b.i.d. and o.d. The patient shall have his eye re-examined once every month in the three postoperative months, including naked vision, diopter, ocular pressure and conditions of cornea.

Chapter Six

Complications of Eximer Laser Keratectomy

Eximer laser photorefractive keratectomy (PRK) has been widely believed to be effective, predictable and safe as it is put into greater application both at home and abroad. Meanwhile, people are starting to be aware of its complications, which are described in the following sections.

Section One Corneal Subepithelial Foggy Haze

Corneal subepithelial foggy haze refers to white crescent opacity under the corneal epithelium in the cut area. It is caused by interlocking arrangement of tissues in the corneal stroma anterior layer as a result of postoperative corneal subepithelial fibrous hypertrophy, collagen formation and abnormal subepithelial extracellular matrix (ECM). Foggy haze is often worse in the postoperative period. It reaches the peak in the third month and begins to disappear in the sixth month.

I. Pathogenesis of corneal haze

The exact cause of post-PRK corneal subepithelial foggy haze is still unidentified. It is generally believed that it is related to the following factors.

1 **Eximer laser.** It has been proven by many researches that fluorine-argon laser and fluorine are toxic and the fluorine will trigger toxic reaction of the cornea and induced reaction of DNA in tissue cells. Laser will bring out slight heat injury with local temperature of the cornea as high as 53.3°C; shortwave energy of laser will trigger sonic vibrating effect. All the factors affect the metabolism of cells, damaging cells and interfering with cellular conjunction, and ruin the corneal epithelium, increasing permeability of the epithelium. Local inflammation will result in corneal haze.

2. **Surgical procedure:** corneal foggy haze is closely related to surgical procedure. The longer the exposure to laser, the more severe the corneal haze. The deeper the cut, the more severe the damage to the corneal epithelium, the more the permeability of corneal epithelium and the more visible the corneal foggy haze. The longer the cut, the more serious the dehydration (corneal dehydration is one of the most important factors to form corneal scar). The more the cut diameter, the more serious the vibration, and the worse the corneal foggy haze.

3. **Healing of corneal wound:** in eximer laser KRP, the corneal epithelium of the cut area is removed and the

subepithelial stroma of cornea is cut off. Corneal foggy haze is associated with the re-arrangement of the epithelial cell layer, re-arrangement of the stroma fibrocytes and corneal cells of the cut area and deposit of subepithelial extracellular stroma. Therefore, healing of corneal wound is the key to corneal haze.

Healing of wound includes three steps—removal of fragments and dead tissues, repair of damaged tissues and re-arrangement of repaired tissues. It is a complicated biological process which is composed of cell chemotaxis and mitosis, vascularization, composition of extracellular stromal proteins and re-shaping of scar; proliferation, locomotion and differentiation of corneal epithelial cells are vital in the healing process while the polypeptide growth factors (PGFs) play an important role in regulating and maintaining tissue repair.

Healing of corneal wound turns out to be the outcome of interaction of various factors. It is found that change of tear fibrinolysin activity following KRP treatment is associated with delayed healing of wound while increased activity of plasmin in tears may delay the healing of the corneal wound. Thus, plasmin inhibitors may be used to relieve post-KRP corneal haze.

Fibronectin is a kind of glycoprotein adhering to the cell surface, which regulates collagen junction, promotes extracellular stromal adhesion, extension and transition of epithelial cells and adhesion between epithelial cells and basal membrane. Thus, postoperative test of activity of fibronectin in tears may be used to indicate the degree of healing of corneal wound and reflect the formation of corneal haze.

Eximer laser may do damage to visual nerves, inhibiting healing of wound and tear secretion.

II. Histology of corneal haze

Histologically, corneal foggy haze is mainly caused by 1. increase of epithelial cells; 2. non-continuous arrangement of stroma and irregular structure of stromal layers; 3. vacuolation; 4. new formation of collagen; 5. non-continuity of basal membrane; and 6. subepithelial deposit and abnormity of extracellular stroma such as fibrinogen, fibronectin, laminin, keratan sulfate, glycosaminoglycan, mucoprotein and hyaluronic acid.

III. Diagnosis of corneal haze

Corneal haze is graded subjectively. At present, no unified criteria are available.

1. Fantes scale:

Level 0: The cornea is completely transparent. No haze is found by any slit lamp examination.

Level 0.5: The cornea is slightly opaque, and haze is only found by the indirect wide tangent line illumination method of slit lamp examination.

Level 1: Haze of low density is only found by the direct illumination method or the diffuse illumnation of slit lamp examination.

Level 2: Slight haze is easily found by the direct focusing illumination method of slit lamp examination and the vision is affected.

Level 3: Haze of middle density and the iris is partially opaque.

Level 4: Severe haze and the intraocular structure is completely opaque.

2. McDonald corneal haze scale

Level 0: The cornea is transparent and possibly with very slight haze.

Level 1: Slight web-like haze but the photorefraction is not affected.

Level 2: Medium haze. Eyesight examination is possible but difficult.

Level 3: The cornea is opaque. Eyesight examination is impossible, but anterior chamber is easily observed.

Level 4: The cornea is opaque and the observation of the anterior chamber is affected.

Level 5: The anterior chamber is not observed.

3. Food and Drug Administration (FDA) scale

Level 0: The cornea is completely transparent

Level 1: The cornea is dubiously opaque and haze is only found by careful slit lamp examination.

Level 2: Light haze is easily found by slit lamp examination.

Level 3: Medium haze and the observation of the anterior chamber and the structure of iris is affected.

Level 4: The cornea is obviously opaque.

4. China's corneal haze draft criteria

Level 0: The cornea is completely transparent and no haze is found by any slit lamp examination.

Level 1: The cornea is slightly web-like opaque. Haze is only found by the indirect wide tangent line illumination method of slit lamp examination, or by the direct illumination method or the diffuse illumnation of slit lamp examination; and vision is not affected.

Level 2: Slight haze is easily found by the direct illumination method of slit lamp examination; and vision is affected.

Level 3: Middle haze and the iris is partially opaque.

Level 4: Severe haze and the intraocular structure is completely opaque.

IV. Treatment and prevention of corneal haze

(1) Postoperative application of corticosteroid eyedrops can effectively prevent corneal subepithelial foggy haze. Gaubet believes corticosteroid eyedrop reduces DNA synthesis of corneal active cells, which reduces activity the corneal cell activity, and relieve specific antimetabolism, which reduces the synthesis of collagen fibers, thus relieving corneal haze. Tuft uses corticosteroid and mitomycin (antimetabolite) to relieve postoperative corneal haze, and finds that the combination effectively reduces the formation of epithelial collagen fibers.

Some experts suspect that postoperative application of hormones may increase ocular pressure, and lead to corneal foggy haze. Precautions must be taken if corticosteroids eyedrops are used.

(2) Eximer laser will increase the local temperature of the cornea and affect the metabolism of cells. It is one of the causes of corneal haze. Use of cool buffer to reduce the local temperature of the cornea and regulate the pH value of the eye surface can hydrate the corneal stroma, wash away fragments, thus relieving corneal haze.

(3) Application of plasmin inhibitors: as a component of tear, plasmin regulates activities of several enzymes such as procollagen enzyme and macrophage elastase, brings out degeneration of stromal proteins such as fibronectin and laminin. Postoperative use of plasmin inhibitors will reduce the formation of foggy haze.

(4) Application of artificial tear: nutrition for the cornea partially comes from tear. As tear contains many substances (especially polypeptide growth factors), it plays an important role in the healing of corneal wound. Cornea break time must be examined before eximer laser PRK. Deficiency of tear film greatly worsens corneal foggy haze. Thus, artificial tear may be used to relieve corneal haze.

(5) Secondary eximer laser treatment: secondary eximer laser treatment may be used to relieve corneal haze. But timing is important and the selection is vital; otherwise, it may worsen the corneal haze.

(6) Continuous renovation of eximer laser equipment and perfection of operative skills and procedures may reduce the formation of corneal subepithelial foggy haze. Eximer laser operation is divided into two parts: to remove corneal epithelium and to cut off corneal stroma. Removal of epithelium requires the smoothness of the cutting surface. If the epithelium is not smooth, corneal haze is easily formed on rough cutting surface of the subepithelial basal membrane. When the corneal stroma is cut off, the cut depth, diameter and slope must be well controlled and the operation must be quick, so the formation of corneal subepithelial foggy haze is reduced.

Section Two Hormonal Ocular Hypertension

Since Francois (1954) reported hydrocortisone-induced hormonal ocular hypertension, it has been reported that hormone drugs administered through vein, mouth, skin, eyelid and nasal cavity cause ocular hypertension. Longtime application of hormones following eximer laser operation results in ocular hypertension among some patients, even leading to glaucomatous optic nerve injury, visual field defect and reduced vision.

I. Pathogenesis of hormonal ocular hypertension

Francois believes that hormones interfere with the metabolism of mucopolysaccharides by separating lysosomes and mucopolysaccharides in chamber angle. The latter which is unable to be decomposed, may accumulate in trabecular meshwork, enhance the resistance to the removal of aqueous humor and thus increasing ocular pressure. Or it may be explained by Becker's inheritance theory. According to Becker's inheritance theory, hormal glaucoma and open angle glaucoma are determined by the same gene. Homozygote is associated with open angle glaucoma while heterozygote or genetic carrier is associated with hormonal glaucoma. Individual difference is manifest for hormonal glaucoma patients and genetic factors are the most important cause of hormonal ocular hypertension.

II. Clinical situation of hormonal ocular hypertension

Degree and occurrence time of hormonal ocular hypertension of normal eyes vary according to types of hormones. Hormonal ocular hypertension occurs earliest in two weeks and latest in five weeks following medication while it is observed in three to five months in most cases.Clinically, the patient suffers from high ocular pressure without subjective symptoms such as ocular redness and ache. Even the atrophy of the optic nerve and whiting of optic papilla will not lead to depression and specific change of visual field. In a few cases, it is reported that hormonal glaucoma will bring about subjective symptoms such as painful eyes and halo vision. Loss of visual field is reported in rare cases.

III. Diagnosis of hormonal ocular hypertension

PRK alters the anatomic structure of the cornea, making it impossible to measure ocular pressure with tonometers at present; post-PRK ocular pressure shall be measured individually. Earlier measure of ocular pressure following the healing of epithelium (generally in three days) is very important, as post-PRK ocular hypertension is associated with frequency and timing of hormonal medication. Routinely dosage of hormones is decreasing month by month. Therefore, if ocular pressure rises significantly soon after the operation or if postoperative ocular pressure exceeds the preoperative ocular pressure, the patient shall be diagnosed as suffering from hormonal ocular hypertension even if it is below 3.19 kPa.

IV. Prevention and treatment of hormonal ocular hypertension

(1) Post-PRK application of mitomycin C in addition to corticosteroid eyedrops may reduce the hormone dosage.

(2) Once ocular pressure is found to be rising, reduce concentration and frequency of hormonal medication, or temporarily cease hormonal medication.

(3) Apply 0.5% timolol eyedrop or Beth eyedrop or Betagan

eyedrop, OD or BID.

(4) Use acetazolamide and baking soda to control ocular hypertension.

(5) In preoperative screening, the patients with ocular pressure and visual disc in clinical pathologic status must be further examined to rule out the possibility of glaucoma. No PRK treatment is conducted without definite diagnosis to avoid any potential hormonal ocular hypertension.

Section Three Corneal Hypoesthesia

I. Mechanism of corneal hypoesthesia

The cornea contains more nerve fibers than any other organs. Most of corneal nerves are sensory fibers come from long ciliary nerves and are distributed in the cornea in a radial manner. Most corneal nerves are distributed in the front one-third of the stroma, subepithelium and intraepithelium of the cornea. In photorefractive keratotomy, the front elastic layer or the front substantial layer of central cornea must be cut off by 10μm to 100 μm or more, which directly damages most anterior stromal, subepithelial and intraepithelial nerves. Removal of nerve fibers is the most important reason why perception of central cornea is greatly reduced after PRK.

II. Regeneration and recovery of damaged corneal nerves

Regeneration and recovery of damaged corneal nerves is also a process to restore corneal perception.

1. **Animal tests:** Xie Lixin treated 22 New Zealand rabbits (140 eyes) with eximer laesr PRK (-5.50D, 5.5 mm in diameter). Auri chloride nerve staining revealed the regeneration and recovery of corneal nerves after PRK. His findings include that PRK directly damage corneal nerves; when the superficial corneal stroma is cut off, and corresponding nerve fibers are removed. In the postoperative-4-hour corneal nerve staining sample, subepithelial nerve plexuses in the cut area vanish completely, but major nerve trunks in the deeper stroma are not affected as well as nervous beyond the cut area. The boundary of damaged epithelial nerve plexuses is clear with fiber nerves are broken. Nerve regeneration occurs soon after PRK; tiny nerve fibers are observed one week after the operation. New nerve fibers come from surrounding undamaged subepithelial nerve plexuses and undamaged nerve trunks in the deeper stroma of the cut area—intrastromal and subepithelial nerve fibers are developing at the same time.

   New fibers are slimmer and deranged with increasing density (possibly even higher than the normal value). In the postoperative 3 to 4 months, the density reaches the peak before the arrangement of new nerve fibers becomes more regular and density becomes lower. Six months after the operation, the form and density of nerve fibers are restored to normal; but nerves in the central part are not recovered completely. Compared with the normal, subepithelial nerve plexuses in the central part of the cut area tend to be sparse, for which longer recovery is needed.

In his observation of regeneration of postoperative corneal nerve fibers, Trabucchi detected acetylcholinesterase (ACHE) 7 days later and reconstruction of corneal subepithelial nerve plexuses 1 month later. However, the newborn nerve plexuses were still abnormal morphologically. About 4 months after the operation, never plexuses became normalized.

Teno conducted PRK upon rabbit eyes and found that 6 weeks after the operation, subepithelial nerves began to develop from the edge of wound to the center. In 3 months, nerves reached the center of wound; but no nerve fibers were found in the center of wound even in 6 months. In 12 months, though intraepithelial and subepithelial nerve fibers would have been normally distributed but chemical reactions of the ACHE in cell membrane were still different from that in the non-cut area. In addition, corneal nerves in the anterior stromal layer were still abnormal.

2. Histological researches: regeneration of functional nerves is associated with neurotrophins (NT) released by corneal epithelial cells and other cells. Some neurotrophins are released by damaged cornea to promote the growth of corneal nerves. Extracellular interstitial proteins may accelerate the outspread of nerves. After eximer laser PRK, the stromal surface of the cut area was covered by a false membrane—a substitute of Bowman's membrane, which helps the regeneration of epithelial cells. Fast regeneration of epithelium may serve as a cause of early postoperative regeneration of corneal nerves. Growth of nerves is also affected by the type and degree of cornea damage and metabolic status of the cornea.

III. Understanding post-PRK recovery of corneal perception

Understanding of post-PRK recovery of corneal perception helps postoperative protection of eyeballs.

(1) Before corneal perception is recovered, the cornea shall be well protected. Prevent foreign substances from falling into the conjunctival sac, which causes secondary infection of the cornea with no perception.

(2) Reduced sensitivity of cornea may slow down mitosis of corneal epithelial cells, reduce secretion of tear, delay healing and cause corneal infection. Postoperative application of antibiotics can prevent infection.

Section Four Reduction of Contrast Sensitivity

I. Introduction to visual contrast sensitivity

Clinically, the eyesight examination refers to the central vision, or the central fovea of macula's spatial resolution of highly contrasted tiny objects. However, in life, people have to distinguish large or lowly contrasted objects. In clinical practice, some patients feel that their vision is reduced while their central vision is still normal. Therefore, in order to evaluate the form sense of vision comprehensively, the subject must distinguish both objects of various sizes and diagrams of various contrasts.

Researches both at home and abroad indicate that the contrast needed by the human visual system to distinguish objects varies with spatial frequency. Thus, a function of contrast sensitivity of human eyes is used to express the degree of contrast sensitivity. The contrast sensitivity function (CSF) is the reciprocal of threshold contrast of human eyes for various spatial frequency. CSF of normal human eyes is distributed in the form of bandpass, indicating that contrast sensitivity for low and high spatial frequency is lower while it is highest for the middle spatial frequency (the peak of CSF curve). The feature means that it is more difficult to detect thick or slim figures and easier to detect figures of medium streaks.

In recent years, CSF test has been widely applied to evaluate from the sense of the visual system. Most researches indicate that the CSF reflects visual functions better than routine visual examination; in addition, the CSF reflects disease-causing disorder of form sense earlier, which is important to early diagnosis and differential diagnosis of visual diseases.

II. Cause of reduction of contrast sensitivity

The patient may suffer from blurred vision and foggy vision although his early naked vision and corrected vision are normal, which means the eyesight examination is not sufficient for overall evaluation of visual functions. The CSF value must be measured to evaluate contrast sensitivity. Many researches prove that contrast sensitivity is reduced to some degree in the first few months after the PRK. The causes of postoperative reduction of contrast sensitivity are complex, including

(1) loss of the front anterior layer;

(2) irregular healing of corneal epithelium;

(3) foggy haze;

(4) irregular astigmatism.

III. Reversion

In the follow-up study for months 1-12, Pallikaris reported that contrast sensitivity was reduced in the first month after PRK and it was restored to normal in three months after PRK. Ambrosio reported that contrast sensitivity was still found to be abnormal in six months after PRK, though it recovered gradually. Wang Zheng reported that it took 12 months for contrast sensitivity to restore to the preoperative level.

IV. Importance of understanding of post-PRK change of contrast sensitivity

Some patients have a higher demand of visual contrast sensitivity in life and work. PRK patients tend to have high expectation of postoperative quality of vision. If they do not understand that the reduction of contrast sensitivity is a common complication of photorefractive keratotomy, their emotions and behaviors may be somewhat affected. When any problem occurs, the oculist shall explain timely and clearly and point out its temporality.

Section Five Optical Center Deviation of Cut Area

I. Cause of deviation of optical center

(1) The geometrical center of pupil is closely related to its diameter. For the purpose of facilitation of focusing and protection of intraocular tissues, PRK is conducted under the condition of miosis (pupil constriction). In addition, the operating microscope lamp also reduced the pupil naturally. However, in most cases, the center of pupil will slightly move towards under the nose under the state of miosis. As the cut center is generally the same as the pupil center, the optical center of the treated eye tends to be deviated.

(2) For the eye of high and extremely high myopia (over −10.00D), the corneal stroma may be made into something like clouded glass as eximer laser cuts with deeper cut and longer time; the change makes it difficult for the oculist to see clearly the He-Ne laser beam projected onto the iris surface and for the patient to see clearly the flashing indicating light, which results in movement of the treated eyeball. An eyeball track system is included in the eximer laser system so that laser transmission will be automatically terminated if the eyeball moves by 0.60 mm. Nevertheless, the eyeball track system detects the pupil with an infrared video

camera; if the corneal stroma is less than transparent, the system will be less sensitive and out of function, leading to the deviation of optical center of the cut area.

(3) If the optical center is deviated towards above the nose (superior nasal side), the cause might be the position of the patient's head. If the lower jaw and the forehead are at the save level, the position of the treated eye may be abnormal. If the patient being treated has higher head and lower jaw, the eyeball rolls downwards, making it deviate towards above the nose.

(4) If the cut takes a long time, the patient may be tired that his eye can not be fixed upon the indicating light persistently and result in deviation or rolling of the treated eyeball or deviation of optic center of the cut area.

II. Deviation's influence upon postoperative eyesight

Post-PRK deviation of optic center of the cut area will interfere with the maximum value permitted for prognostic eyesight. There have been many reports as to the influence. Chen Yueguo believes that it is associated with the diameter of the cut area. For those with mild or moderate myopia, primary observations indicate that if the deviation from the optic center of the cut area is within 1.00 mm, the prognostic eyesight is not significantly affected. For those with severe myopia, a deviation of 0.5 mm may lead to poor recovery of eyesight, such as monocular diplopia and dazzling and dizziness. It is especially obvious at night when the pupil is enlarged beyond the cut edge.

III. Prevention and treatment

(1) The cause for the deviation of the optic center of the cut area under the nose (inferior nasal side) is associated with constriction and downward deviation of the pupil during PRK treatment while the constriction of pupil is caused by preoperative application of miotic and exposure to strong light of the microscope lamp. Therefore, try to avoid using miotic before operation and reduce the brightness of microscope lamp during operation, so that the pupil may be kept in a state of relief and deviation may be reduced.

(2) Further improve the eximer laser system. For example, the flash indicator may be updated to be adjustable. Increase the brightness for severe myopia eyes, making it easier to see the object clearly. Increase the sensitivity of the eyeball track system, making it workable when the the phenomenon of “clouded glass” appears in the corneal stroma.

(3) For eyes of severe myopia, the cornea tends to be dry and opaque as the cut takes longer time, leading to reduced

ability to fix eyes upon the object. Therefore, offer detailed instructions to patients and ease their anxiety; improve operating skills and reduce operation duration; properly fix the patient's head and closely observe the eye's movement. If necessary, stop the operation and re-establish the optic center so as to prevent deviation.

(4) Instruct the patient with deviation of the optic center to wear suitable spectacles.

Section Six Muscular Asthenopia

I. Introduction of muscular asthenopia

When one fixes his eyes upon an object, visual lines of both eyes must be kept in the same manner so as to obtain clear binocular single vision. The phoria patient has disordered ocular muscles, needs extra work of the extraocular muscle to correct reflection in order to keep his eyeball properly positioned. Thus, his ocular nerves and muscles are constantly overstressed, eventually causing muscular asthenopia.

Severity of muscular asthenopia depends on not only the degree of strabismus but also (more importantly) the patient's internal and external conditions, including the constitution, stability of the nervous system, reserved ability to combine reflection and psychology at work. Generally, for distant objects, esophoria is more tolerable than exophoria. For nearby objects, it is the opposite. The ability to control cyclophoria and vertical phoria is less powerful—that is, fusion abilily is less powerful. The highest incidence is cyclophoria, the second highest is vertical phoria and the smallest is horizontal phoria.

II. Cause of muscular asthenopia

Muscular asthenopia is caused by deviation of the optic center of the cut area. The deviation is equivalent to wear a pair of spectacles with an optic distance not matching the interpupillary distance or with an optic center is not on the same level as that of the pupil. Though it does not affect the vision of an individual eye, but upsets the balance of ocular muscles or causes phoria, interferes with the vision of both eyes and causes muscular asthenopia. Original degree of phoria and myopia varies from patient to patient; as a result, deviation that causes muscular asthenopia also varies. The "triangular prism" effect, which consists of small deviation, may also lead to muscular asthenopia.

III. Clinical observation and diagnosis

(1) Symptoms: Inability to read persistently, blurred vision, diopia, swollen eyes and headache. The subjective symptoms will be relieved or disappear when one eye is covered.

(2) Diagnosis

Case history: above symptoms appear after PRK.

Examination: Wu Guoen uses Reftester RF1000 multipurpose dioptometer and CHART project CH-1000 projector's visual coordinate to carry out the triangular prism examination. Polarization lenses which are perpendicular are used to separate the left eye and the right eye, so that any eye can see the respective part of the visual coordinate used to test consistency. If the patient still suffers from shift of visual coordinate and visual deformation when the remaining refractive error has been corrected, select and place proper triangular prism on proper meridian (facing the base) to separately correct the left and right eye and to make the visual coordinates for both eyes symmetric and consistent.

The naked vision of either eye is between 0.8 and 1.2 and wearing triangular prism can make vision clear, free from diopia and subjectively relieved.

Corneal topography indicates the existence of deviation of the optic center.

IV. Treatment

Wear proper triangular prism whose degree is equal to the theoretical degree of the corneal "triangular prism effect" caused by deviation of the optic center. The base of triangular prism is 180 degrees (in radial direction) from the corneal triangular prism caused by deviation.

Section Seven Recurrence of Viral Keratitis

I. Cause of recurrence of viral keratitis

The cause of recurrence of viral keratitits is unknown at present. The symptom is supposed to be associated with following factors:

1. **Direct action of eximer laser.** When type I herpes simplex viruses infect the cornea for the first time, masked infection will happen in corneal cells as well as in the trigeminal ganglion which controls the corneal area. The masked infection might be the main cause of herpes simplex keratitis. In PRK treatment, eximer laser cuts the front elastic layer and the front stromal layer of the cornea, which, in addition to flattening the cornea of the cut area might induce reactivation of latent herpes simplex viruses, damage corneal nerves and interfere with the formation of tear film. After the surgery, the central area of cornea is less sensitive.

2. **Change of variety and amount of tear components.** Post-PRK immunoglobulin (Ig) test of tear indicates that contents of IgA, IgG and IgM are all reduced compared

with the preoperative level. Seven days after the operation, the average level of immunoglobulin is restored to the preoperative level. Nevertheless, in a few cases, the Ig level in tears are still lower than the preoperative level. In addition, concentration and content of other components are so altered that the formation of tear film is affected, causing a change of the normal tear environment.

3. **Postoperative application of hormones.** Though opinions vary as to postoperative application of hormones, corticosteroids are routinely applied to prevent and relieve diopter reversion and corneal subepithelial haze, mostly for 3 to 6 months. Longtime application of hormones will reduce the immunity of the eye to some degree, thus inducing infection or spread of latent infection focus and increasing risk of viral keratitis.

II. Diagnosis

1. **Case history:** viral keratitis, all recovered, post-PRK.

2. **Symptoms:** sense of foreign substance in the eye, blurred vision, fear of light and tearing.

3. **Vital signs:** conjunctival congestion of the disease eye, map-like or branch-like shedding of corneal epithelium, edema of superficial stroma.

III. Prevention and treatment

(1) Not all patients who once had viral keratitis will have reoccurrence of the disease; viral keratitis is not a contraindication of photorefractive keratotomy. It is necessary to wait for KRP until the patient has recovered from viral keratitis for six months or longer. Antiviral agents may be used to prevent the disease, but it is yet to be studied whether antiviral agents help the prevention of viral keratitis.

(2) Postoperative viral keratitis may not have obvious induction factors and postoperative subjective symptoms are less severe than preoperative ones, possibly as a result of postoperative decline of corneal perception. Eyesight decline is the most important symptom, so the oculist shall attach great important to early discovery of the disease.

(3) Recurrent viral keratitis shall be treated the same way as common viral keratitis. If diagnosed early, the disease can be satisfactorily treated.

Section Eight Accompanied Fundus Changes of Eximer Laser PRK

In view of the biological features of eximer laser, it is unlikely that eximer laser reaches the retina and directly causes injury. However, it is still unknown whether shock waves created by high energy laser photons play a role in fundus changes.

The most common fundus change after PRK is macular hemorrhage and non-traumatic rhegmatogenous retinal detachment.

(1) Non-traumatic rhegmatogenous retinal detachment: PRK corrects refractive error by reshaping the corneal surface through laser cutting the optic area of the cornea. For the refractive system, once a new refractive mechanism is established, the pull strength for the retina is changed. As the retina with severe myopia is characterized by degeneration, atrophy and thinness, PRK might cause retinal detachment among those with vulnerable retinas.

(2) Macular hemorrhage: choroidocapillaries are the source of blood. In most cases, the blood will be absorbed in two to three months, leaving no significant traces.

Section Nine Formation of Central Island

I. Corneal central island

"Central island" refers to an island-like area which appears in the central area of corneal topography and which has a diameter over 1 mm and has a diopter 1D more than the surrounding tissue. As a type of postoperative cut, the central island is one of the most important reasons why early postoperative eyesight is at least one line inferior to the best-corrected eyesight.

II. Mechanism

The mechanism of central islands is still a mystery. Generally, there are following causes to be considered.

(1) Unevenness of laser beam or attenuation of central laser energy will lead to lower central energy of laser beam. For example, remaining corneal fragments may work as a barrier to eximer laser. The fragments shall be timely removed to avoid uneven distribution of laser energy once they are cut off.

(2) Accumulated water in the central part of the cut area will absorb partial laser energy, forming so-called "cold spot" and reducing cutting power.

(3) Laser beam has impact upon the cornea to make liquid flow towards and accumulate in the center and reduce heating action of central laser beam. This is the principle of vibrating wave advanced by Machat.

(4) The cornea, like sponge, is thinner in the middle. Lin thinks that the surface water of cornea evaporates while the endothelial layer hydrates. The deeper stroma is easier to hydrate compared with the surface. The 2-to-3-mm central area of cornea is an even area, which

is easier to hydrate from the endothelial layer compared with the surrounding area, making the cut of the wet cornea smaller.

(5) The epithelium is capable of being reshaped.

(6) The surgery is wrongly calculated.

(7) The central part of cornea is slightly swollen.

III. Prevention and reversion of corneal central island

1. Prevention: increase the energy density of central laser beam; cut the central part of the cornea by 2.5 to 2.8 mm before myopia correction, so as to make up for cutting insufficiency.

2. Reversion: 88.89% of the central island type (8/9) will be converted into the evenly-cut type or other types in postoperative 3 to 6 months. It is believed to be associated with post-PRK healing of tissue.

Section Ten Degeneration or Reversion of Photorefraction

I. Post-PRK change of photo-refraction

(1) Post-PRK change of photo-refraction is regular and accompanied by simultaneous change of corneal

topography.

(2) After PRK, the patient has farsightedness, which reaches the peak in 10 days, significantly declines in 1 to 3 months and stabilizes in 3 to 6 months. The widely found postoperative changing farsightedness is termed as "farsightedness shift". The shift is faster in the early period following the surgery and slower in 3 months. Corneal topography indicates that postoperative diopter declines most significantly in the first month, rises in 1 to 6 months and stabilizes in 3 to 6 months (with little change of diopter). The cause of farsightedness shift might be that in the early period, re-formed epithelium becomes flattened significantly and in the late period, recovered stromal tissue is re-filled, subepithelial fibrous tissue is constricted, the newborn collagen deposits in corneal cells and the flattened cornea protrudes.

II. Cause of reversion of diopter

(1) It is related to permanently increased thickness of corneal epithelium, swollen cornea and reshaping of stroma. The higher the degree of myopia, the wider the degree of reversion.

(2) PRK is unable to control the intrinsic factor of hereditary myopia while the postnatal factor still works leading to myopia (not because KRP is ineffective).

(3) Insufficient correction might occur as a result of very high preoperative diopter or following scleral staphyloma.

(4) Spadea thinks that reversion of diopter is the result of insufficient correction caused by deviation of the cut area and true reversion of diopter. Insufficient correction caused by deviation of the cut area is latent reversion.

III. Treatment

(1) Increase laser energy to improve stability of diopter; but the method does not prove effective for diopter reversion of very severe myopia.

(2) Conduct a second PRK treatment.

Indications: reversion of diopter, corneal haze, staged operation for very high myopia.

Timing: corneal diopter and eyesight still fluctuates as a result of corneal reshaping in half a year following eximer laser KRP. Later, the fluctuation tends to stabilize though corneal reshaping still exists. It is believed that the secondary eximer laser KRP shall be conducted when corneal diopter and eyesight have been stable. The second operation is carried out one year after eximer laser KRP, so as to avoid hyperplasia of cornea which has been in a state of hyperplasia. Stimulation of proliferative cornea may interfere with the efficacy of surgery.

Section Eleven Pain in Eyes

I. Cause

The cause of pain in treated eyes is still unknown. Zhou Yuehua thinks that vibration and heat effect caused by laser and uncovered sensitive nerves of epithelial area are among the factors to trigger painfulness.

II. Treatment

(1) Diclofenac sodium eyedrops

Principle: diclofenac sodium eyedrops, a kind of non-steroid anti-inflammatory drug (NSAID), selectively cuts off the action of epoxide hydrolase in the metabolism of arachidonic acid, so that synthesis of prostaglandin E2 is inhibited. It has been proven in the post-PRK rabbit cornea test. It is well known that prostaglandin causes painfulness. Therefore, reduced synthesis of prostaglandin accordingly reduces pain.

Administration: in a study of post-PRK painfulness, Paul finds that pain is significantly relieved in 24 hours regardless of the treatment. The best way to apply diclofenac sodium to control post-PRK pain in eyes is one day before and after operation, BID and TID. The way not only effectively relieves post-PRK pain but also avoids prolonging healing time of wound (prolonged healing time may increase risk of infection).

(2) Oral administration of non-steroid anti-inflammatory drugs such as metindol and Naproxen.

Section Twelve Others

I. Dizziness

Dizziness refers to the patient's sensing a ring of brightness surrounding nocturnal light sources. If the cut diameter is small than the pupil diameter or if the pupil enlarges at night, vision becomes unclear when light travels from the corneal tissue outside the cut area to the fundus.

Treatment: avoid small diameter of the cut area.

II. Dryness and sense of foreign substances of eyes

Longtime application of corticoids following PRK will change the composition of tear film and the function of lacrimal gland. Additionally, the removal of corneal nerves will change metabolism of cornea, thus affecting the formation of tear film.

Treatment: Reduce dosage of hormones, apply artificial tear drops.

III. Insufficiency or excess of correction

1. Cause

(1) As the energy of eximer laser is quite unstable, relatively low energy will result in insufficient correction and relatively high energy will result in over-correction. The error is more obvious for severe myopia which requires deeper cut and longer time.

(2) The operation is difficult to anticipate as biological features of the cornea vary from one person to another.

(3) Longtime exposure to air, dehydration of corneal stroma and excessive removal of corneal epithelium will make the actual cut deeper than expected.

2. Prevention and treatment

(1) Correctly design operation parameters.

(2) Avoid deviation of the optic center of the cut area.

(3) Prevent and relieve postoperative corneal haze.

(4) Use a secondary eximer laser PRK to make up for insufficient correction.

IV. Diplopia

Diplopia is related to edema of corneal epithelium and stroma, which requires no special treatment.

V. Defect of corneal epithelium

In 3 to 5 days after PRK, corneal epithelium will completely recover.

Persistent defect of corneal epithelium usually happens to the elderly, who have problems in the formation of tear film or who suffer from connective tissue disorders, metabolic disorders or consumptive disorders. Wearing corneal contact lenses or corneal shields contributes to the repair of epithelium.

VI. Recurrent corneal erosion

Postoperative wear of contact lenses interferes with normal oxygen conveying on the corneal surface. Lack of oxygen and damage by ultraviolet light are likely to prevent the healing of corneal epithelium or cause recurrent corneal erosion.

Treatment: autohemotherapy

VII. Prolonged healing of corneal wound

Bowman's membrane contributes to the healing of corneal wound anatomically and functionally. In PRK treatment, the membrane will disappear in the cut area, leading to prolonged healing of corneal wound and increased the risk of corneal infection and haze. Generally the corneal wound will recover in 3 to 5 days. Local anti-infective treatment shall be carried out in the early period after the surgery.

VII. Increase of astigmatism

Lack of expertise, deviation of the cut area and formation of corneal haze will lead to the increase of astigmatism.

IX. Acute keratoconjunctivitis

Cause: postoperative bacterial infection. Treatment: local anti-infective treatment.

X. Embedding of corneal epithelium

Mostly found in 3 to 5 days after the surgery, the cut-off corneal epithelium is on top of the newborn corneal epithelium. The patient will experience a sense of foreign substances. Removal of the corneal epithelium with a wet cotton swab can get rid of the sense and restore vision.

Chapter Seven

Eximer Laser In-situ Keratomileusis

It is widely accepted that eximer laser KRP can satisfactorily treat slight and mild myopia. Unfortunately, when it is used to treat severe and very severe myopia, deeper cut rids the cut area of the front elastic layer, inducing corneal epithelial proliferation and corneal cell and collagen fiber proliferation in subepithelial stroma and thus increasing the risk of power reversion, scar formation and corneal haze and reducing predictability. People are striving for a more stable and predictable way to treat severe myopia.

Section One History of Eximer Laser In-situ Keratomileusis

Barraquer first advanced in 1964 keratomileusis, a term derived from two Greek roots meaning “cornea” and “chisel”. In keratomileusis, certain corneal stroma is cut off to correct refractive error by re-establishing the corneal surface curvature. The surgery is conducted in the intralamellar part of the cornea as follows: use a special pneumatic negative-pressure ring to fix the eyeball; use an electrical mini corneal knife (designed with principle of planning machine) to cut off the disciform corneal sheet parallel to the corneal surface; freeze the corneal sheet in a freezing lathe; reshape the corneal sheet based on the principle for corneal contact lens lathe according to specific photorefractive state; defrost the reshaped corneal sheet and suture it to the original optic area of cornea. This is the procedure for keratomileusis (KM). Barraquer treated a few KM cases successfully.

However, keratomileusis was found to have a few problems: 1. it was very difficult to cut open the intralamellar part of cornea with the mini corneal knife available at that time; 2. the frozen corneal sheet and lathe parts would be deformed as result of freezing, making it difficult to precisely reshape the corneal sheet; 3. histological examination revealed that corneal tissue still underwent significant histological change and biological injury even with the use of cryoprotectant; and 4. corneal edema lasted for a long time after the surgery.

In 1977, keratomileusis was developed into non-freezing keratoplasty, namely the Barraquer-Krumeich-Swinger therapy. An improved mini corneal knife was used to cut off a disciform corneal sheet. The corneal sheet was reshaped on a die and sutured to the original place without being frozen. In the therapy, the cornea became transparent again comparatively faster and cold injury to corneal tissues was prevented. Unfortunately, the procedure was complex with low predictability.

In 1987, Barraquer developed in-situ keratomileusis, altering the corneal curvature by cutting twice with a mini corneal knife. In 1988, Ruiz cut the corneal stroma for the second time after a layer of corneal tissue had been cut off with the mini corneal knife. Then he sutured the corneal cap to the original place. The therapy, known as the Automated Lameller Keratoplasty (ALK), requires cutting the cornea twice, so that the treated eyeball has to be fixed with the negative pressure ring for a longer time. It is very difficult to ensure that two operations are carried out on the same optic center. Deviation of the optic center is likely to happen, leading to poor predictability.

In 1990, Pallikaris advaced eximer laser in-situ keratomileusis (Lasik) in a study of rabbit eyes, combining traditional keratomileusis and eximer laser keratotomy. Chiron Company developed a mechanical mini corneal knife which converted the free corneal cap into a stalked corneal flap.

In 1990, Pallikaris advanced the corneal flap technique with blind eyes. Large scale clinical researches have proven its efficacy in mid 1990.

Section Two Screening of Patients

I. Restriction

The restrictions of Lasik are similar to (but not the same as) those of PRK such as:

(1) Age between 18 and 50;

(2) Diopter is relatively stable for at least 2 years, annual development of degree of myopia is less than 0.5D;

(3) Corrected power is relatively good (preferably >= 0.5);

(4) Unsuitable to wear contact lenses;

(5) Desirous to relieve myopia through surgery and understands potential complications;

(6) For regular contact lens users, stop wearing soft corneal contact lenses for at least 2 weeks or hard corneal contact lenses for at least 4 weeks.

II. Contraindications

(1) Active ocular diseases;

(2) Dry eye syndrome;

(3) Blepharitis;

(4) Keratoconus;

(5) Exophthalmia;

(6) Corneal thickness is under 450 μm or over 700 μm;

(7) K value is under 40D or over 47D;

(8) Systemic connective tissue diseases, autoimmune diseases and scarred body;

(9) Diabetes.

III. Preoperative examination

1. Eyesight: distant vision, near vision and best correction vision;

2. Diopter: computerized eyesight examination, mydriasis eyesight examination or retinoscopy eyesight examination, including sphere diopter, cylinder diopter and axis direction;

3. Fundus: fully mydriatic; carefully examine fundus with three mirror contact lens and indirect funduscope (especially peripheral part) to determine whether there is degeneration or hole; fluorescence fundus angiography (if necessary);

4. Ultrasonic measure of corneal thickness: abandon surgery if corneal thickness is below 450 μm; if it is below 500 μm, use thinner corneal flap and smaller laser cutting. The corneal thickness shall be at least 250 μm after the construction of corneal flap and treatment with laser are completed.

5. Case history: for patients with glaucoma or vascular diseases, if intraocular pressure is over 8.66 kPa (65 mmHg) when corneal flap is being made, damage to visual nerves and diseases of vascular occlusion may be induced.

6. Other examinations: ocular pressure, corneal topography, corneal epithelial cells (similar to those for PRK);

7. Tests: tear secretion test, tear break time, contrast sensitivity, corneal epithelial cell count and photography, corneal perception test shall be conducted on potential applicants.

IV. Preoperative evaluation

Any potential Lasik patient must be comprehensively evaluated before surgery in terms of suitability and smoothness.

1. Corneal thickness: for those with severe myopia and especially very severe myopia, consider whether full correction will be achieved and whether the corneal thickness will be over 250 μm after the construction of corneal flap and treatment with laser are completed.

2. Corneal diopter: the size of corneal flap depends on negative pressure ring and corneal diopter while selection of negative pressure ring depends on corneal diopter.

Corneal diopter shall be fully considered before operation and negative pressure ring shall be carefully selected. For patients with severe astigmatism, the negative pressure ring shall be properly positioned to prevent complications such as incomplete corneal flap or deviated corneal flap.

3. Palpebral fissure: for patients with small palpebral fissure, it must be consider before operation if the negative pressure ring can be placed and whether it is necessary to cut open palpebral fissure or turn to PRK.

Section Three Method and Procedure of Surgery

1. Eyebath, sterilization and surface anesthesia the same as routine ocular surgery.

2. Calibrate laser equipment and corneal knife. Calibration of corneal knife varies from one to another, mainly including cut diameter, cut thickness and smoothness of corneal knife rotation. Laser calibration refers to hitting template to observe the stability of laser.

3. Expose the eyeball. Carefully separate eyelashes with sterile membrane; use eye speculum to open the eye; make sure that the eye is fully uncovered; determine optic center.

4. Make repositioning mark. Mark a radial reference cornea in infratemporal region with methyl violet, so as to

facilitate postoperative repositioning of corneal flap.

5. Select a proper suction ring. Make the diameter of the corneal flap 7 to 9 mm and the thickness of the corneal flap 130 to 160 μm.

6. Place negative pressure ring. Place the negative pressure fixing ring at the center of cornea to fix the eyeball. Ocular pressure must be no less than 8.66 kPa (65 mmHg). Moist the corneal with balanced saline solution.

7. Cut cornea. Take the electric rotating knife for example. Insert the tip of the mini rotating corneal knife into the track of negative pressure ring; switch on with the foot to make the corneal knife move in the slot from the temporal side (or the infratemporal side) to the nasal side (or superior nasal side); cut a disciform corneal flap (130 to 160 μm in thickness and more than 7.2 mm in diameter). When the corneal flap is made, remove the corneal knife out of the slot of the negative pressure ring and then remove the negative pressure ring.

8. Turn over and observe the corneal flap. Overturn the corneal flap towards the nasal side (or superior nasal side), uncover the corneal stroma, observe the thickness and completeness of the corneal flap, examine whether the stroma is penetrated.

If the flap is too thin, too thick or irregular, terminate the surgery.

9. Laser cutting of cornea: use the calibrated eximer laser equipment (input the data into the computer based on myopia degree to be corrected), the treated eye fixed upon the laser fixation lamp, cut the corneal stroma with laser.

10. Repositioning of corneal flap. Use BBS balanced saline solution to wash the stromal bed and the stromal surface of the corneal flap, reposition the corneal flap according to the pre-made mark, absorb excessive water with dry cleaning rod, take away the eye speculum when the corneal flap has been stably repositioned.

11. Examine the corneal flap and apply antibiotic eyedrops. Examine for any remaining fragments between different layers and proper repositioning. Apply antibiotic eyedrops and protect the treated eye with a hard eye shield.

Section Four Postoperative treatment and complications

I. Postoperative treatment

Apply antibiotic eyedrops to the treated eye during the first postoperative week. Locally apply hormones from the first postoperative day (such as FML, q.i.d., dosage reduced based on symptoms) until the end of the first month.

Generally, the dosage is q.i.d., t.i.d., b.i.d. and o.d. for week 1, 2, 3, 4 respectively.

Postoperative follow-up: generally, the corneal epithelium of the treated eye will be completely recovered within 24 hours and free from strong sense of stimulation in one day. The wound shall be carefully observed in the week following the surgery and regular examination shall be taken in 1 week, 2 weeks, 3 weeks, 1 month, 3 months, 6 months and 12 months, mainly observing fluctuation of vision, ocular pressure, dizziness and monocular diplopia. Slit lamp examination includes the corneal wound, the inter-layer reaction, foreign substance and corneal haze.

II. Complications and their treatment

1. Intraoperative complications and their treatment

(1) Thin corneal flap: any corneal flap, if its thickness is under 100 μm, turns out to be thin flap, irregular flap or penetrated flap. The ideal thickness of corneal flap is between 130 and 180 μm. Excessive thinness will make it difficult to reposition the corneal flap and lead to wrinkles or haze.

Cause: there are three causes as to the formation of thinner corneal flap.

Insufficiency or lack of negative pressure; improper placement or blockage of tubes during operation; and blinking or rolling of eyeball during the operation.

Bluntness of knife: poor quality or repeated use of knife.

Improper calibration during knife placement, uneven force upon the knife during operation.

Clinical observation: the cut-off corneal flap is visibly thin, sometimes composed of the epithelium or the epithelial layer and the front elastic layer while the edge of flap is incomplete.

Prevention: examine the tube and negative pressure system before the operation to avoid twisting, squeezing or knotting; to maintain smoothness of the tube system; and the stability of negative pressure.

When the mini corneal knife is calibrated, observe the state of knife and examine whether the knife rotates smoothly. Generally, a knife is used to treat two eyes and repeated use is avoided.

Take care of the patient's psychology and inform him the procedure of surgery. The patient will feel comfortable after negative pressure treatment, but cooperation is required.

(2) Incomplete corneal flap

Main cause:

Movement of corneal knife is resisted or blocked.

The patient's eyeball moves during operation.

Special anatomic construction of eyeball: small palpebral fissure or enophthalmos. Clinical observation: the corneal flap is not cut as scheduled.

Prevention: examine any resistance (such as foreign substance) on the track of knife.

Fully expose the eyeball during operation. If necessary, slight lift the eyeball, making it slightly above the surface of the eye speculum.

Treatment: slightly withdraw the tip of knife and then advance it.

If the corneal flap is found to be incomplete, the treatment depends on the actual situation.

If the exposed area is bigger than the cut area, proceed the operation. Take special care of the stem of the corneal flap.

If the exposed area is slightly smaller than the cut area, consider reducing the diameter or further removing the corneal flap until the visual area is fully exposed.

If the stem of corneal flap is positioned in the pupil area, re-place and operate after 3 to 6 months.

(3) Amputation, evulsion and detachment of corneal flap

Main cause: knife stopper is not installed, small corneal diopter (K value) (below 40D), thicker negative pressure ring improperly selected or thicker cornea.

Prevention: select thin negative pressure fixing ring for those with small K value.

Immediately stop cutting when the stem has been produced.

Mark before operation so as to facilitate repositioning of corneal flap.

Treatment: if the corneal flap's diameter is at least 5 mm is fully detached, proceed laser treatment and then replace the detached corneal flap according to the mark.

If the diameter of the detached corneal flap is under 5 mm, stop the surgery and immediately replace the detached corneal flap. During the repositioning, take care to distinguish the epithelial side and the stromal side of the corneal flap; otherwise, the detached corneal flap can not survive.

The detached corneal sheet shall be placed into a simple moisture room to prevent dryness or edema.

(4) Deviation of corneal flap

Cause: irregularity of corneal and/or sclera.

Imbalance force of ocular muscles.

The patient's eyeball moves during operation. Prevention: observe the position of the corneal when the eyeball is fixed with negative pressure. Re-fix the eyeball when deviation is detected.

Treatment: slight deviation will not interfere with the laser treatment. Reduce the cut area properly and proceed with the operation.

Terminate the operation if severe deviation is detected. Carry out LasiK half a year or one year after the corneal flap heals.

(5) Penetration of cornea. This is the most severe complication of LasiK, which is very difficult to treat. The key lies in prevention.

Cause:

The ocular pressure is over 8.66 kPa (65 mmHg) after the eyeball is fixed with negative pressure.

The patient's original ocular pressure is relatively low.

The patient's cornea is not hard enough.

Thickness plate is not used before cutting corneal flap.

The eyeball is small so the negative pressure ring is placed too deep.

Clinical observation: aqueous overflow during operation, ocular pressure reduction, negative pressure detachment, damage to iris and lens.

Prevention: carefully examine the patient's eye, including ocular pressure and corneal hardness/ Strictly examine the automatic cornca shaping device and correctly install the plate.

Conduct the operation in accordance with routine procedures, measure the ocular pressure and observe the cornea.

Treatment: for undamaged ocular tissues, re-place the corneal flap and suture.

For damaged lens and iris, suture the corneal flap and treat for ocular complications.

(6) Intralayer foreign substance remaining: intralayer foreign substances include oily substances in conjunctival sac, dressings, particles in air, eyelashes, talcum, metal fragments of knife, blood, etc. Its cause is incomplete wash of space between corneal layers.

Prevention: wash the corneal layers completely during operation and avoid any foreign substance residual.

Treatment: if foreign substance is positioned in the pupil area, overturn the corneal flap and wash completely. If it is positioned at the edge (not in the pupil area), no treatment is required.

(7) Poor replacement of corneal flap: when the corneal flap is re-placed, the fissure of the cut is not even, the line of mark is not corrected placed and wrinkles (like cat eyes) are found on the stem side of corneal flap or on the surface of corneal flap. Turn over the corneal flap, clean the wound and replace the corneal flap until it is completely even.

(8) Subconjunctival hemorrhage: when the suction ring stops suctioning, spot bleeding or plate bleeding appears under conjunctiva. Negative pressure leads to break of subconjunctival blood vessels. The blood will be absorbed in two weeks in most cases.

(9) Corneal pannus hemorrhage: mostly among those who wear corneal contact lenses for a long time or with large corneal flap.

Prevention: select small corneal flap, avoid meeting with pannus.

Treatment: press with the sponge to stop bleeding, and conduct laser treatment when hemorrhage stops.

(10) "Washboard phenomenon": if the knife is resisted or the force upon the knife is uneven, the thickness of corneal flap is uneven, leading to the step-like appearance in the stroma layer of cornea.

If a big step is positioned in the pupil area, replace the corneal flap and conduct the therapy half a year later.

If the step is positioned outside the pupil area, proceed with the surgery, as the "peak" and the "bottom" of the corneal stroma are evenly exposed to the laser.

(11) Severe edema of bulbar conjunctiva: caused by repeated suction by negative pressure or excessive squeezing of eyelids, mostly among the second treated eye of double eye treatment. The conjunctiva can be massaged to promote the elimination of edema.

(12) Fundus injury

Cause: excessively longtime negative pressure suction causes ischemia of visual nerves, retinal hemorrhage, subretinal hemorrhage, occlusion of retinal central artery, central vein or branch blood vessels.

Prevention: try to reduce negative pressure suction time to under 15 seconds if possible.

2. Postoperative complications and their treatment

(1) Glaring and dizziness: mostly among those with mild or severe myopia. The patient has a sense of reduced eyesight in dim light or at night. He senses shining rings and dizziness when he watches bright objects and lights; in addition, he senses the color of object turns lighter. The most important cause is that when treating severe myopia, the cut is deeper in depth and small in diameter so that the diameter of pupil exceeds the treated area of the cornea when the pupil becomes bigger at nigh or in dim light, leading to double refraction.

To prevent the complication, make the cut area (or the diameter of light spot) as large as possible if the corneal thickness permits. Examine the pupil diameter and corneal thickness before surgery. If the patient has large pupil and thin cornea, he shall be informed of the high risk of dizziness.

The complication attacks in the early period and disappears later. If necessary, conduct pupil constriction with 0.5% pilocarpine eyedrops to relieve symptoms.

(2) Corneal flap displacement: mostly found on the first day after the surgery, the corneal flap leaves its original place and corneal epithelium grows under the corneal flap by 2 to 3 mm. If it happens, completely remove the corneal epithelium with a spatula, completely wash the area

under the corneal flap, and replace the corneal flap to the original place. Generally, do not suture the corneal flap; otherwise, irregular astigmatism may occur.

(3) Corneal epithelium implantation: mostly found at the early postoperative period, gray cream-like round spots are observed between the corneal layers. The most important cause is incomplete washing of the area under the corneal flap so epithelial cells are left there. To prevent the symptom, wash the area under corneal flap completely. If corneal epithelium implantation is observed, wash the area under corneal flap with a special washing needle, or remove the corneal flap, completely remove the implanted epithelium and then replace the corneal flap.

(4) Corneal epithelial endogenesis: the incidence of post-Lasik corneal epithelial endogenesis is around 2%, mostly found in a few weeks after the surgery. small nest cells or transparent materials are observed between layers of corneal, growing from the edge of corneal flap to the center in a radial manner. Some develop fast and others are self-limited. The stroma between corneal epithelium and implanted intraepithelial stroma are more likely to have necrosis.

Cause: flap displacement and distortion.

Break or excessive thinness of the central cornea.

Strong reaction to surgery and edema of the corneal flap.

Treatment: those with self-limitation are to be observed carefully.

If the corneal epithelial endogenesis exceeds 2 mm, endangers vision or is progressive, treat it as soon as possible to avoid matrilysis.

(5) Corneal infection: post-Lasik corneal infection is rarely observed, though it is very severe. Clinically, a gray round invaded area is found at the corneal center, 3 to 4 mm in diameter, making the cornea obviously thicker. The patient suffers from pain, fear of light, tearing and sharp lowering of eyesight. Once the infection is diagnosed, turn over the corneal flap and wash thoroughly, conduct bacterial culture, use sensitive systemic and local antibiotics.

(6) Sands of Sahara syndrome: local immune reaction, mostly found in postoperative first to seventh days. Clinically, gray and tiny spot exudates are observed between corneal layers, mostly at the edge and rarely in the corneal center. Generally, it does not interfere with vision. If it is accompanied by edema of corneal flap or much exudation is positioned in the corneal center, eyesight is reduced.

Raise dosage of hormone therapy and apply antibiotics to relieve the symptom. Generally, exudates will be fully absorbed in two weeks, leaving no effect upon vision.

(7) Postoperative increase of astigmatism: astigmatism is increased by 1.00D compared with the preoperative value.

Causes:

Patient: With high diopter, longtime exposure to laser, movement of eyeball, poor compliance.

Laser: uneven beam and unstable energy.

Corneal flap: unsatisfactory replacement leading to wrinkles.

Treatment: if astigmatism is severe accompanied by symptoms, use secondary laser therapy to correct astigmatism.

(8) Increase of irregular astigmatism: mostly found in the early postoperative period, it goes away in most cases in 2 to 4 weeks with recovery of edema of corneal flap.

(9) Insufficient correction or over-correction of diopter: clinically, nearsightedness or farsightedness re-appears in 1 or 3 months after the surgery.

Cause: individual difference of patients.

Energy loss caused by tissue fragments or water during laser treatment.

Postoperative collagen hyperplasia.

Treatment:

For insufficient correction: re-open the corneal flap in postoperative 3 to 6 months, conduct secondary treatment and re-place it.

For over-correction: reduce the correction by opening cutting the intralamellar part of cornea and replace it.

(10) Reduction of best corrected eyesight: rarely occurs for Lasik operations, there are several causes such as postoperative irregular astigmatism of the cornea, formation of the corneal central island, deviation of laser cutting, keratoconus and corneal flap wrinkles. All may lead to irregular refraction and reduced the best corrected eyesight.

(11) Intralayer foreign substances and blood: mostly tiny fragments or blood, caused by incomplete wash between corneal layers. Generally, they do not affect vision. For the sake of prevention, wash between corneal layers properly during operation to avoid residual. If the particle is relatively large or if the liquid is positioned in the corneal center, turn over the corneal

flap and wash away the foreign object or blood.

(12) Secondary corneal ectasia: corneal ectasia or keratoconus may be diagnosed in rare cases.

Cause: there exist keratoconus-causing factors.

Corneal thickness with corneal flap and laser cut is below 250 μm.

The disease is associated with the patient's collagen elastic fibers.

Prevention: carefully examine before surgery to eliminate keratoconus.

Make room for secure corneal thickness when designing the surgery.

Closely observe the ocular pressure after the surgery.

(13) Partial haze of corneal flap: mostly found in 3 to 6 months after the surgery. Clinically, a ring-shaped opaque area is observed in the edge of corneal flap, with the width ranging from 0.1 mm to 0.5 mm. As opacity exists in the edge, vision is not affected. The cause is still unknown. Assumedly, the front anterior layer of the opened cornea is damaged, leading to degeneration of inferior corneal stroma.

(14) Pigmentation of corneal center: mostly found in 1

month after the surgery. Clinically, a 2-to-3-mm brown pigment ring is observed under the epithelium of the corneal center, which does not affect vision. With the passage of time, pigment may accumulate towards the center, forming small round pigments in the center. It is supposed that it is caused by the change of trace elements in the treated cornea (especially Fe^{3+}). The brown pigmentation is one of the indicators that the cornea has received photorefractive surgery.

(15) Corneal epithelial detachment: though the patient does not have any subjective symptoms, slit lamp examination reveals spot-like or sheet-like epithelial detachment in or below the corneal center. The cause is still unknown, possibly by postoperative malnutrition of corneal epithelial nerves. Generally, it does not affect vision so no special treatment is required.

(16) Slow recovery of nearsightness: the older the patient and the higher the preoperative degree of myopia, the slower the recovery of myopia. Have conscious training and wear presbyopia glasses if necessary.

(17) Hormonal ocular hypertension: the incidence of post-Lasik ocular hypertension, about 1%, is far lower than that of the post-PRK ocular hypertension, as less hormone eyedrops are used. If ocular hypertension occurs, reversion of myopia will be worsened. Control

of ocular pressure can relieve the reversion of myopia. Thus, it is very important to take ocular pressure after Lasik.

Section Five Advantages and Disadvantages of Lasik

I. Advantages of Lasik

(1) Less pain and faster vision recovery after surgery.

(2) Less wound of stroma and thus less stromal haze.

(3) Less local application of hormones and non-corticosteroid antibiotics.

(4) Maintenance of the front elastic layer of the cornea offers smooth corneal surface, so that diopter can stabilize faster.

(5) Corneal flap can be turned over again for secondary treatment if necessary.

(6) Treatment covers diopter ranging from –2.00 to 30.00D as well as astigmatism and farsightedness.

II. Disadvantages of LasiK

(1) Complicated equipment and costly expenses.

(2) High skill for operation is required as the mini corneal knife is used for the surgery.

(3) Unsatisfactory operative detection.

(4)More potential complications.

Chapter Eight

Repeat Photorefractive Keratectomy

Since eximer laser is used to correct refractive errors, many researches have proven that PRK, PARK and LASIK are safe and effective. Though 70% to 90% treated patients have power of 0.5 or better, some do not attain the expected goal as a result of diopter reversion, insufficient correction or corneal subepithelial haze. In August 1991, Seiler first reported successful cases of repeat photorefractive keratectomy (PRRK) at Geneva Advanced Technology International User Symposium. Recent researches indicate that RPRK is an effective approach to reinforce PRK and to promote success of first surgery though its success rate is lower compared with PRK.

Section One   Risk Factors of RPRK

I. Severe myopia

Snibson finds that following PRK, 5% of those with power below –5.00D have a second surgery, 13% of those between –5.00D to –10.00D have a second surgery and 19% of those with over –10.00D have a second surgery. 71% of RPRK patients have diopter over –5.00D before the first surgery and the proportion of a second surgery for those over

–10.00D is 3 to 4 times higher than that for those below –5.00D. It is concluded that the predictability and effectiveness of PRK is reduced when severe myopia is corrected. The higher the degree of myopia, the more significant the reversion of power, the higher the remaining degree and the more likely the second surgery.

II. Simultaneous correction of astigmatism

The proportion of RPRK is higher for astigmatism correction than for simple myopia correction. Snibson conducted astigmatism correction for 42 eyes (72%) among 58 RPRK eyes. With the same preoperative power, the likelihood of RPRK for correction of both myopia and astigmatism is twice of that for correction of simple myopia. The likelihood of RPRK for astigmatism correction is nearly three times that for simple myopia correction. Pop reports that 47.8% of the 90 RPRK eyes have astigmatism ranging from –0.5 to –3.00D.

III. Size and shape of the cut area

Corbett finds that the 6-mm cut area is better than the 5-mm cut area and the multiple-cut area in treatment of severe myopia. The former leads to less deviation, better predictability and stability while the latter might result in corneal haze and night dizziness, increasing the possibility of a second surgery.

IV. Operative application of nitrogen

To wash the cornea with nitrogen during PRK might be one of the most important factors to reduce its effectiveness. The treatment might lead to reversion of refraction, formation of corneal haze and reduction of best corrected eyesight; even a second surgery can not solve the problem of reversion of refraction and formation of corneal haze. Seiler reports that less scar is formed after RPRK if no nitrogen is used. Matta observes that the average one-year corneal haze is 0.68 for those without the use of nitrogen and 0.2 for those with the use of nitrogen. The difference is quite significant.

V. Individual difference of healing reaction

Operative results vary among individual patients even with the same preoperative power and the surgical parameters, indicating the existence of individual difference of reaction to healing. Excessively strong reaction to stroma injury may significantly raise density of postoperative corneal haze, thus increasing the possibility of a second surgery.

Section Two Indications of RPRK

I. Reversion of refraction

Reversion of refraction refers to the 6-month degree of diopter is at least 0.75D higher than the 3-month value after

PRK. It is caused by post-PRK epithelial hyperplasia and subepithelial deposit of glucosans, mucopolysaccharides and newborn irregular collagens. About 10% to 20% patients may have reversion of refraction.

II. Insufficient correction

Insufficient correction refers to the postoperative-3-month remaining degree of myopia is at least 0.5D higher than the expected degree. Snibson believes that RPRK is mainly applied to treat insufficient correction for patients with or without corneal haze and with abnormal corneal topography. It is reported that 58 eyes receive RPRK as a result of insufficient correction. Risk of insufficient correction increases as the myopia degree and first correction degree increase.

III. Corneal subepithelial haze and scar

Corneal subepithelial haze usually occurs in 2 weeks or 1 month after PRK. It develops gradually, reaches the peak in 3 to 4 months and relieves gradually in 6 months for most patients. It is believed that corneal haze is a normal corneal reaction to PRK, which helps the eye to reach and maintain the satisfactory state of refraction. However, severe haze is harmful to the treatment. Astin finds that subepithelial or low-stromal haze, often accompanied by irregular astigmatism, makes 10% to 20% patients lose the best correction eyesight. Hanna believes that persistent existence of corneal haze means the formation of corneal scar. Snibson thinks that enlarged corneal haze or scar is one of the most important indications of RPRK.

IV. Deviation of the cut area

In his local anatomic study of 1-month-after-PRK cornea, David finds that the average deviation of the cut area from the pupil center is 0.34 mm. Deviation below 0.5 mm leads to no subjective symptoms and is well tolerable. Deviation over 0.5 mm leads to symptoms such as monocular diplopia, visual hallucination, flash, dizziness and deformed vision. Ruben conducted two RPRK cases for PRK patients who had optical deviation and irregular astigmatism. RPRK relieved their visual symptoms and lessened astigmatism. In addition, the position of corneal center was normalized after RPRK. It is concluded that RPRK effectively treats post-PRK deviation of the optical center.

V. Central island

Central island, also known as the central visual island, refers to the post-PRK corneal central area which is insufficiently corrected. Morphologically, it is a central bulge (at least 1.00D). Levin divides central island into three levels: level A, diopter < 3D and diameter < 3 mm; level B, diopter < 3D and diameter > 3 mm; level C, diopter > 3D. Snibson observed 12% of RPRK patients had central islands in the preoperative examination, which were relieved after RPRK.

VI. Unable to use contact lenses

The use of contact lenses helps PRK patients with insufficient correction or power reversion to obtain satisfactory vision. For those with slight irregular astigmatism, it significantly increases the best corrected eyesight. If the patient can not wear contact lenses or his best corrected eyesight is reduced by at least two lines, RPRK can be considered.

Section Three Timing of RPRK

I. State of refraction

It is very important to keep stable refraction prior to RPRK. Stable refraction refers to the difference of two measured diopters (with an interval of one month) is no more than 0.5D without any treatment (except for artificial tear).

Some experts believe that it refers to the difference of three measured diopters (with an interval of at least one month) is no more than 0.5D. Seiler thinks that only when refractive error exceeds –1.00D and refraction remains stable for at least three months should RPRK be considered. Pop thinks that preoperative degree shall be at least –0.75D while Matta suggests that the best corrected eyesight shall not exceed 0.4.

II. Time for surgery

In most cases, RPRK is conducted 9 to 20 months after the first surgery. If the patient receives RPRK within 6 months after the first surgery, scar might be stimulated, leading to reversion of refraction. Hanna believes that active formation of tissues still exists in postoperative 18 months. If the second surgery is to be conducted on the transparent cornea, it is advisable to wait for a few months. Snibson thinks that RPRK shall be taken when the patient has been followed up for 6 months and when refraction has been stable for 3 months after the termination of hormone therapy. Their average interval between the first surgery and RPRK is 9 months, as most cases of central islands and corneal haze occur in the period. In Matta's report, all patients have PRPK at least 13 months after the first surgery—to be more exact, on the average, 19.15 months for mild myopia patients (13 to 37 months), 25.3 months for medium myopia patients (13 to 50 months), and 20 months for all patients.

Section Four Method and Postoperative Treatment of RPRK

I. Method of surgery

1.Removal of epithelium: manual removal or laser cutting. If haze is found, remove it with PRK. Remove corneal epithelium for about a third of the corneal diameter, remove the residual epithelium with PRK. Epithelium can be manually removed if haze is not observed.

Elevate corneal flap along the edge of original corneal flap and conduct laser treatment for the second surgery of Lasik.

2. Cut diameter: the cut diameter for RPRK is bigger than for the first surgery. The cut area is especially large for severe myopia patients who have insufficient correction as the cut depth must adapt to correction of all refraction.

3. Re-cut depth: usually the minimum depth for correction of residual myopia and central island. Post-PRK stroma must be at least 300μm thick. Post-Lasik corneal stroma must be at least 250 μm except for thickness of former corneal flap and thickness for the second surgery. Chatterjee believes that considering power reversion and insufficient correction, RPRK can over-correct by 25%.

4. Deviation of cut center: the cut diameter for the second surgery may be 1 to 1.5 mm bigger than for the first one. The epithelium attached in the first surgery can be used as a mark for the second surgery. Talamo covers the deviated cut area with methylcellulose and conducts the second laser treatment through epithelium. In the first step, cut off a 6-mm area, remove epithelium and partial subepithelial

stroma in the cut area. Then, cut another 4-mm area so as to correct the cut center.

II. Postoperative treatment

Apply antibiotic ointments to the treated eye and cover it for the whole night. Use antibiotics until the epithelium fully grows. Soft contact lenses may be used. When the epithelium recovers, use hormones routinely or when reversion appears. Most oculists suggest using hormones for 3 to 5 months with decreasing dosage. All the patients are followed up with the same examination criteria, including naked vision, corrected vision, subjective eyesight examination, corneal astigmatism, ocular pressure, corneal topography and slit lamp examination. Examinations are taken before surgery and in postoperative 1, 3, 6, 12 and 24 months.

Chapter Nine

Eximer Laser Phototherapeutic Keratectomy

Since eximer laser is put into clinical practice in the early 1980s, its effectiveness and safety for myopia treatment has been widely accepted as it is highly precise in cutting and it does little damage to the human body. Some experts are actively developing eximer laser into a therapy for corneal anterior stroma diseases, so as to improve vision, treat diseases and promote beauty. To use eximer laser to treat various superficial tissue diseases of cornea is referred to as eximer laser phototherapeutic keratectomy (PTK).

Section One Indications and Contraindications of PTK

I. Indications

Generally, phototherapeutic keratectomy (PTK) is used to 1. improve vision; 2. improve suitability of contact lenses; 3. promote healing of wound; and 4. promote beauty. The most common purpose is to improve vision by 3 lines or above.

Hersh classifies indications as 1. irregularity, deposit and vegetation of corneal surface; 2. scar on corneal superficial stroma; and 3. recurrent erosion of cornea.

The purpose of PRK is divided into 1. remove diseased corneal surface; 2. flatten uneven surface of cornea; and 3. treat superficial ocular diseases.

1. Removing diseased corneal surface

(1) Granular corneal dystrophy: subepithelial boundary-clear gray glass-like turbid substances or combined turbid areas in the central area of the cornea. PTK is the best therapy which elininates corneal implantation and improves eyesight. If the disease spreads to the deeper layer, PTK is not applicable.

(2) Band-shaped corneal degeneration: PRK can significantly improve the eyesight when edetic acid eyedrops and mechanical removal fail.

(3) Reis-Bucklers corneal dystrophy: subepithelial web-like or honeycomb-like turbidity in the central area of the cornea. Small amount of eximer laser can remove the lesion with less recurrence and complications when compared with the traditional method.

(4) Lattice corneal dystrophy: PRK is most suitable for the disease positioned in the superficial layer or accompanied by recurrent epithelial erosion.

(5) Others: superficial scar caused by injury or infection, herpes simplex keratitis in quiescent period and experimental C.albicans keratitis have been reported to be treated successfully with PTK.

2. Flattening uneven surface of cornea

(1) Colloid guttate corneal dystrophy: often accompanied by serious fear of light, tearing and sense of foreign body. In most cases, corneal implantation is required. PRK can relieve symptoms and create conditions for corneal implantation.

(2) Dysmorphic corneal and conjunctival diseases: shield-shape corneal ulcer combined with vernal keratoconjunctivitis, a hard-to-treat persistent epithelial loss, can be treated with PTK by removing turbid part of ulcerated stroma and abnormal epithelium of ulcerated edge, accelerating epithelial repair of the wound.

(3) Others: PTK can be used to remove remaining corneal scars and granulation tissues in treatment of Salzmann nodular corneal dystrophy and pterygium, creating smooth eye surface.

3. Treating superficial ocular diseases.

(1) Recurrent epithelial erosion and persistent epithelial loss: PRK can cut off abnormal epithelial basal

membrane. No recurrence is observed in half a year.

(2) Superficial ocular diseases with disappeared fence-like wrinkles of corneal limbus such as corneal chemical burn, Stevens-Johnson syndrome and ocular pemphigus: eximer laser can be used to treat newborn blood vessels of corneal limbus, effectively relieving formation of newborn blood vessels on corneal surface and growth of pseudopterygium.

Section Two Preoperative Examination and Evaluation of PTK

I. Preoperative examination

Like PRK, general and ophthalmologic examinations are conducted before PTK. In routine examination, pay special attention to the position and depth of diseased parts, state of refraction, corneal curvature, corneal topography, ultrasonic measure of corneal thickness, dizziness, contrast sensitivity and photography of anterior segment of eye. If necessary, carry out lacrimal secretion examination and corneal epithelial cell count.

II. Preoperative evaluation

For PRK cases, various factors affect the effectiveness of the surgery such as the type of the disease and the depth of the diseased area, closeness of diseased area and pupil center and post-operative refractive error; they are of great importance for preoperative evaluation.

1. Type of disease: researches indicate that the corneal epithelium, the front elastic layer and the stroma layer are cut in different rates and different diseases may be cut in different rates. For example, corneal scar is cut faster than corneal calcification, Edematous cornea is quite different from normal cornea. To ensure success of surgery, it is very important to fully understand the type of disease and its cutting features.

2. Depth of the diseased area: generally, any diseased part beneath the front elastic layer shall be treated with laser. For example, map-dot-fingerprint dystrophy and Salzmann Salzmann's nodular dystrophy may be treated by mechanically removing the front elastic layer.

   If mechanical treatment leads to incomplete removal or irregular surface, eximer laser may be used to remove the remaining nodules and smooth out the surface. Eximer laser effectively removes any disease in the front elastic layer and stroma layer. But it is optimal to set the cut depth within 100 μm of the front stroma layer.

3. Closeness of diseased area and pupil center: generally, superficial irregularity and front haze of central cornea is a good indication of PTK, which also effectively reduces

irregular astigmatism. Irregular scar on the surface of paracentral cornea significantly interferes with vision, which requires PRK. Haze or irregularity of peripheral cornea does not interfere with vision, which does not require PRK.

As for the anterior stromal scar left by the removal of pterygium, if it is located in paracentral part and affects vision, it should be smoothed; if it is located in peripheral part and vision is not affected, it does not need to be smoothed. PTK may result in unnecessary risk of astigmatism; if the chances of eyesight improvement are slim, avoid the risk. As for recurrent erosion of corneal epithelium, its closeness to the pupil is of no importance, as only 4 to 5 μm of the front elastic layer is removed in the treatment, leading to slight change of diopter.

4. Refractive error: the thickness of the central part, the paracentral part and the peripheral part of the diseased cornea is not the same, so removal of the anterior diseased part of cornea might bring about refraction error. If not carefully considered before operation, PRK may lead to both successful anatomic change and unscheduled photorefractive change.

   A comparatively large area of cutting in central cornea will flatten the central part of the cornea and shift the diopter to farsightedness. If the patient has nearsightedness, it is optimal; if the patient has farsightedness, the degree will increase.

On the other hand, phototherapeutic keratectomy of the paracentral cornea will shift the diopter to nearsightedness. More importantly, a paracentral PTK of greater range may lead to unnecessary astigmatism at the edge of the cut area. If the cornea is so diseased that penetrating keratoplasty is required, it is unnecessary to take refractive error into consideration. Conduct PTK and if serious refractive error occurs, use contact lenses to correct it. In this way can penetrating keratoplasty be postponed or cancelled.

5. Nature and stability of disease: corneal scar caused by injury requires at least one year of stability; one to two years of the recurrence of herpes simplex viral keratitis.

Section Three Surgical Procedure and Postoperative Treatment of PTK

I. Key points of PTK

(1) The operation is conduced with surface anesthesia instead of retrobulbar anesthesia and juxtaglomerular anesthesia.

(2) The patient lies on the back; with eyes opened with eye speculum and ask the patient to fix his eyes upon the indicator lamp of the operating microscope.

(3) As for those with smooth epithelium and superficial diseases, it is unnecessary to remove the corneal epithelium. As for those with rough epithelium and deep diseases, it is necessary to remove corneal epithelium. Water content of the corneal stroma will alter when epithelium is removed, so it is advisable to conduce surgery as soon as possible to achieve the best results. Apply proper amount of blocking agents if the diseased surface of cornea is rough so it is easier to precisely cut out a smooth surface and to avoid astigmatism. Methylcellulose is the best blocking agent.

(4) Locate the corneal center: the patient is asked to fix his eyes upon the red helium-neon laser aiming point which is positioned straightforward. The projection point located in the center of pupil is the corneal center.

(5) Cut the cornea with the corneal center as the center. Select proper parameters according to the specific equipment; usually, 5 to 7 mm for the central visual area, 50 to 120 μm for the cut depth. Sometimes, it is very difficult to judge whether the diseased part has been fully removed. If necessary, stop surgery and examine with slit lamp. Then proceed with the cutting until a satisfactory result is obtained.

(6) Carefully examine the wound after the surgery, conduct subconjunctival injection of antibiotics and

corticosteroids, apply antibiotic ointments, gauze or therapeutic soft contact lens.

II. Postoperative treatment

(1) Bind up both eyes and take good rest to facilitate the repair of epithelium.

(2) Take Oral pain-killers or tranquilizers. When the patient suffers from pain, fear of light and tearing as a result of epithelial loss, prescribe valium, luminal or pain-killer. Do not use surface anesthetic.

(3) Change drugs daily and examine the wound.

(4) Apply antibiotic and hormone eyedrops when epithelium recovers, with the dosage at q.i.d. or t.i.d. Reduce hormone concentration and times two weeks after. Keep the treatment for 2 to 4 months.

Section Four Complications of PTK

1. Farsightedness: almost all patients will have this change of vision, usually 4 to 6D in 3 months and about 3D in 6 months. RPRK may correct farsightedness by steeping the flattened peripheral part of cornea. However, repeated cutting may increase the risk of corneal haze.

2. Astigmatism.

3. Diplopia.

4. Subepithelial haze: slight subepithelial haze may occur in 2 weeks, aggravate in 1 to 2 months, gradually relieve in 3 months and nearly vanish in 6 months.

5. Ocular hypertension: some patients may have increased ocular pressure as a result of longtime application of corticosteroids.

6. Recurrence of ocular diseases: simulation of surgery and application of corticosteroids may induce recurrence of keratitis, especially herpes simplex keratitis.

Appendix I

Technical Guidelines for PRK, ALK and LASIK Treatment of Ametropia stipulated by the Keratopathy Group of Ophthalmology Society, China Medical Association in December 1995

I. Technical guidelines for PRK treatment of ametropia (revised version)

(1) Indications

1. Age over 20 (the restriction on age may be relaxed under special conditions).
2. Diopter is relatively stable for at least 2 years (annual change within ± 0.5D).
3. Corrected eyesight is over 0.5.
4. Diopter ranges from –2.00 to –8.00D (properly relaxed for the multiple-area cutting, but the maximum cut depth shall not exceed 100 μm).
5. The applicant shall not have the following diseases:
   * Generalized connective tissue diseases and serious auto-immune diseases such as systemic lupus erythematosus (SLE), rheumatoid arthritis (RA), multiple sclerosis and diabetes

* Serious diseases of ocular adnexa, such as eyelid coloboma, deformation, lagophthalmos and chronic dacryocystisis
* Xerophthalmia
* Keratoconus
* Viral keratitis (active phase)
* Corneal endothelial dystrophy
* Glaucoma
* Iritis

6 Interval with another surgery of the same eye for at least half a year.

7. Insufficient correction of PRK treatment for at least 2 years.

(2) Preoperative preparation

1. Explain the purpose of surgery, simplified principle of the surgery, procedure of the surgery and potential consequences to the patient. The patient shall sign on the consent for operation.
2. The following examinations shall be conducted:
   * Farsightedness and nearsightedness
   * Ocular pressure
   * Breakup time of tear film (BUT)
   * Ultrasonic measure of corneal thickness
3. The following examinations shall be conducted if necessary:
   * Contrast sensitivity

* Photography of corneal endothelium
* Corneal perception

(3) Operative techniques

1. Examine the eye to be treated with slit lamp on the operating day.
2. Two persons carefully check the operative data that are input into computer.
3. Give the patient tranquilizers of proper dosage before surgery; wash and sterilize the eye as routine corneal surgery.
4. Open the eye with an eye speculum; train the patient to fully adapt to and cooperate in the surgery before removing corneal epithelium.
5. Remove corneal epithelium via mechanical removal, drug removal or laser removal.
6. Start cutting as soon as possible (within one minute) after the removal of the corneal epithelium to avoid excessive dryness of the corneal surface.
7. Closely monitor the position of the treated eyeball during cutting (especially when no automatic tracker system is available); stop cutting when necessary.
8. Apply antibiotic eyedrops or ointments after surgery and wear therapeutic contact lens or dress the treated eye.

(4) Postoperative treatment and follow-up

1. Re-examine the treated eye in 1 day, 3 days, 1 week, 2 weeks, 1 month, 2 months, 3 months, 6 months and 1 year after the surgery. The following items must be included and completely recorded from the 1-week examination.
   * Symptoms including dizziness and iridization
   * Naked eyesight
   * Diopter and corrected eyesight
   * Slit lamp examination, state of epithelium (fluorescence staining) and grade of corneal subepithelial haze
   * Corneal topography
   * Ultrasonic measure of corneal thickness
2. The following examinations may be taken when necessary.
   * Contrast sensitivity
   * Photography of corneal endothelium
   * Corneal perception

(5) Evaluation of effects

Evaluation of effects takes at least one year of observation, based on comprehensive analysis of diopter, naked eyesight, corrected eyesight and complications. Effectiveness is ranked as:

Successful: diopter under ±0.5D, naked eyesight over 1.0, corneal haze under 0.5, corrected eyesight not degenerated.

Marked improved: diopter under ±1.0D, naked eyesight over 0.5, corneal haze below grade 1, corrected eyesight degenerated no more than 2 lines.

Improved: diopter under ±1.0D, naked eyesight improved, corneal haze below grade 2, corrected eyesight degenerated no more than 2 lines.

Failed: eyesight degenerated, corrected eyesight degenerated more than 2 lines, or severe complications emerged such as infection, the cut area deviated by at least 2 mm and corneal haze more than grade 2.

II. Technical guidelines for LASIK treatment of ametropia (revised version)

(1) Qualifications of LASIK surgeons

1. The hospital to conduct LASIK treatment shall have qualified equipment and conditions for anterior part of the eye. The LASIK surgeon shall have mastered ophthalmic microsurgery, anatomic structure and physiological function of eyeball and cornea, basic theory of refraction and examination of refraction.
2. The surgeons shall be trained to be familiar with:
   * Anatomy and physiology of the cornea
   * Basic theory and examination of refraction
   * History of photorefractive surgery
   * Principles of LASIK
   * Techniques of LASIK

* Complications of LASIK

3. The surgeon shall have systematically operated on animal eyes for at least 100 times. Only after mastering the operation of corneal knife can he conduct surgery on human eyes.
4. The surgeon shall first work as an assistant before conduct LASIK independently. He shall get familiar with surgical procedures and techniques under the instruction of an experience surgeon.
5. The first surgery shall be conducted with the guidance of an experience LASIK surgeon.

(2) Indications

1. Age over 20 (or over 18 under special conditions).
2. Diopter relatively stable for at least 2 years (annual change within ± 0.5D).
3. Good corrected eyesight (preferably over 0.5).
4. Diopter usually ranging from –4.00 to –30.00D
5. The applicant shall not have the following diseases:
   * Generalized connective tissue diseases and serious auto-immune diseases such as systemic lupus erythematosus (SLE), rheumatoid arthritis (RA), multiple sclerosis and diabetes. In principle, anyone who once had herpes simplex viral keratitis shall not receive LASIK. Should any doubt about the disease arise, carry out laboratory diagnosis for herpes simplex viral keratitis.

* Serious diseases of ocular adnexa, such as eyelid coloboma, deformation, lagophthalmos and chronic dacryocystisis
* Xerophthalmia, keratoconus, corneal endothelial dystrophy
* Glaucoma, iritis, severe retinal diseases
* Visible opacity of refractive media, such as cataract and vitreous hemorrhage.

6. Insufficient correction of PRK treatment for at least 2 years.

(3) Preoperative preparation

1. Explain to the patient about the purpose of the surgery, simplified principle of the surgery, procedure of the surgery and potential consequences. The patient shall sign on the consent for operation.
2. The following examinations must be conducted:
   * Farsightedness and nearsightedness
   * Mydriasis examination and corrected eyesight (pay special attention to the distance between the lens and the top of the cornea. All lenses for eyesight examination must be checked to make sure that the error is within tolerance)
   * Corneal topography or corneal keratometer
   * Ocular pressure
   * Ultrasonic measure of corneal thickness
   * Tear secretion test and breakup time of tear film

(BUT)

3. The following examinations may be conducted when necessary:
   * Contrast sensitivity
   * Photography of corneal endothelium
   * Corneal perception
   * Breakup time of tear film (BUT)
   * Fundus fluorescein angiography for patients of severe myopia
   * Mydriasis test for fundus, to rule out peripheral retinal diseases and holes

(4) Operative techniques

1. Examine the eye to be treated with slit lamp on the operating day.
2. Two persons carefully check the operative data that are input into computer.
3. Assemble and examine corneal knife according to its operating procedures.
4. Give the patient tranquilizers before surgery; wash and sterilize the eye as routine corneal surgery.
5. Conduct surgery under surface anesthesia.
6. Open the eye with eye speculum and determine the optic center.
7. Fix the eyeball with negative pressure fixing ring.
8. Cut off corneal cap with the automated mini corneal knife (the cut depth varies from 130 to 160 μm based

on central thickness of cornea and degree of correction).

9. Turn over corneal flap.
10. Cut with eximer laser, make sure that the cutting surface is relatively dry during operation. Closely monitor the position of the treated eyeball during cutting (especially when no automatic tracker system is available); stop cutting if necessary. Re-place the corneal flap and fully wash the cutting surface. Dry in air for 3 to 5 minutes. Take out the eye speculum when corneal flap is well-positioned and firmly-adhered. Instruct the patient to wink to make sure that the corneal flap is not deviated. Apply antibiotic eyedrops and cover the treated eye with hard eyeshield.

(5) Postoperative treatment and follow-up

1. Examine on the first day following surgery and observe position of corneal flap and state between layers.
2. Apply corticosteroid eyedrops for 2 to 4 months from the first day following surgery.
3. Observe for three successive days. Re-examine the treated eye in postoperative 1 week, 1 month, 3 months, 6 months and 1 year. The following items must be included and completely recorded from the 1-week examination.
   * Symptoms including dizziness and iridization

* Naked eyesight
* Diopter and corrected eyesight
* Slit lamp examination
* Ocular pressure
* Corneal topography
* Ultrasonic measure of corneal thickness
* Fundus examination

4. The following examinations may be taken when necessary.
   * Contrast sensitivity
   * Photography of corneal endothelium
   * Corneal perception

Appendix II

Outline of Examination for National Large Facilitates Operators (Eximer Laser Equipment Doctor)

Chapter one Ocular structure

Section one Optic organs

1. Composition of optic organs
2. Layers of eyeball wall and distribution and structure of different layers.
3. Name and function of eyeball.
4. Pathway of circulation of aqueous humor.
5. Distribution of conjunctiva.
6. Composition of lacrimal apparatus.
7. Name and function of extraocular muscles.

Section two Blood circulation of eyeball

1. Source and distribution of blood in eyeball.
2. Venous blood circulation of eyeball.

Section three Nerve distribution of eyeball

1. Nasociliary nerve.

2. Ciliary ganglion.

Chapter two Physiology and biochemistry of cornea

Section one General anatomy of cornea

1. Diameter: horizontal: 11.7 mm (11.0 to 12.5 mm)
   vertical: 10.2 mm (10.0 to 11.5 mm)
2. Thickness: central: 0.5 mm, 1 mm
3. Curvature radius: front: 7.8 mm, back: 6.5 mm.

Section two Composition and content of cornea

1. The epithelial cell layer: 50 μm in thickness, rich in glycogen, metabolism through (1) aerobic and anaerobic bating; (2) tricarboxylic acid cycle pathway; (3) pentose-phosphate pathway.
2. The anterior (or front) elastic layer): 8 to 14 μm in thickness, composed of collagen fibers.
3. The stroma layer: composed of collagen fibers. Between fibers is stroma, which is surround by three aminocaproic acids keratan sulfate chondroitin sulfate and chondroitin). Water accounts for 70% of substance in volume. Corneal cells are scattered between fibrous layers.
4. The posterior (or back) elastic layer: basal membrane of endothelial cells, 8 to 12 μm in thickness, mainly composed of collagen as well as acid

mucopolysaccharide.

5.Endothelial cells: composed of simple hexagon cells.

Section three Function

I. Epithelial cells: mainly function as barrier; influence tear's permeability to stroma and eyedrops' permeability to aqueous and anterior segment. The barrier function is selective—any water-soluble substances or ionic substances cannot penetrate the barrier easily while fat-soluble substances can penetrate easily.

II. Endothelial cells: mainly function as the pump and barrier. Only normal endothelial cells have the two functions. The pump function is provided by Na-K-ATP enzyme and the barrier function by closeness of endothelial cells. Endothelial injury will lead to functional disorders and the increase of corneal edema.

III. Corneal transparency: (1) because collagen fibers are regularly arranged in the form of layers; (2) endothelial cells and epithelial cells maintain constant water content in normal cornea.

Section four Metabolism of cornea

I. Cornea needs energy to maintain its transparency and behavior.

II. Energy source: glucose is the only source of energy, 88% of which is decomposed through bating pathway and 12% of which is decomposed through tricarboxylic acid cycle pathway. Both produce energy in the form of ATP.

III. Active mitosis of corneal epithelial cells is the key mechanism for repair of corneal epithelial cells. Glucose forms amyl-elements through pentose phosphate pathway, making it possible to produce DNA and division of nuclei.

Section five   Optics of cornea

I. Refractive index: air 1.00, cornea 1.376, aqueous 1.3336.

II. Diopter of cornea: anterior surface 48.2D, posterior surface –6.2D and total cornea 42.0D.

Section six   Healing of corneal wounds

I. Injury of corneal epithelium: its healing depends on area and age and nutrition of patient. Even epithelial injury of large area may recover in a few days.

II. Injury of parenchyma: repaired by collagen.

III. Injury of endothelial cell layer and back elastic layer: the endothelial cell area will expand and shift to cover the wound. Endothelial cells secrete to form the new back elastic layer.

IV. Tear film: vital to physiological functions of cornea, composed of three layers. The surface layer, about 0.1

µm thick, contains lipid; the middle layer or the tear layer, about 6 to 7 µm thick, contains inorganic salt, as well as glucose, protein and enzyme secreted by lacrimal gland; the deep layer or the mucus layer, about 0.02 to 0.05 µm, is secreted by Chalice cells.

Chapter three Pathology of cornea

Section one Corneal inflammations

I. Pathology of corneal inflammations.
II. Clinical observations of corneal inflammations.
III. Corneal degeneration and corneal dystrophy.

Section two Post-PRK repair of cornea

I. Post-PRK morphologic change of cornea
II. Post-PRK repair of cornea

Chapter four Eximer laser therapy equipment

I. Definition of eximer laser.
II. Principles for formation of eximer laser.
III. Principles for ametropia correction via eximer laser.
IV. Basic composition of eximer laser therapy system.
V. Characteristics of argon-fluoride gas.
VI. Energy density and frequency of laser transmitted to treat eye.

VII. Routine test of equipment before surgery.

Chapter five Safety precautions for operation of eximer laser therapy equipment

I. Levels of laser injury and corresponding degree of injury.

II. Argon-fluoride gas's harm to human body.

III. Conversion between voltage, current and power of electricity.

Chapter six Principle for ametropia correction

with eximer laser photorefractive keratotomy (PRK)

Section one History and experimental researches of eximer laser

I. History of eximer: Stephen and Trokel started to cut corneal tissues of calf with eximer laser in 1983; FDA's three research stages upon PRK and their detailed information.

II. Biological features of eximer laser: eximer laser's features of tissue cutting (permeability, evenness, damage to adjacent tissues, controllability of cutting shape, etc.), features of tissue reactions (molecular degradation, breakup of molecular chain).

Section two Photorefractive keratotomy and its treatment principle

I. Definition of photorefractive keratotomy (PRK)

II. Principle of PRK: the dimer is stimulated to produce high-energy photons of 193-nm laser, which break up chemical bonds of tissue molecules. The cornea is reshaped through gasification of corneal tissues so that curvature (diopter) of corneal anterior surface is altered and ametropia (nearsightedness, farsightedness and astigmatism) is corrected.

Chapter seven Clinical application of photorefractive keratotomy (PRK)

Section one Indications of PRK

I. Desire to get rid of spectacles.

II. Age over 18.

III. Diopter is stable for at least 2 years.

IV. Best corrected eyesight is at least 0.5 (except for anisometropic amblyopia).

V. Best range of correction (suggested below –6.00 to –8.00D).

VI. For contact lens regular users, stop wearing soft corneal contact lenses for at least 2 weeks or hard corneal contact lenses for at least 3 weeks.

VII. Interval with other keratorefractive surgery should be over 1 to 2 years.

VIII. Interval for another surgery for the same eye should be over 1 year.

Section two Contraindications

I. Eye diseases: keratitis, blepharitis, dacryocystisis, xerophthalmia, lagophthalmos, glaucoma, iridocyclitis, corneal endothelial dystrophy, keratoconus.

II. Systemic diseases: auto-immune diseases (systemic lupus erythematosus, rheumatoid arthritis, multiple sclerosis and diabetes), scar constitution (scar hyperplasia, keloid).

Chapter eight Preoperative examinations and preparations for PRK/LASIK

Section one Preoperative examinations for PRK/LASIK

I. Definitions and examination methods of farsightedness and nearsightedness.

II. Slit lamp microscopy of anterior segment of the eye, behavior of anterior segment of a normal eye.

III. Routine measurement methods of ocular pressure and normal values of ocular pressure.

IV. Methods and significance of fundus examination

V. Measure methods of corneal thickness and its significance for PRK and LASIK.

Section two Preoperative preparations for PRK/LASIK

I. Preoperative preparations of patients, laser device and corneal knife.

II. Significance of preparations for various items.

Chapter nine Procedures of PRK

Section one Key points for procedures of PRK

I. Key points for the surgeon.

II. Key points for the patient.

Section two Procedures of surgery

I. Basic knowledge about surgery of external eye.

II. Patient posture during operation.

III. Method of anesthesia.

IV. Training method.

V. Method of corneal epithelium removal. Master the mechanic method for removal of corneal epithelium. Master the PTK method for removal of corneal epithelium.

VI. Determination of corneal center.

VII. Process of cutting cornea.
VIII. Treatment when operation ends.

Chapter ten Postoperative treatment of PRK

Section one Postoperative treatment

I. Dressing of the treated eye or use of the soft contact lens. Time for application of the soft contact lens (2 to 3 days following operation).
II. Prescription of drugs to the treated eye.
III. Clinical observations and treatment principles for the postoperative-3-day treatment of the patient.
IV. Treatment of painful eyes.

Section two Postoperative re-examination

I. Purpose and time for regular examinations after operation.
II. Items for re-examination after operation.
III. Routine medication after operation. Use of hormones and antibiotics (antibiotics for 7 to 10 days until the epithelium recovers).
IV. Key points for re-examination of severe myopia patients.
V. Time for postoperative measure of ocular pressure (start to measure in postoperative 3 weeks to 1 month).

Chapter eleven Major postoperative problems and complications of PRK

Section one Major problems and complications

I. Major postoperative problems of PRK and their clinical observations.

II. Concept and grade of corneal subepithelial haze.

III. Difference between haze, corneal nebula and spot.

IV. Concept, clinical observation and danger of hormonal ocular hypertension (preperably measured with applanation tonometer and non-contact tonometer).

V. Difference between hormonal ocular hypertension and hormonal glaucoma.

VI. Difference and similarity of myopia reversion and insufficient correction.

Section two Mechanism of major complications

I. Possible mechanism and treatment principles of reversion (an interval of at least one year is required for another surgery for reversion, patient with hormonal ocular hypertension shall not take a second surgery).

II. Cause, prevention and treatment of corneal haze.

III. Cause, prevention and treatment of hormonal ocular hypertension.

IV. Varieties and application principles of hormone eyedrops.

V. Cause and avoidance of dizziness.

VI. Cause and avoidance of reduction of best corrected eyesight.

Chapter twelve Corneal topography

Section one Overview

I. Concept of corneal topography.

II. History of corneal topography: shape and examination method of Placido disc, brief analysis of image.

Section two Normal corneal topography and its area division

I. Anterior surface of a normal cornea: change patterns of corneal curvature radius from the corneal center to the edge, relationship between corneal curvature radius and corneal power. Main prevailing methods for measure of corneal topography, relationship between corneal curvature radius and image size.

II. Area division of corneal topography: four concentric anatomic areas of cornea.

III. Corneal meridian and semi-meridian: concept of corneal meridian, starting points and rotating directions on both eyes, concept of semi-meridian, concept of polar coordinates.

Section three Features and advantages of corneal topography

I. Disadvantages of corneal keratoscope: observation range, sensitivity and degree of precision.

II. Disadvantages of keratometer: principle of keratometer, limitation and predictability.

III. Advantages of computer-aided corneal topography system: corneal coverage, area, data point and other advantages.

Section four Composition and working principles of corneal topographic device

I. Three components of corneal topographic device (note: Placido disc projection system, real-time image monitor system and computer image processing system).

II. Working principles for difference components of corneal topographic device: projection range of Placido disc projection system, function of real-time image monitor system and working principle for computer image processing system.

Section five Evaluation of corneal topography

I. Color and respective corneal power: corneal power represented by cold color or warm color. Concept of grade, concept of Paring standards (or international standard scale).

II. Concept, measurement principle and normal value of corneal surface asymmetry index (SAI).

III. Concept, measurement principle and normal value of corneal surface regularity index (SAI).

IV. Concept and measurement principle of simulated keratoscope reading (SimK).

V. Concept of potential vision (PVA).

Section six Significance of corneal topography in PRK

I. Preoperative significance

Normal corneal topography: common types and respective proportions, meanings of difference types; screening of early keratoconus: screening of early keratoconus: proportion of keratoconus in PRK patients, consequences of PRK patients with keratoconus, main features of corneal topography of early keratoconus, diagnosis and screening criteria for subclinical keratoconus (note: central corneal power, difference between superior corneal power and inferior corneal power, difference between central corneal powers of both eyes).

II. Postoperative significance

Post-PRK shapes of corneal topography, relationship between shape, cutting quality and effect. Definition, cause and influence of corneal central island; evaluation of cutting position, tolerance of deviation of cutting center, consequences of visible deviation of cutting center (note: corneal astigmatism, reduction of best corrected eyesight); evaluation and dynamic observation of cut depth; three types and respective behaviors of post-PRK healing of the cornea.

Chapter thirteen Myopia treatment with LASIK

Section one History of LASIK

I. Advantages and disadvantages of LASIK.
II. Types and maintenance of microscopic corneal knife.

Section two Indications and contraindications of LASIK

I. Range of myopia for LASIK treatment (LASIK is suggested for over –6.00 to –8.00D).
II. Ocular diseases and systemic diseases making LASIK unsuitable.

Section three Key points for LASIK

I. Procedures and respective key points for LASIK.
II. Postoperative stroma thickness beneath corneal flap is suggested to be over 250 μm.

III. Possible complications and treatments of LASIK.

Section four Postoperative treatment and complications of LASIK

I. Key points of medication and nursing for LASIK.

II. Possible complications and respective treatment of LASIK.

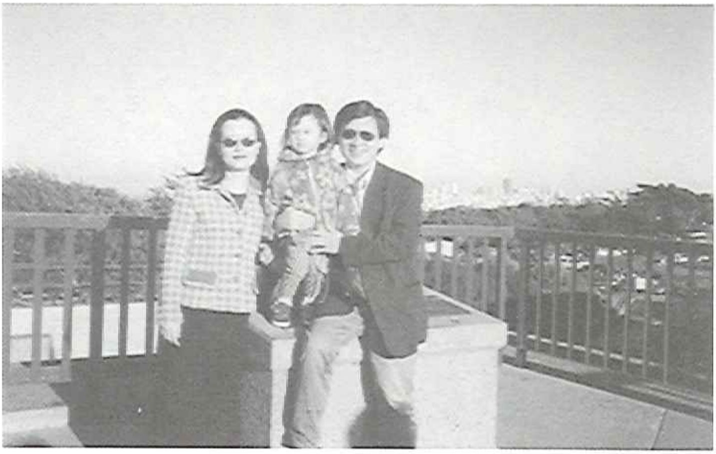
Chapter fourteen Phototherapeutic keratectomy (PTK)

I. Definition and indications of PTK.

II. Preoperative examination and evaluation of PTK. Contraindications of PTK.

III. Operative skills and special problems of PTK.

IV. Major complications of PTK.

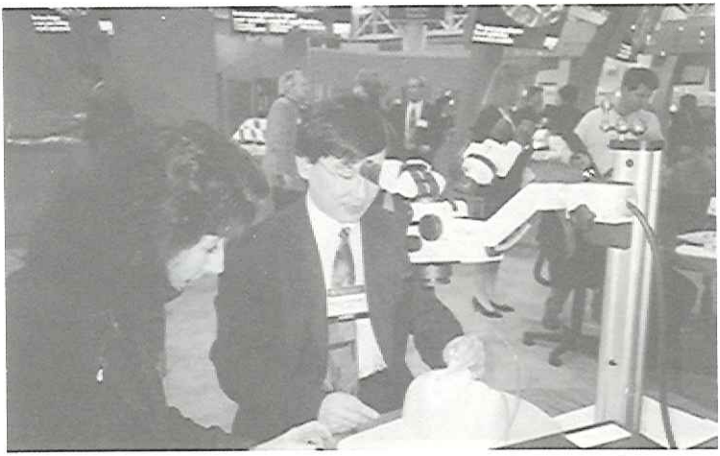


Dr, David Chang, with families at San Francisco, California, U.S.A in 1997 **AAO**

Dr, David Chang, at New Orlean Louisiana, U.S.A in 1998 **AAO**

Dr, David Chang , the 2^{nd}, right, at Orlando , Florida, U.S.A in 1999 **AAO**

Dr, David Chang, the $2^{nd,}$ right, with families at Dallas , Texas, U.S.A in 2000 **AAO**



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2002 **AAO**

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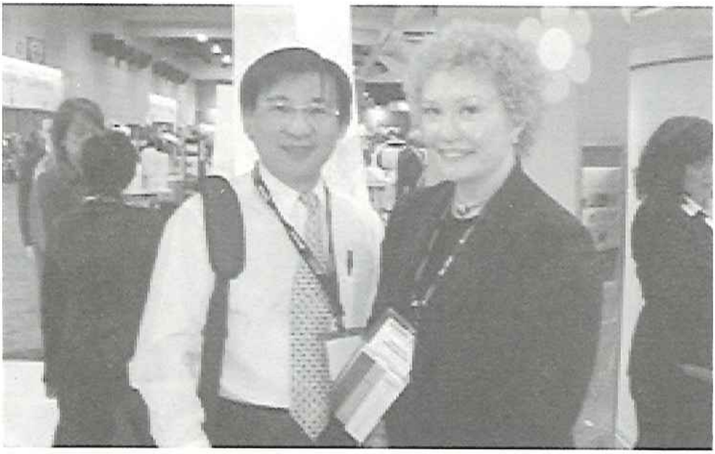

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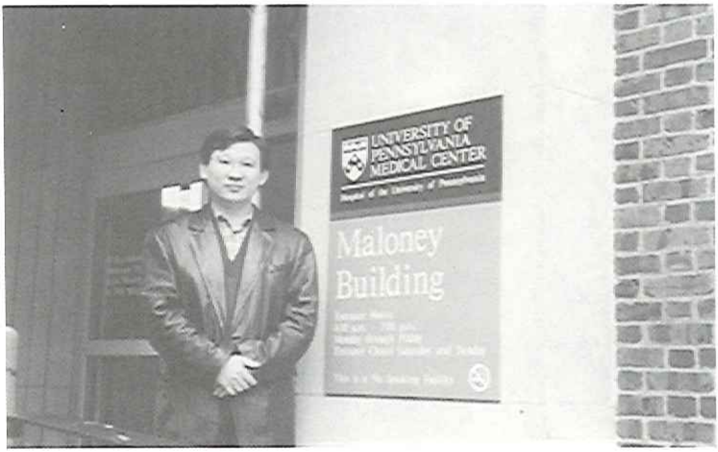

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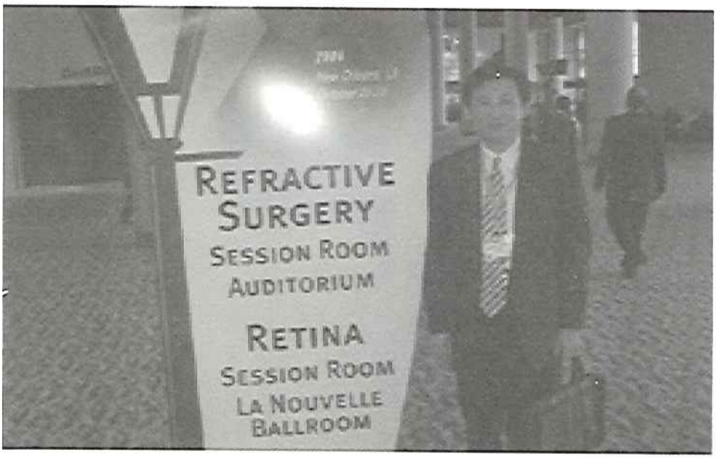

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