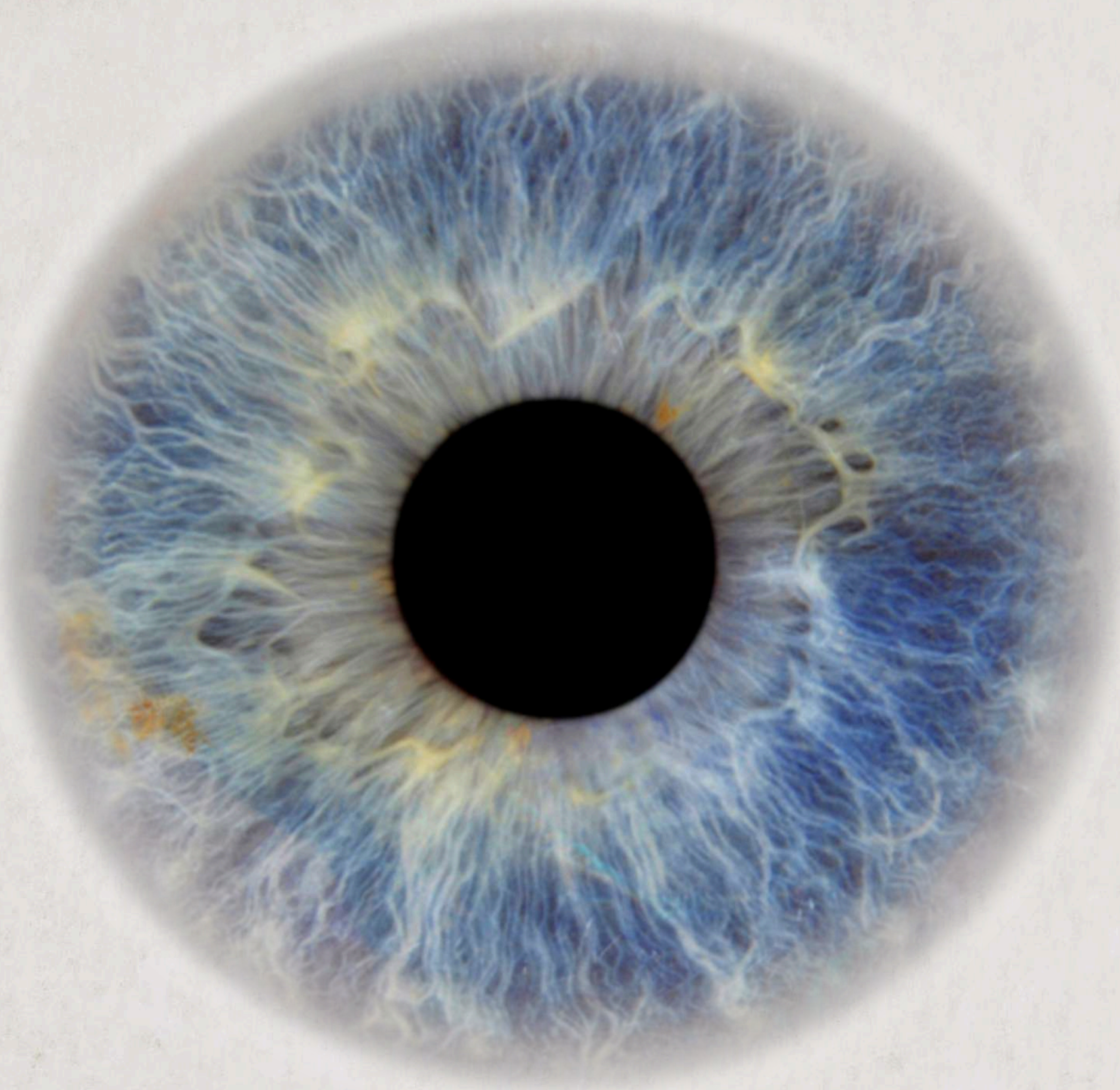
Contact Lens Practice Manual

A Comprehensive Guide to Wearing and caring Contactlens



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CONTACT LENS PRACTICE MANUAL

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Preface

Welcome to the "Contact Lens Practice Manual." This comprehensive guide is designed for both new and experienced practitioners who wish to enhance their understanding and skills in the field of contact lens fitting and management.

In recent years, advancements in contact lens technology and materials have transformed the field, making it crucial for practitioners to stay abreast of the latest developments. This manual aims to bridge the gap between theoretical knowledge and practical application, providing a resource that is both informative and practical.

The content has been carefully curated to address a wide range of topics, including the latest innovations in contact lens design, detailed fitting techniques, troubleshooting common issues, and best practices for patient care. Each chapter combines evidence-based practices with real-world scenarios to help you apply concepts effectively in your daily practice.

Our goal is to empower you with the knowledge and skills necessary to deliver optimal patient outcomes and enhance their overall experience with contact lenses. Whether you are a seasoned professional or just starting out, we hope this manual serves as a valuable tool in your professional journey.

We would like to extend our gratitude to the contributors, whose expertise and dedication have been instrumental in bringing this manual to fruition. Their insights and experiences have enriched the content and ensured that it remains relevant and practical.

Thank you for choosing this manual as your resource for contact lens practice. We look forward to supporting your continued growth and success in this dynamic field.

Acknowledgements

The creation of the "Contact Lens Practice Manual" has been a collaborative effort, and it is with great appreciation that we acknowledge the individuals and organizations who have made this project possible.

First and foremost, we extend our heartfelt thanks to our contributors and reviewers, whose expertise and insights have been invaluable in shaping the content of this manual. Your dedication and commitment to advancing the field of contact lens practice have greatly enriched this work.

Special thanks to Mr. Saurabh Adhikari, Chief Operating Officer Swami Vivekananda University, Barrackpore, West Bengal, whose insightful feedback and support have been instrumental in the completion of this work. Additionally, we appreciate the contributions of the Swami Vivekananda University for providing the necessary resources and support for this study. Your ongoing investment in scientific inquiry and innovation is crucial to the progress of our field. We are particularly grateful for the funding agencies whose financial support has enabled the research featured in this book.

We also wish to acknowledge our colleagues and collaborators whose discussions and shared knowledge have enriched the content of this book. Your intellectual generosity and enthusiasm for eye and vision science are truly inspiring.

Our sincere thanks to the editorial team for their hard work and dedication. Your meticulous attention to detail and unwavering commitment to excellence have been vital in bringing this project to fruition.

We are grateful to our families and friends for their patience, encouragement, and support throughout the preparation of this book. Your understanding and unwavering belief in our work have been a source of strength and motivation.

Finally, we extend our appreciation to the readers of this book. Your curiosity and passion for eye and vision science drive the continuous exploration and discovery that propel our field forward. It is our hope that this book will serve as a valuable resource and inspire further research and innovation.

Thank you all for your contributions and support.

Content

Chapter 1: History of Contact Lens

The history of contact lenses (CLs) spans several centuries and includes contributions from numerous inventors and scientists.

Early concepts (1508-1887)

Several researchers considered inserting an optical device into the eye to improve eyesight before the late 19th century, when contact lenses were first used. It was impossible to implement any of these ideas.

Figure 1: Scientist Leonardo Da Vinchi

In 1508, Leonardo da Vinci (figure-1) first introduced the concept of contact lenses in his work titled "Codex of the Eye, Manual D." He described two techniques for managing corneal power: submerging the entire head in water or wearing a glass hemisphere filled with water over the eye (figure-2). Neither of these theories was

Figure 2: Leonardo da Vinci's idea to counteract corneal power

realistic during his time or any other, but he did not advocate their use for correcting eyesight. He was interested in the eye's inner workings (Heitz and Enoch, 1987).

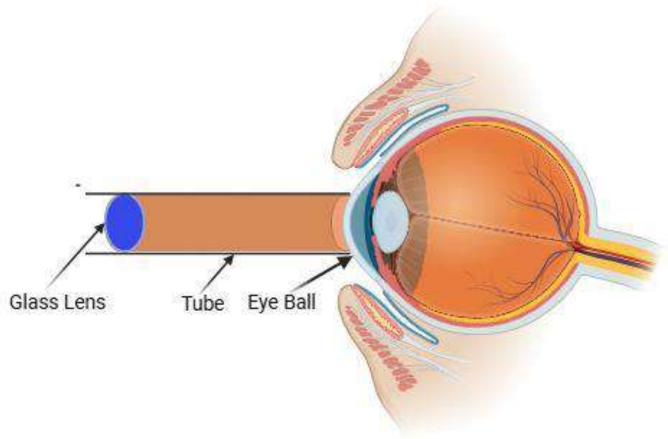

Figure 3: René Descartes' fluid-filled tube

A glass tube filled with fluid and intended to be placed directly on the cornea was reported by René Descartes in 1636 (Figure-3). The form of the transparent glass at the tube’s end determined the optical correction. While it is true that blinking is not feasible, Descartes’s application of the notion of directly nullifying corneal dioptric power is in line with the ideas underpinning the contemporary design of contact lenses (Enoch, 1956).

Figure 4: Scientist Thomas Young

Thomas Young (figure-4) constructed an apparatus in 1801, as part of his experiments on the mechanics of

accommodation, which consisted essentially of an eyecup filled with liquid

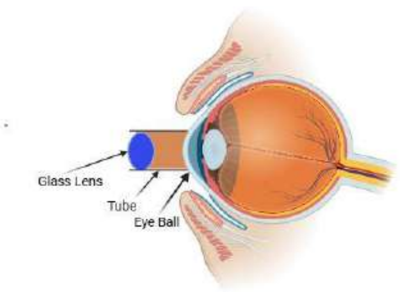

Figure 5: Thomas Young's eyecup design

that tightly fit into the orbital rim. (Young, 1801) (Figure-5). Mounting a microscope eyepiece to the top of the eyecup was a part of this approach, as in Descartes's work. While Young's innovation had the advantages of being fastened to the head with a band and allowing for blinking, he never intended for it to be used to correct refractive defects. Sir John Herschel presented two novel concepts in the Encyclopedia Metropolitana in 1845: the first was a glass sphere that could be filled with animal jelly, and the second was an unidentified cornea mold that could imprint on a transparent material. Dallos and István Komáromy of Hungary built upon these concepts in 1929; however, there is no proof that he actually tested them.

Glass CLs

Figure 6: Adolf Eugene Fick

There was a flurry of activity in the late 1880s about research on CLs, which prompted a debate regarding the individual who first used a contact lens. It is said that the foremost person to record the procedure of making and fitting CLs was Adolf Eugene Fick, a German Ophthalmologist (Figure-6). Before testing them on himself and a handful of consenting subjects, he first tried putting afocal scleral contact shells on rabbits (Efron and Pearson, 1988). A patient sent to them by Dr. Sämisch was described in a textbook from 1910 by ocular prosthesis makers Müller and Müller as having a partly transparent protective glass lid fitted to their eye. (Müller and Müller, 1910). The French ophthalmologist Eugène Kalt successfully equipped two keratoconic patients with afocal glass scleral shells (Figure 7), reporting substantial improvements in their eyesight. Professor Photinos Panas, a prominent Kalt medical colleague, reported this work to the Paris Academy of Medicine on March 20, 1888. This report effectively confirmed that Fick's work had occurred earlier (Pearson, 1989). August Müller, a German student studying medicine at Kiel University, was the first to successfully install a powered contact lens (Figure-8) (Pearson and Efron, 1989).

Figure 7: Scientist Eugène Kalt

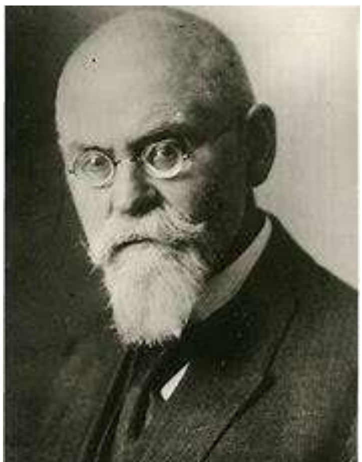

Figure 8: Scientist August Muller

Müller submitted his first paper to the Faculty of Medicine in 1889, detailing the process of correcting his own high refractive error (myopia) using a scleral CL with power. Müller wore the CLs of Karl Otto Himmler (1841–1903), an optical engineer whose company was well-known worldwide for producing microscopes and related equipment. His business thrived until the start of World War II. Therefore, we must recognize Himmler as the pioneer of optically ground CL manufacturing (Pearson, 2007). Despite these pioneering therapeutic studies, very little progress occurred in the half-century that followed. Clinicians such as Dallos meticulously documented advancements in scleral lens fitting techniques, focusing on the lens's design to enable tear flow beneath it (Dallos, 1936). In addition, Dallos developed methods for grinding lenses based on the impressions of the human eye.

Plastic scleral CLs

Plastic scleral lenses mark a significant evolution from the early glass scleral lenses to more advanced and comfortable designs. In 1936, with the introduction of transparent polymethyl methacrylate (PMMA) to the U.S. market by Rohm and Haas, another American scientist, Feinbloom, detailed a scleral lens with a transparent center and an opaque plastic haptic part.

The use of PMMA in scleral lenses was followed shortly by their machining. One important reason for using PMMA in contact lens production was that it was thought to have no biological effect on the eye.

Military doctors reached this conclusion after studying the eyes of WWII pilots who had sustained irreversible damage to their vision while flying dogfights and flying through the air with cracked cockpit windshields. Long after these mishaps had occurred, their eyes still did not respond. Lightweight, resistant to breaks, and simple to lathe and polish are some of PMMA’s other benefits.

Plastic corneal CLs (1948)

Kevin Tuohy, an optical technician, made a mistake in his lab that sparked the creation of corneal lenses, also known as hard lenses. The lathed PMMA scleral lens caused the corneal and haptic parts to separate. Curious about the corneal section's wearability, after smoothing the edge, Tuohy put it into his own eye and discovered it was bearable (Braff, 1983). Additional studies led to the advancement of rigid CLs, previously known as "hard" lenses when made from PMMA. After Tuohy patented his invention in February 1948, the contact lens entered a period of widespread use. The spherical Tuohy lens design had two main flaws: too much apical bearing caused abrasion in the central cornea and swelling, and too much corner lift made the lens easy to remove. As a result of these problems, multicurve and aspheric concepts emerged, which are now widely used today, thanks to the use of better gas-permeable materials (PMMA is practically extinct).

Silicone elastomer CLs (1965)

There is a special class of contact lens materials to which silicone rubber belongs. Lenses made of this material take the shape of a soft lens because of the way they physically behave. Since silicone elastomer is devoid of water, it is similar to a hard lens material, in contrast to all other types of soft lens materials. Although silicone elastomer is minimally invasive to corneal respiration because of its high oxygen and carbon dioxide permeability, it is challenging to produce and requires treatment to make it comfortable to wear due to its hydrophobic surface. Since its initial fitting, there has been no improvement in surface wettability, which has limited this lens's clinical applicability. The public's access to silicone elastomer lenses remains uncertain. Mandell (1988) states that there was some patent action from the mid-1960s to the early 1970s; he claims to have observed ten users in 1965 with these lenses and had very negative clinical outcomes.

Soft CLs (1972)

Wichterle and Lim published their study "Hydrophilic gels for biological use" in Nature on January 9, 1960. The paper's final sentence suggests that trials conducted in various scenarios, including the production of contact lenses and arteries, have yielded promising outcomes. This may be the biggest understatement in the literature regarding contact lens development. Otto Wichterle's early efforts to make cast-molded soft CL from hydroxyethyl methacrylate (HEMA) were unsuccessful (Figure-9). Discouraged by his superiors and unable to secure assistance from his company, Wichterle resorted to conducting his clandestine study from home. Figure-10 shows the spincasting technique that Wichterle invented using a children's building set for mechanical projects. He

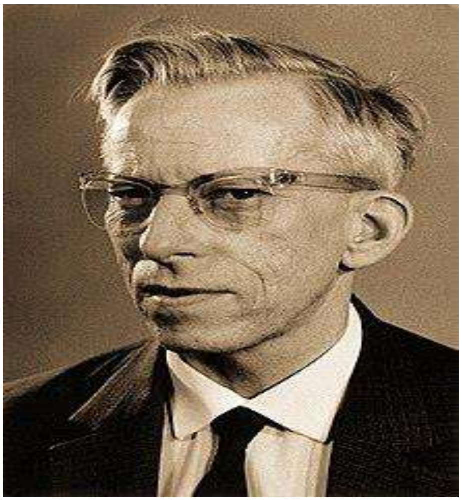

Figure 9: Scientist Otto Wichterle

Figure 10: Spincasting Machine

successfully persuaded his colleagues to conduct more experiments at the institute. His creation of "the first suitable contact lenses" was probably around the time the first soft CL was worn on a human eye, which occurred in late 1961 (Wichterle, 1978). Bausch & Lomb, an American company that had previously secured the patent for their commercial development, introduced the soft contact lenses to the global market in 1972.

Because of their increased biocompatibility and heightened comfort, HEMA lenses became an instant hit with consumers. Still, studies and clinical observations show that thinner, more water-filled soft lenses might help the front of the eye's poor physiological response to early thick HEMA lenses by making them more permeable to oxygen. Research and development in the field of contact lenses has largely focused on improving biocompatibility. The improvement of corneal oxygenation and the reduction of protein, lipid, and tear absorption have primarily achieved this (McMahon and Zadnik, 2000).

The introduction of fixed-in-place gas-permeable lenses occurred in 1974. If you are looking for a perfect CL material, PMMA is your best. One area for improvement could be its ability to prevent gases from passing through the cornea, a crucial component of aerobic metabolism. It prevents carbon dioxide from entering the atmosphere and oxygen from moving into the cornea. This limitation has primarily motivated the development of gas-permeable, stiff lens materials. Citric acid butyrate was one of the earliest attempts at a stiff gas-permeable material; it allowed for some oxygen permeability but was warp-prone. Norman established a new class of contact lens materials known as silicone acrylates in 1974 when he successfully added silicone to the basic PMMA structure (Gaylord, 1974).

Therefore, people have supplemented hard materials with substances like styrene and fluorine to make them more biocompatible. The year 1988 was the year of disposable lenses. During the early stages of soft lens growth and development, users frequently wore the same lenses until they became uncomfortable or outgrew them, caused significant ocular reactions, broke, or lost them. It soon became clear that lens deposition and spoilage were the two biggest problems with successful long-term lens usage. The expensive cost per unit of CLs was a major deterrent, even though replacing them regularly would have been an easy solution to some of these issues. Klas Nilsson of Gothenburg, Sweden, and other progressive eye doctors began prescribing monthly lens replacements to their patients in the early 1980s after successfully educating them on the benefits of the practice.

Nilsson established beyond a shadow of a doubt that substituting CLs on a daily basis was beneficial in a subsequent seminal scientific article she co-authored, the "Gothenburg study" (Holden et al., 1985). Thus, the idea of routine CL renewal emerged, although it was still somewhat costly for patients back then. Something must be done regarding the cost of lenses if they are to become the norm for regular replacement. Under the direction of ophthalmologist Michael Bay, a team of Danish engineers and physicians created a molding technology that allowed for the mass production of inexpensive individual lens packs (Mertz, 1997). Known by the brand name "Danalens," this product made its market debut in Scandinavia in 1984 and became well-known for being the first completely disposable CL. Nevertheless, there were several reports of issues with the lenses and packaging due to the unsophisticated original manufacturing process (Benjamin et al., 1985; Bergmanson et al., 1987). After purchasing the Danalens technology in 1984, the pharmaceutical behemoth Johnson & Johnson—which had no prior experience in the contact lens industry—took a fresh approach to the production, packaging, and shaping of lens polymers (Mertz, 1997). The USA introduced the Acuvue lens in June 1988, and it quickly gained global recognition as an affordable extended-wear lens that only required weekly replacements. After this lens became popular, Johnson & Johnson became the market leader in contact lenses. All other major CL manufacturers adopted a similar approach, and today, 98% of prescribed soft CLs in the UK undergo monthly or more frequent updates (Morgan, 2009).

Daily disposable CLs (1994)

Daily lens replacement is the maximum possible frequency. Award, a Scottish company that was acquired by Bausch & Lomb in 1996, developed the manufacturing process; they manufactured the lens cases using the majority of the lens mold. Because this method significantly reduces the price per lens, daily disposability becomes a realistic prospect. In 1994, the United Kingdom debuted the "Premier" throwaway CLs for everyday use.

At approximately the same time, Johnson & Johnson introduced the “1-Day Acuvue” daily disposable lens to western areas of the United States. There has been continuous back-and-forth concerning whether Award or Johnson & Johnson introduced the foremost daily throwaway CL (Meyler and Ruston, 2006). In 1997, CIBA Vision introduced a product named “Dailies” to the market for everyday disposable lenses.

Silicone hydrogel CLs (1998)

A substance that exhibits exceptionally high oxygen performance has always captivated the CL industry. Developing this kind of CL is essential for addressing hypoxic lens-related issues, which considerably reduce the therapeutic value of CLs, particularly for long-term use. Even though silicone elastomers were a natural choice, they were never going to be able to make effective lenses due to the reasons mentioned above. For a long time, researchers in the field of CLs had known that a silicone-hydrogel hybrid might theoretically solve many of the issues related to silicone elastomers used in those lenses. In 1998, Bausch & Lomb introduced Purevision and CIBA Vision, two spherical silicone hydrogel CLs, to the market after more than a decade of dedicated study. Many in the CL industry consider the release of these lenses as the most groundbreaking innovation in the field.

The field has been evolving since the introduction of Wichterle's HEMA in the 1960s. In the past decade, all of the major contact lens companies have released silicone hydrogel lenses. These lenses come in a variety of replacement mechanisms, including daily disposable lenses, which are available in toric and multifocal forms.

The Evolution of CL Technology: A Timeline of Significant Events

John Herschell,1845	Significantly advanced the theoretical understanding of contact lenses.
1886	Utilized therapeutic contact lenses to deliver medication directly to the cornea, showcasing their potential in medical treatment.
Müller Brothers,1887	Developed transparent blown glass shields for a patient with lid disease, representing an advancement in protective eyewear.
Adolf Fick,1888	Research on the application of glass shells on rabbit corneas, pioneering experimental work in the use of contact lenses on animals.
Dr. Eugene Kalt,1888	Pioneered the application of glass shells for patients with keratoconus, demonstrating the efficacy of contact lenses in managing this corneal condition.
Dr. August Müller,1889	Conducted self-experiments using glass lenses on his own eyes, carefully observing the impact of corneal edema and contributing to our understanding of the physiological effects of contact lenses.
Dr. D. E. Sulzer,1892	Documented the utilization of lathe-cut glass lenses, highlighting advancements in contact lens manufacturing methods.
Henry Dor,1892	Proposed using normal saline instead of glucose solution behind the lens, enhancing the comfort and practicality of contact lenses.
Dr. Thomas Lohnstein,1896	Pioneered the creation of 'water spectacles', which are now recognized as the Hydrodiascope, representing a significant advancement in contact lens design.
Adolf Fick, 1896	Discontinued his work on contact lenses following critical commentary by A. Elschnig in 1894, demonstrating how scientific critique can influence research directions.
1896-1912	Minimal progress was made in the field of contact lenses during this period.
1911, (Manufacturer Carl Zeiss)	Based in Jena, pioneered the development of the first one-piece fully ground lens. This innovative design incorporated numerical specifications, enabling accurate and reproducible manufacturing.
(Manufacturer Carl Zeiss), 1912	Around 2,000 lenses were manufactured for patients, with the majority produced by Carl Zeiss.
Dr. DH Erggelet,1913	Conducted a study on the application of contact lenses for the treatment of monocular aphakia.
1920s	The combined production of contact lenses in the USA and Europe amounted to less than 5,000 pairs.
Dr. Fischer,1929	Expressed concerns regarding the impact of corneal respiration on contact lens tolerance. He proposed the use of an air bubble between the lens and the eye, acting as a CO_2 reservoir.

Dr. Von Csapody,1929	Conducted experiments involving the use of low-melting-point paraffin wax to mold the eye. The wax would then solidify on the eye surface.
Dr. Poller,1930	Pioneered the use of Negocoll, an alginate-based material, for eye molding. The casting substance employed was Hominit.
Dr. Andrew Rugg-Gunn,1930	Caised concerns regarding the adoption of contact lenses in Britain, suggesting that the British public might harbor reservations about their widespread use. Meanwhile, Röhm and Haas, based in Philadelphia, pioneered the development of an acrylic resin (known as Plexiglass, a precursor to PMMA) initially intended for the aviation industry.
Dr. Joseph Dallos,1934	Incorporated small openings (fenestrations) in the limbal region of contact lenses. Meanwhile, John Crawford and Rowland Hill secured a patent for poly (methyl methacrylate) (commonly known as PMMA), a material widely used in contact lens manufacturing.
1935-1939	In the United States, sales of glass lenses reached an estimated 10,000 pairs.
Adolf Müller-Welt,1935	A German contact lens pioneer, developed a commercially viable and marketable hand-blown, fluidless glass scleral contact lens. Unlike other scleral lenses of the time, his design allowed tears to circulate beneath the lens during wear. Müller-Welt's innovative manufacturing process involved blowing glass into a pre-shaped mold of gypsum and marble. His lenses were not only durable but also resistant to chemical erosion from tear film components. His contributions significantly advanced the field of contact lenses.
Dr. William Feinbloom,1937	Endeavoured to innovate a hybrid contact lens design that integrated a glass corneal portion with a plastic scleral segment.
Dr. J. Teissler, 1937	Conducted experiments that aimed to fabricate corneo-scleral shells using celluloid, but these attempts did not yield successful results.
Theodore Obrig,1938	Initiated the use of 2% sodium fluorescein along with ultraviolet light as a method to assess the fit of contact lenses.
1938	Ongoing advancements in the development of poly (methyl methacrylate) (PMMA).
Dr. William Feinbloom, Theodore Obrig, Ernest Mullen, and Istvan Gyorrfy,1938	Instrumental in developing the initial scleral lenses made of PMMA.
Clifford Barnes and Harry Hind,1939	Established Barnes-Hind, a company specializing in ophthalmic solutions."
1940s	The heightened awareness of contact lenses being used by service personnel during World War II resulted in a significant increase in consumer demand after the war. Additionally, this period saw advancements in the chemistry of PMMA (poly(methyl methacrylate)), a material commonly used for contact lenses.
1946	Roughly 50,000 pairs of contact lenses found buyers in the United States.
Dr. Kevin Tuohy, 1948	Pioneered the creation of large-diameter corneal PMMA lenses (ranging from 11.5 mm to 12.5 mm). These lenses were intentionally

	fitted flatter than the natural corneal curvature (K), resulting in a notable transition away from traditional scleral PMMA lenses
1949	In the USA, it is estimated that approximately 200,000 pairs of contact lenses were distributed.
1950s	There has been a surge in studies and scholarly articles examining the effects of wearing contact lenses on the health and function of the cornea.
Kevin Tuohy,1950	Received a patent for his innovative design of corneal lenses.
George Butterfield, 1950	Suggested the concept of fitting corneal lenses ‘on K’ and was awarded a patent for pioneering the initial multicurve lens design.
Sohnges, Neill, and Dickinson,1953	The concept of ‘micro lenses’ was first introduced. These lenses, characterized by their small 9.5 mm diameter, are designed to have a flatter curvature than the standard K value by approximately 0.3 to 0.6 mm.
Otto Wichterle and Drahoslav Lim,1956	Pioneers in developing an innovative hydrophilic polymer. Their research indicated that this material could be suitable for creating disposable lenses.
Walter E. Becker,1956	Initiated studies exploring the application of silicone rubber in the manufacturing of contact lenses.
Wichterle and Lim,1961	Pioneered the development of a practical hydrophilic polymer and secured a patent for their innovative spin-casting manufacturing technique.
1966	Bausch & Lomb entered into a licensing agreement related to hydrogel lens material and production technology.
John de Carle,1970	Pioneered the development of the Permalens™, a high-water-content lens made from a hydrophilic polymer. This innovative lens material, with a water content of 72%, was designed to enhance comfort and oxygen permeability for contact lens wearers. Dr. de Carle’s Permalens had a diameter of 12.50 mm and required a steeper inner radius to maintain proper fit and stability on the cornea.
1971	Bausch & Lomb initiated the commercial distribution of Soflens, a hydrogel contact lens, within the United States.
Dow Corning,1972	Secured the rights to the technology behind silicone elastomer lenses.
1974	The patent for the Gaylord gas permeable hard lens was officially granted.
Orlando A. Battista,1978	Development of a contact lens made from collagen, although it was later found to be unstable and would dissolve in certain tear enzymes.
1984	Vistakon acquired the Dana Disposable Lens technology originating from Denmark.
1987	Vistakon initiated a selective rollout of Acuvue disposable lenses within the American market.
1988	Vistakon, Bausch & Lomb, and CIBA Vision introduced disposable soft contact lenses (SCLs) to the market.

The progression from Leonardo da Vinci's simple ideas to the complex lenses used today is a reflection of the resilience and creativity of the human spirit. The CL has transformed millions of lives, offering a clearer view of the world without the barriers of traditional spectacles. And as science and technology continue to evolve, the future of contact lenses holds even more promise, potentially merging with digital technology to create smart lenses that can do much more than improve vision.

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Chapter 2: Optics of Contact Lens

Human eye is a complex optical system which has the ability to focus at different distances in order to see objects clearly. In this focusing system, anterior cornea contributes about three-fourth of ocular power followed by the crystalline lens which is responsible for the rest supplementary power. Refractive error is a kind of defocus which arises due to change in this optical power or the curvature of the cornea. This can be corrected with the help of spectacles and contact lenses.

Contact lenses are referred as thin, curved lenses which sits on the anterior surface of cornea directly providing correction for different types of refractive errors. The optical principle of vision correction of contact lenses is same as that of traditional glasses but the key difference lies in the way the contact lenses interact with the eye. The two main strands that must be remembered when handling CL optics are:

A. Influence of the wearer on the optical variation from the spectacles
B. Necessity of the practitioner to understand the components which affects the dioptric value of CL at the back surface.

In this chapter, we will briefly learn about the possible effects of optical variation between glass prescription and CL. Later in the section, we will also learn about the set of rules of thumb that must be followed by practitioners to make quick changes in the power of the contact lenses with changes in the lens parameters.

1. Differences in the Optical properties: Contact lens Vs Spectacles

- Contact lenses are placed on the anterior surface of the eye, whereas the spectacles are placed at the distance of 12 to 14 mm from the anterior surface of the cornea. This results in the need for the vertex compensation of the spectacle power.
- In cases of high power, when a person wears spectacles, the eyes appear smaller or bigger based on the spectacle power the individual is wearing. This scenario is not seen in cases of contact lenses as they sit on the eye surface.
- Contact lenses provide fewer degrees of freedom in optical design compared to spectacles.

- Relative to other ophthalmic lenses, CL materials offer a lower as well as a narrower range of refractive indices.
- The accommodative response is more in myopes and less in hyperopes in case of contact lenses compared to spectacles.
- The amount of convergence in case of contact lenses is greater in case of myopes and less in case of hyperopes.

1.1 Back Vertex Compensation

Vertex distance is the width between the rear surface of the spectacle and the anterior side of the cornea. In case of contact lens, the vertex distance is zero, whereas the average vertex distance of a spectacle is 12 to 14 mm. Due to this reason, the effective power of the CL differs from the spectacle power. The formula used for the vertex power of contact lens is:

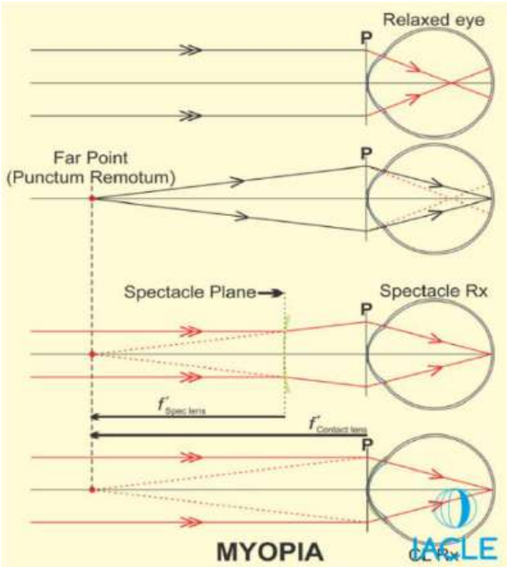
$\mathbf{F_{CL} = F_{SP} / (1-dF_{SP})}$ where,

F_{CL} = Contact lens power

F_{SP} = Spectacle lens power

d = Vertex distance in metres

This is to note that vertex compensation must be done in cases of spectacle power ≥ 4.00 dioptres. In the case of myopes, the dioptric value of CL is less than that of the spectacle lens because, compared to spectacle lens, the contact lens needs to focus light across a longer distance, i.e., $f_{CL} > f_{SP}$, as shown in Fig.1 (below). Whereas in hyperopes, the scenario is exact opposite of that in myopes. The contact lens needs to focus light across a shorter distance compared to spectacles lens, i.e., $f_{CL} < f_{SP}$. This leads to a lesser effective power of the contact lens as compared to spectacles in the case of hyperopes as shown in Fig.2 (below).



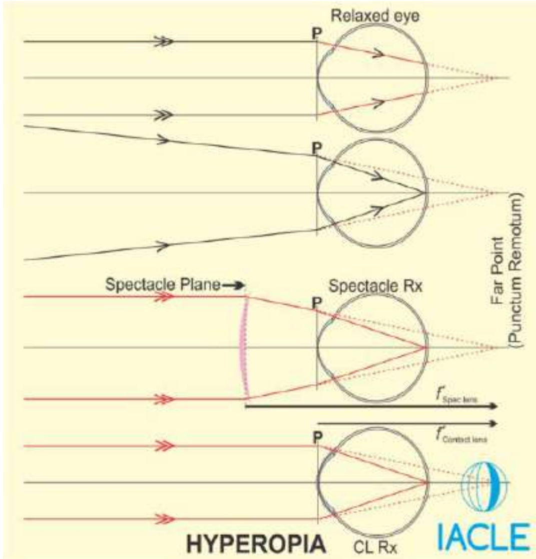


Figure: 1

Figure: 2

Example:

The dioptric value of glass prescription is -8 dioptres. The spectacle is 14mm away from the cornea. Calculate the dioptric value of CL?

Solution:

$\mathbf{F_{CL} = F_{SP} / (1-dF_{SP})}$

We know, F_{SP} = -8.00 D, d = 14mm = 0.014m

F_{CL} = -8.00/ {1-(0.014x-8.00)}

= -8.00/1.112

= -7.19 D

Hence, it is seen from the above example that the minus power required in a contact lens is less than that of the spectacle power.

For **astigmatic prescription**, the vertex compensation must be done individually for each principal meridian. If it is hypermetropic astigmatism in the spectacle prescription then the ocular lens will have greater cylinder power after vertex compensation, and vice-versa for myopic astigmatism. A vertex compensation table (table 1) is provided below for quick reference for the practitioner.

Table: 1 Back Vertex Power Compensation

1.2 Accommodation

Accommodative demand changes when a patient shifts to contact lens from glasses. It is seen that myopes accommodate more with CL as compared to glasses, whereas, hyperopes accommodate less with contact lenses. To illustrate, let's refer to the figure below.

The fig. 3a shows a near object (O) placed (l) 25cm far away from the plane of spectacles. The power of the glass prescription is -8 D. The vertex distance (d) is taken as 12 mm from the cornea. Hence the CL power will be -7.30D. To see the object clearly at 25cm, accommodation of 4 D is required. Therefore, the Vergence demand (L') = -8+(-4) = -12D.

The image of object O is formed at point O'.

Biofinity® toric Conversion
Back Vertex Distance=12mm
Plus

Plus	-0.75		-1.00		-1.25		-1.50		-1.75		-2.00		-2.25		-2.50	
Spheres	Sph	Cyl	Sph	Cyl	Sph	Cyl	Sph	Cyl	Sph	Cyl	Sph	Cyl	Sph	Cyl	Sph	Cyl
0.25	0.25	-0.75	0.25	-0.75	0.25	-1.25	0.25	-1.25	0.25	-1.75	0.25	-1.75	0.25	-2.25	0.25	-2.25
0.50	0.50	-0.75	0.50	-0.75	0.50	-1.25	0.50	-1.25	0.50	-1.75	0.50	-1.75	0.50	-2.25	0.50	-2.25
0.75	0.75	-0.75	0.75	-0.75	0.75	-1.25	0.75	-1.25	0.75	-1.75	0.75	-1.75	0.75	-2.25	0.75	-2.25
1.00	1.00	-0.75	1.00	-0.75	1.00	-1.25	1.00	-1.25	1.00	-1.75	1.00	-1.75	1.00	-2.25	1.00	-2.25
1.25	1.25	-0.75	1.25	-0.75	1.25	-1.25	1.25	-1.25	1.25	-1.75	1.25	-1.75	1.25	-2.25	1.25	-2.25
1.50	1.50	-0.75	1.50	-0.75	1.50	-1.25	1.50	-1.25	1.50	-1.75	1.50	-1.75	1.50	-2.25	1.50	-2.25
1.75	1.75	-0.75	1.75	-0.75	1.75	-1.25	1.75	-1.25	1.75	-1.75	1.75	-1.75	1.75	-2.25	1.75	-2.25
2.00	2.00	-0.75	2.00	-0.75	2.00	-1.25	2.00	-1.25	2.00	-1.75	2.00	-1.75	2.00	-2.25	2.00	-2.25
2.25	2.25	-0.75	2.25	-0.75	2.25	-1.25	2.25	-1.25	2.25	-1.75	2.25	-1.75	2.25	-2.25	2.25	-2.25
2.50	2.50	-0.75	2.50	-0.75	2.50	-1.25	2.50	-1.25	2.50	-1.75	2.50	-1.75	2.50	-2.25	2.50	-2.25
2.75	2.75	-0.75	2.75	-0.75	2.75	-1.25	2.75	-1.25	2.75	-1.75	2.75	-1.75	2.75	-2.25	2.75	-2.25
3.00	3.00	-0.75	3.00	-0.75	3.00	-1.25	3.00	-1.25	3.00	-1.75	3.00	-1.75	3.00	-2.25	3.00	-2.25
3.25	3.25	-0.75	3.25	-0.75	3.25	-1.25	3.25	-1.25	3.25	-1.75	3.25	-1.75	3.25	-2.25	3.25	-2.25
3.50	3.50	-0.75	3.50	-0.75	3.75	-1.25	3.75	-1.25	3.75	-1.75	3.75	-1.75	3.50	-2.25	3.50	-2.25
3.75	3.75	-0.75	3.75	-0.75	4.00	-1.25	4.00	-1.25	4.00	-1.75	4.00	-1.75	3.75	-2.25	3.75	-2.25
4.00	4.25	-0.75	4.25	-0.75	4.25	-1.25	4.25	-1.25	4.25	-1.75	4.25	-2.25	4.25	-2.25	4.25	-2.25
4.25	4.50	-0.75	4.50	-0.75	4.50	-1.25	4.50	-1.25	4.50	-1.75	4.50	-2.25	4.50	-2.25	4.50	-2.25
4.50	4.75	-0.75	4.75	-0.75	4.75	-1.25	4.75	-1.25	4.75	-1.75	4.75	-2.25	4.75	-2.25	4.75	-2.25
4.75	5.00	-0.75	5.00	-0.75	5.00	-1.25	5.00	-1.25	5.00	-1.75	5.00	-2.25	5.00	-2.25	5.00	-2.25
5.00	5.25	-0.75	5.25	-0.75	5.25	-1.25	5.25	-1.25	5.25	-1.75	5.25	-2.25	5.25	-2.25	5.25	-2.25
5.25	5.50	-0.75	5.50	-0.75	5.50	-1.25	5.50	-1.25	5.50	-1.75	5.50	-2.25	5.50	-2.25	5.50	-2.25
5.50	5.75	-0.75	5.75	-0.75	5.75	-1.25	5.75	-1.25	5.75	-1.75	5.75	-2.25	5.75	-2.25	5.75	-2.25
5.75	6.00	-0.75	6.00	-0.75	6.00	-1.25	6.00	-1.25	6.00	-1.75	6.00	-2.25	6.00	-2.25	6.00	-2.25
6.00	6.50	-0.75	6.50	-0.75	6.50	-1.25	6.50	-1.25	6.50	-1.75	6.50	-2.25	6.50	-2.25	6.50	-2.25
6.25	6.50	-0.75	6.50	-0.75	6.50	-1.25	6.50	-1.25	6.50	-1.75	6.50	-2.25	6.50	-2.25	6.50	-2.25
6.50	7.00	-0.75	7.00	-0.75	7.00	-1.25	7.00	-1.25	7.00	-1.75	7.00	-2.25	7.00	-2.25	7.00	-2.25
6.75	7.50	-0.75	7.50	-0.75	7.50	-1.25	7.50	-1.25	7.50	-1.75	7.50	-2.25	7.50	-2.25	7.50	-2.25
7.00	7.50	-0.75	7.50	-0.75	7.50	-1.25	7.50	-1.25	7.50	-1.75	7.50	-2.25	7.50	-2.25	7.50	-2.25
7.25	8.00	-0.75	8.00	-0.75	8.00	-1.25	8.00	-1.25	8.00	-1.75	8.00	-2.25	8.00	-2.25	8.00	-2.25
7.50	8.00	-0.75	8.00	-0.75	8.00	-1.25	8.00	-1.25	8.00	-1.75	8.00	-2.25	8.00	-2.25	8.00	-2.25
7.75	8.00	-0.75	8.00	-0.75	8.00	-1.25	8.00	-1.25	8.00	-1.75	8.00	-2.25	8.00	-2.25	8.00	-2.25

Therefore, l' = -83.33mm, but b = l'-d = -83.33 -12 =-95.3mm

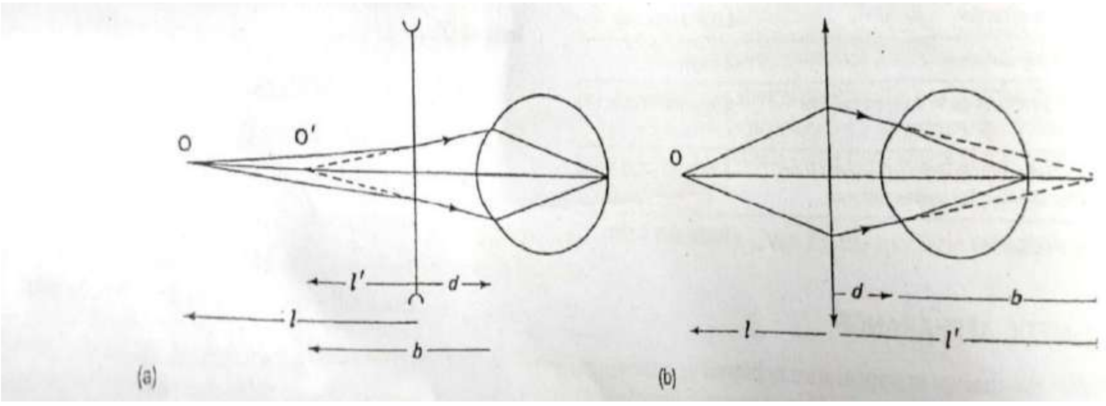
B = 1/b = -10.5 D.

This 10.5 D can be managed by the dioptric value of CL of -7.30D, and rest vergence demand i.e., -3.20 D needs to be neutralized by the accommodation of the myopic patient. Hence, we can conclude that myopes accommodate more with contact lenses.

Fig. 3b shows an equivalent condition in the case of hyperopes where the accommodation required with contact lens is less than spectacles.

Myopes accommodating more with contact lenses brings a disadvantage in cases of presbyopic patients. A myope patient who was not used to using near additions in spectacles might need a near correction with contact lenses. This can cause early presbyopia in patients using contact lenses as the accommodation demand is less in reserve.

Figure: 3- Seeing a near object through spectacle lens. (a) Myope (b) Hypermetropia



Hypermetropia patients have an advantage as presbyopia sets in late while using contact lenses. Using contact lenses in hyperopia gives an advantage in controlling the accommodative squint to a great extent.

1.3 Convergence

Spectacles are centred in front of the eye at a vertex distance of 12 to 14 mm in such a way that the optical centre coincides with the pupillary centre to avoid any prismatic effect. When a person tries to see off-axis, a prismatic effect occurs. Since the contact lens is placed on the ocular surface, it moves with the eye movement, and no prismatic effect is seen.

1.3.1 In Myopes

As shown in Fig. 4, myopic patient needs to converge more with contact lens than with spectacles. The reason is that when a patient wears spectacles and sees a near object, the light passes through the base-in prism, causing a base-in prismatic effect that reduces the convergence demand with spectacles. But in case of myope wearing a contact lens, there is no base-in prismatic effect, as the contact lens sits on the ocular surface. Hence, the amount of convergence required is greater.

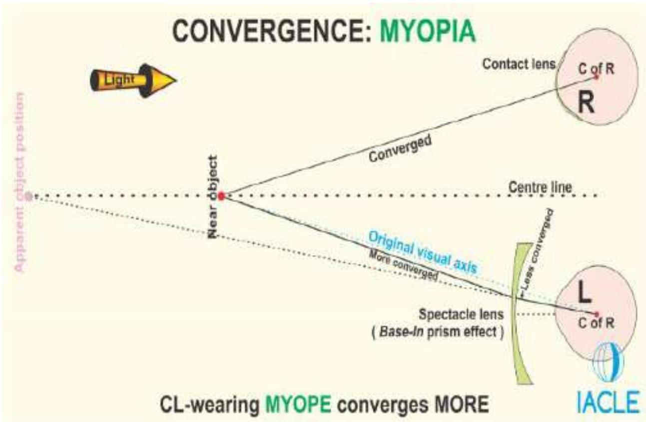


Figure: 4

1.3.2 In Hypermetropia

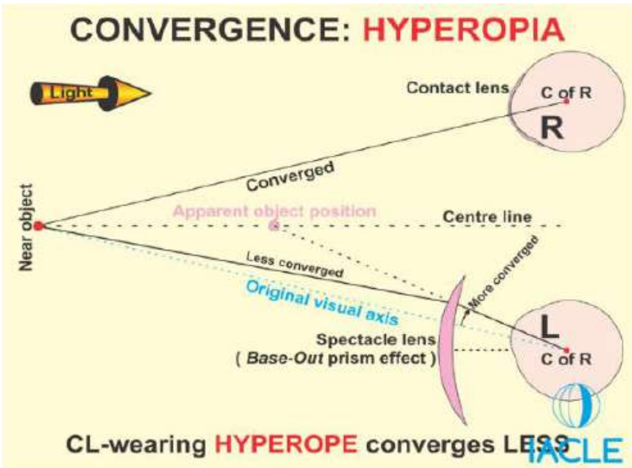
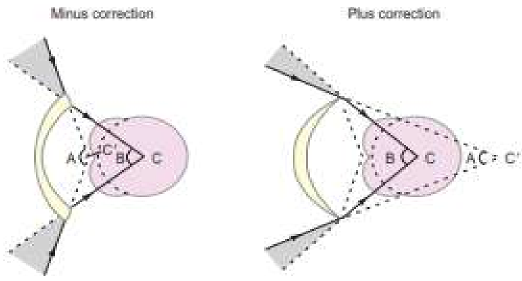


Figure: 5

As shown in Fig.5, hyperopes need to converge less with contact lenses than spectacles. This is because when a patient wears a plus spectacle and sees a near object, base-out prismatic effect occurs. This moves the eyes outwards, but to see the near object, the eye needs to converge. Hence, the motor action of eyes is greater than the prismatic effect, leading to more convergence with spectacles compared to contact lenses.



1.4 Field of Vision

Spectacles are good option for refractive error correction, but, on the contrary, they have a high impact on the visual experience. When a person sees through the peripheral region of high-plus powered spectacle, there is a limitation in the visual field called the ring scotoma (Fig. 6). Similarly, in high-minus powered spectacles, diplopia occurs when seeing through edges of the spectacles (Fig. 6). In both cases, there is a restriction of visual field. The contact lens moves with the eye rotation, so there is no problem of peripheral field distortion, leading to a better visual field.

Fig.6: Field of view with spectacles. C is the centre of rotation, and C' is the image formed by spectacles. B is the virtual field of view and A is the actual field of view

1.5 Magnification

When we talk about contact lenses, understanding their magnification is crucial. Magnification of a lens refers to how much larger or smaller an image appears when viewed through the lens compared to viewing it directly with the naked eye. Plus-powered spectacles provide magnification of images, whereas minus-powered spectacles provide minification of images.

While comparing the magnification of spectacles and contact lenses, it must be taken into account that magnification is strained by lens form and width.

1.5.1 Spectacle Magnification

It is the fraction between uncorrected retinal image with the corrected retinal image.

$$SM = \frac{Uncorrected\ retinal\ Imgae}{Corrected\ Retinal\ Image}$$

1.5.2 Contact lens Magnification (CLM)

To produce less magnification, contact lenses are the best option. Since they are placed on the anterior corneal surface, very close to the entrance pupil, they produce unit magnification.

$$CLM = \frac{Corrected\ image\ size\ with\ Contact\ lens}{Corrected\ Image\ size\ with\ Spectacles}$$

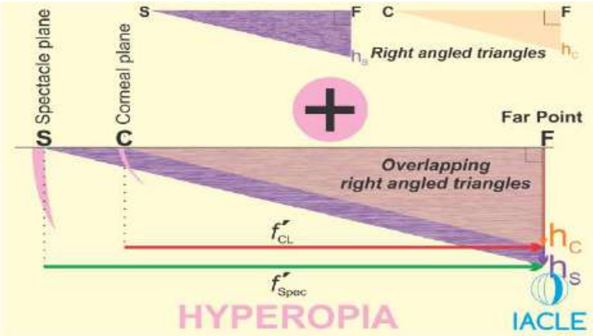


Fig. 7: Contact lens Magnification in case of Hyperopia.

Expression of CLM:

In fig.7, looking at the right-angled triangles CFh_c and SFh_S,

$$CLM = \frac{Image\ size\ with\ Cl}{Image\ size\ with\ spectacles}$$

$$CLM = \frac{Fh_C}{Fh_S}$$

We know, Images are directly proportional to focal length, therefore,

$$CLM = \frac{f'_{CL}}{f'_{SP}} = \frac{F'_{SP}}{F'_{CL}} \ldots\ldots(i)$$

We already know, $\mathbf{F_{CL} = F_{SP} / (1\text{-}dF_{SP})}$, so substituting the value of F'_{CL},

$$CLM = \frac{F'_{SP}}{F'_{SP}/(1-dF'SP)}$$

After Simplification,

$CLM = (1\text{-}dF'_{SP})$

1.6 Tear Lens

A tear lens is a layer of tear film joining the rear side of contact lens and the cornea. The tear lens formed will be uniform if we choose the correct contact lens base curve leading to zero tear lens power. The tear lens is very thin in case of soft lenses. Whereas, the tear lens in the case of a rigid contact lens depends on the lens fitting.

If the contact lens fitted has a steeper base curve, then a positive tear lens is formed, i.e., the tear lens is centrally thick and peripherally flat. This tear lens will act as a plus lens.

If the contact lens fitted has a flat base curve, then a negative tear lens is formed i.e., the tear lens is centrally flat and peripherally thick. This tear lens will act as a negative lens.

Rule of thumb

For a steeper or flatter base curve of contact lens by 0.05mm a tear lens of 0.25 Dioptres approx. is formed either plus or minus.

1.7 Aberrations - Spectacle vs Contact Lens

As the contact lenses are worn on the corneal surface, they produce very small amount of aberration as compared to spectacles. The amount of chromatic aberration is very unpredictable using contact lenses.

1.8 Over-refraction

Over-refraction is an important step in contact lens fitting as it helps to determine the final contact lens power. It must be noted that over-refraction must not be > 4.00 D because it will cause problems in vertex compensation of the trial lens.

Over refraction also gives the practitioner an idea about the fitting of the contact lens.

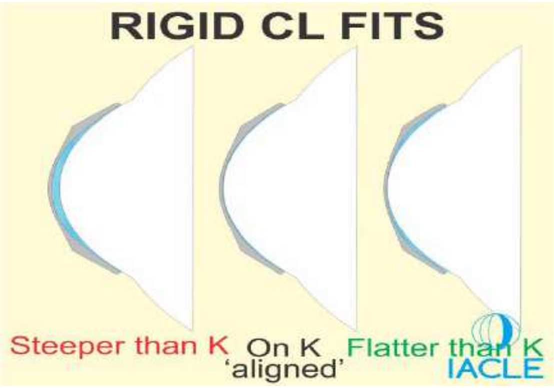


Fig.8- Relationship between base curve and tear

If the patient accepts more minus than required, then a positive tear lens is formed between the lens and the cornea. In such cases, re-evaluation of base curve must be considered.

Final Contact lens Power = Trial lens power + Tear lens + over- refraction power

In case of rigid contact lens, the tear lens is formed based on the lens fitting relationship with cornea. To understand it clearly refer to fig. 9a.

Figure- 9a

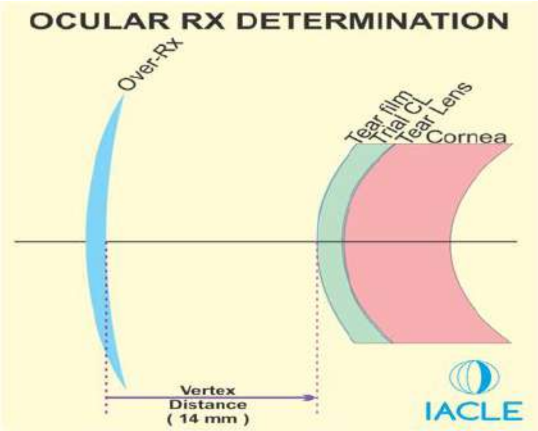
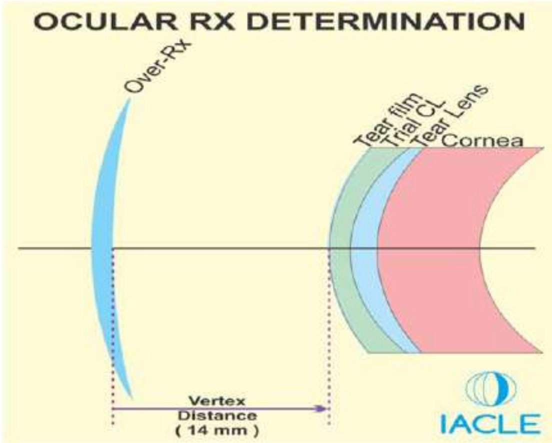


Figure: 9b



Soft contact lens since takes the shape of the cornea the tear lens formed is negligible. Hence the tear lens power is zero (Fig. 9b). In such case,

Contact lens power = Trial lens power+ over-refraction.

1.9 Summary

- Contact lens powered more than 4 dioptres need back vertex compensation before deciding the trial lens
- Myopes wearing Contact lens requires more accommodation and convergence as compared to spectacles lens.
- Hyperopes wearing contact lens requires less accommodation and convergence as compared to spectacle lens.
- Field of vision is more with contact lens as the peripheral distortions are eliminated.
- Aberration is less likely found with contact lens.
- Magnification occurs more with spectacles compared to contact lens.

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Chapter 3: Contact Lenses and the Anterior Segment of the Eye

Introduction

Contact lenses is outstanding innovation in eyesight correction, providing wearers an alternative to glasses. These lenses sit on the pre corneal tear film of the eye, providing clear vision and freedom of movement. However, the interaction between contact lenses and the anterior part of the eye is complex and multifaceted, with implications for ocular health and visual outcomes. In this chapter, we explore the anatomy of the anterior segment, discuss various types of contact lenses, and delve into their effects on corneal physiology, tear film dynamics, conjunctival health, and inflammatory responses.

Anatomy of the Anterior Segment

The anterior segment of the eye comprises several structures crucial for vision and ocular health.

1.Cornea: It is the transparent, dome-shaped layer covering the iris and pupil. It is primarily responsible for focusing light on the retina, contributing significantly to image clarity.

Epithelium: The outermost layer of the cornea is the epithelium, which serves as a protective shield against pathogens, foreign particles, and mechanical damage. It also contributes to the smoothness of the corneal surface, crucial for clear vision. When fitting contact lenses, the interaction with the epithelium is significant. Soft contact lenses conform to the irregularities of the epithelial surface, while rigid gas permeable (RGP) lenses interact more with the tear film above the epithelium.

Bowman's Layer: Beneath the epithelium, Bowman's layer is placed, which is a thin, acellular layer primarily composed of collagen fibers. While Bowman's layer doesn't have a direct role in vision, it provides mechanical support to the cornea and helps maintain its shape. Contact lens fitting, especially in irregular corneas, requires consideration of Bowman's layer. Conditions like keratoconus may necessitate specialized contact lenses to accommodate the irregularities in this layer.

Stroma: The stroma is the thickest and densed layer of the cornea, comprising 90% of overall thickness. It consists of collagen fibrils arranged in a highly organized manner, providing transparency and mechanical strength to the cornea. The regular arrangement of collagen fibrils is essential for light transmission and clear vision. Contact lenses interact closely with the stroma, particularly RGP lenses, which sit directly on this layer. Proper fitting of RGP lenses involves considerations of corneal curvature and tear film dynamics to ensure proper alignment and comfort.

Descemet's Membrane: It is a thin, acellular layer located between the stroma and the endothelium. It serves as a basement membrane for the endothelium and contributes to the structural strength of the cornea. Although it has a minor role in vision, Descemet's membrane can be affected in certain corneal diseases. When fitting contact lenses, especially in patients with compromised endothelial function, it's crucial to minimize potential damage to Descemet's membrane to prevent complications.

Pre-Descemet's layer or Dua layer: Although the pre-Descemet's layer is a relatively new discovery, its presence has implications for contact lens fitting and management, particularly in cases of corneal diseases and irregularities. Since it is located in the periphery of the cornea, where contact lenses often rest or exert pressure, understanding its presence and properties is crucial for optimizing contact lens fit and comfort.

Endothelium: The endothelium is the innermost layer of the cornea, consisting of a one layer of specialized cells responsible for maintaining corneal transparency by regulating hydration levels and removing excess fluid from the stroma. Endothelial cells do not regenerate, so their health is crucial for corneal function. Contact lenses, particularly those with prolonged wear, can affect endothelial function by disrupting corneal hydration balance. Therefore, proper lens selection, fitting, and regular monitoring are essential to prevent endothelial damage and maintain corneal health.

2.Conjunctiva: A thin, transparent membrane covering the sclera and covering the inner surface of the eyelids. The conjunctiva helps maintain the integrity of the ocular surface and produces mucin, a component of the pre corneal tear film.

Interaction with the Epithelium: The conjunctival epithelium forms the outermost layer of the conjunctiva and acts as a protective covering against pathogens and mechanical injury. Contact lenses come into contact with the bulbar conjunctival epithelium when placed on the eye. Soft contact lenses (SCL), made of hydrogel or silicone hydrogel(SiHy) materials, conform to the shape of the ocular surface and rest gently on the conjunctival epithelium. Rigid gas permeable (RGP) lenses may exert slight pressure on the conjunctival epithelium due to their rigid nature, especially if the fit is not optimal.

Interaction with Goblet Cells: Goblet cells are specialized cells within the conjunctival epithelium that produce mucin, a key component of the pre corneal tear film that helps lubricate the ocular surface. Contact lens wear can influence the function of goblet cells. Prolonged lens wear or poorly fitting lenses may reduce mucin production, leading to tear film instability and discomfort. Reduced mucin production can also increase friction between the contact lens and the conjunctival epithelium, potentially leading to epithelial damage and irritation.

Interaction with the Lamina Propria: Beneath the conjunctival epithelium lies the lamina propria, a layer of connective tissue comprising of blood vessels, nerves, and immune cells. Contact lens wear can affect the microenvironment of the lamina propria, leading to changes in blood flow, inflammation, and immune responses. Prolonged lens wear, especially if the lenses are not properly cleaned and disinfected, can increase the risk of microbial contamination and inflammatory responses in the lamina propria.

Interaction with Blood Vessels: Blood vessels within the conjunctiva play a crucial role in maintaining ocular health by supplying nutrients and oxygen to the surrounding tissues. Improperly fitting contact lenses or extended wear of lenses with inadequate oxygen permeability can lead to hypoxia, which may stimulate the growth of new small blood vessels (neovascularization) in the conjunctiva. Neovascularization of the conjunctiva can compromise ocular health and increase the risk of inflammation and infection.

Interaction with Immune Cells: The conjunctiva contains immune cells, including lymphocytes and macrophages, which help protect the eye from infections and other foreign invaders. Contact lens wear can modulate the immune response in the conjunctiva. Poorly fitting lenses or lens materials that induce irritation may trigger inflammatory reactions, such as giant papillary conjunctivitis (GPC).

3.Tear Film: The pre corneal tear film is a thin, complex layer covering the surface of the eye. It comprises of three layers: the lipid layer, aqueous layer, and mucin layer. The pre corneal tear film provides lubrication, nourishment, and protection to the cornea, helping maintain ocular health and comfort.

Interaction with the Lipid Layer: The lipid layer is the outermost layer of the pre corneal tear film and serves to reduce evaporation and maintain tear film stability. Contact lenses can affect the lipid layer by altering its thickness and composition. Certain lens materials and designs may interfere with the lipid layer's ability to spread evenly across the ocular surface, leading to increased tear evaporation and dryness. Improperly fitting contact lenses can disrupt the lipid fluid, causing pre corneal tear film instability and compromising ocular comfort.

Interaction with the Aqueous Layer of the pre corneal tear film: The aqueous layer is the middle layer of the pre corneal tear film and accounts for the majority of its volume. It provides moisture and nutrients to the cornea and helps flush away debris and foreign particles. Contact lenses interact closely with the aqueous layer, as they sit directly on the surfaceof the eye. Soft contact lenses (SCL) absorb moisture from the aqueous layer, which can lead to dehydration of the pre corneal tear film and dryness. Inadequate oxygen transmission through contact lenses can compromise the health of the cornea and the surrounding tissues, leading to reduced tear production and increased osmolarity of the pre corneal tear film.

Interaction with the Mucin Layer: The mucin layer is the innermost layer of the pre corneal tear film and acts as a lubricant, helping to spread tears across the surface of the eye and adhere to the epithelial cells. Contact lenses can affect the mucin layer by altering its thickness and composition. Prolonged lens wear or improper cleaning and disinfection can lead to the accumulation of debris and protein deposits on the lens surface, which may disrupt the mucin layer and compromise its function. Changes in the mucin layer can increase friction between the contact lens and the ocular surface, leading to discomfort and irritation.

4.Sclera: While contact lenses primarily interact with the cornea, they can also affect the sclera, especially during lens insertion and removal. Prolonged contact lens wear or poor hygiene may result in conjunctivitis (inflammation of the conjunctiva) or scleritis (inflammation of the sclera). When contact lenses are worn, they interact with different layers of the sclera in various ways:

Outer Surface Interaction: The outer surface of the sclera is the part that comes into direct contact with the contact lens. Soft contact lenses conform to the curvature of the sclera, while rigid gas permeable (RGP) lenses rest on the sclera with minimal deformation. Contact lenses exert mechanical forces on the outer surface of the sclera, which can affect comfort and fit. Poorly fitting lenses may cause discomfort, irritation, or even abrasions on the scleral surface.

Vascular Layer Interaction: The sclera contains a dense network of blood vessels within its vascular layer. These blood vessels supply nutrients and oxygen to the scleral tissue and play a role in regulating ocular temperature. Contact lenses may influence the vascular layer of the sclera by altering blood flow dynamics. Inadequate oxygen permeability of contact lenses can lead to hypoxia, causing dilation of blood vessels (vasodilation) and potentially contributing to ocular redness and discomfort.

Connective Tissue Interaction: The sclera consists primarily of collagen and elastin fibres in its connective tissue layer. These fibres provide strength and flexibility to the scleral tissue. Contact lenses can exert mechanical forces on the scleral connective tissue, particularly during lens insertion and removal. RGP lenses, in particular, may apply pressure to the sclera, which can lead to temporary indentations or impressions on the tissue.

Nerve Fiber Interaction: Nerve fibres innervate the scleral tissue and play a role in transmitting sensory signals, including pain and discomfort. Contact lenses may stimulate nerve fibres in the sclera, leading to sensations of discomfort or irritation, particularly if the lenses are improperly fitted or if foreign bodies become trapped between the lens and the sclera.

Immune Response Interaction: The sclera, like other tissues in the body, is subject to immune responses to protect against foreign invaders and pathogens. Contact lenses may trigger immune responses in the sclera, particularly if microbial contamination occurs or if the lenses are worn for extended periods without proper cleaning and disinfection. Inflammatory reactions, such as conjunctivitis or keratitis, can occur as a result.

5.Iris and Pupil: Contact lenses do not directly interact with the iris or pupil. However, specialized contact lenses, such as cosmetic or prosthetic lenses, may alter the appearance of the iris for aesthetic purposes. Orthokeratology lenses temporarily reshape the cornea to reduce myopia, indirectly affecting pupil size and iris function.

Interaction with the Iris: The iris is the colored part of the eye that borders the pupil and regulates the amount of light entering the eye by adjusting the size of the pupil. Contact lenses do not typically interact directly with the iris. However, the presence of a contact lens (CL) on the cornea can affect the appearance of the iris, particularly in individuals with lighter eye colors. Some contact lenses, such as cosmetic or colored lenses, may alter the appearance of the iris by enhancing or changing its color. These lenses are designed to cover the entire visible portion of the eye, including the iris, to achieve the desired cosmetic effect.

Interaction with the Pupil: The pupil is the circular opening in the centre of the iris that allows light to enter the eye. Contact lenses do not directly interact with the pupil itself, as the lens sits on the cornea infront of the pupil. However, the size and movement of the pupil can be influenced by various factors related to contact lens wear. The pupil naturally dilates and constricts in response to changes in lighting conditions and visual stimuli. Contact lenses, particularly those with tinted or opaque designs, may affect the perceived size of the pupil by altering the contrast between the iris and pupil. Some specialized contact lenses, such as prosthetic or therapeutic lenses, may incorporate features to help manage certain eye conditions that affect the pupil's function. For example, lenses with pinhole optics can help improve vision in individuals with irregular pupil shapes or sizes.

Ocular Physiology and Function: While contact lenses do not directly interact with the iris or pupil, they can influence ocular physiology and function, which may indirectly affect these structures. Improperly fitted contact lenses or lenses with inadequate oxygen permeability can lead to ocular discomfort, dryness, and irritation. These symptoms can cause the pupil to constrict or dilate as a natural response to ocular stress. Contact lenses that alter the tear film dynamics or induce inflammation in the ocular surface may affect the regulation of the pupil's size and responsiveness to light.

6.Lens: Contact lenses serve as a substitute for the eye's natural lens in cases of corneal irregularities or after cataract surgery. Multifocal or bifocal contact lenses mimic the functionality of the eye's natural lens, providing clear vision at different distances.

Impact on Accommodation: The crystalline lens is responsible for accommodation, the process by which the eye changes focus to see objects at different distances. Contact lenses do not directly interact with the crystalline lens in a mechanical sense, but they can influence the accommodative response. Contact lenses alter the effective power of the ocular surface by adding refractive correction in front of the cornea. This can affect the accommodative demand and response, especially in individuals who wear multifocal or bifocal contact lenses designed to correct presbyopia.

Visual Acuity and Clarity: Contact lenses sit on the cornea, in front of the crystalline lens. They correct refractive errors such as myopia, hyperopia, and astigmatism by modifying the way light focuses on the retina. Properly prescribed contact lenses provide clear and sharp vision by compensating for the refractive errors of the eye. They do not directly interact with the crystalline lens but work in conjunction with it to ensure clear vision at various distances.

Indirect Effects on Lens Health: While contact lenses do not come into direct contact with the crystalline lens, they can indirectly affect its health and function. For example, contact lens wear can alter tear film dynamics and oxygen supply to the cornea, which may influence the overall health of the ocular structures, including the crystalline lens. Prolonged contact lens wear, especially if lenses are not properly cleaned and disinfected, can increase the risk of ocular infections and inflammation. Although the crystalline lens itself is not directly affected, systemic complications from contact lens-related infections can potentially impact overall eye health.

Presbyopia Correction: Presbyopia is a natural age-related phenomenon in which the crystalline lens hardens,making it difficult to focus on close objects. Multifocal and bifocal contact lenses are designed to address presbyopia by providing different powers for near, intermediate, and distance vision. These contact lenses work by creating simultaneous images at multiple focal distances on the retina. The crystalline lens, although aging, still plays a role in the accommodative process, albeit less effectively than in younger individuals.

7.**Aqueous Humor:** The aqueous humor consists of fluid, which is watery in nature, that fills the anterior chamber of the eye, located in between the cornea and the iris. It serves several critical functions, including maintaining intraocular pressure, providing nutrients to the avascular structures of the eye (such as the cornea and lens), and removing metabolic waste products.

Interaction with the Anterior Chamber:

The anterior chamber consists of aqueous humor, which provides nutrients and oxygen to the surrounding structures, including the cornea and the lens. Contact lenses interact indirectly with the aqueous humor by sitting on the cornea's surface and influencing tear film dynamics. Contact lenses should not impede the flow of aqueous humor within the anterior chamber of the eye, as this can lead to changes in intraocular pressure and potential complications such as angle-closure glaucoma. Properly fitted contact lenses allow for normal aqueous humor circulation and maintain ocular health.

Hydration and Nutrient Supply: The aqueous humor supplies nutrients and removes metabolic waste products from the cornea, the lens, and other structures in the anterior segment of the eye. Contact lenses should not disrupt this delicate balance. Properly fitted contact lenses maintain hydration levels on the ocular surface and allow for the diffusion of nutrients from the aqueous humor to reach the cornea and the lens. This interaction supports ocular health and function during contact lens wear.

8.Retina: While contact lenses do not directly interact with the retina, their optical properties can influence retinal image quality. Proper contact lens fit and design are essential to minimize optical aberrations and ensure clear, comfortable vision.

Interaction of Contact Lenses with the Anterior Segment

Contact lenses directly interact with the anterior segment of the eye, influencing various aspects of ocular physiology and health:

1.Corneal Physiology

Oxygen Transmission: Adequate oxygen supply to the cornea is crucial for maintaining corneal metabolism and health. Soft contact lenses with high oxygen permeability allow sufficient oxygen transmission, reducing the risk of corneal hypoxia. Conversely, low-oxygen-permeable lenses may lead to corneal edema and neovascularization.

Epithelial Changes: Contact lens wear can induce epithelial changes, including thinning and irregularity. Epithelial microtrauma, superficial punctate keratitis (SPK), and epithelial erosions are common findings. Proper lens fitting and replacement schedules are essential for minimizing epithelial stress.

Corneal Shape Alterations: Contact lenses can temporarily alter corneal shape, leading to changes in corneal curvature and refractive error. Orthokeratology lenses and RGP lenses are designed to reshape the cornea temporarily.

Corneal Physiology and Contact Lens Interaction**:** The cornea serves as the eye's primary refractive surface, contributing significantly to vision. When contact lenses are placed on the cornea, they alter its optical properties, refracting light to compensate for refractive errors such as myopia, hyperopia, astigmatism, and presbyopia. Understanding corneal physiology is crucial for optimizing contact lens design and fitting, as well as ensuring visual acuity and comfort for the wearer

Oxygenation and Metabolism**:** The cornea is avascular, relying on the tear film and aqueous humor for oxygen and nutrient supply. Contact lenses must allow sufficient oxygen permeability to maintain corneal metabolism and prevent hypoxia-induced complications. Oxygen deprivation can lead to corneal oedema, neovascularization, and epithelial microcysts, highlighting the importance of selecting lenses with adequate oxygen transmissibility

2.Tear Film Dynamics

Tear Film Instability: Contact lens wear can disrupt tear film stability, leading to tear film breakup and dry eye symptoms. Evaporative dry eye is more common with soft contact lenses.

Tear Film Composition: Contact lenses interact with the tear film, altering its composition and osmolarity. Protein deposition on lenses can lead to discomfort and increased risk of microbial contamination.

The pre corneal tear film plays a pivotal role in maintaining eye health and optical quality. It consists of three layers: the mucin layer, aqueous layer, and lipid layer, each contributing to tear stability, lubrication, and protection. Contact lenses interact with the tear film, affecting its dynamics and composition. Improper tear film distribution or stability can lead to discomfort, dryness, and visual disturbances during contact lens wear.

Meibomian Gland Dysfunction: Wearing contact lens may exacerbate MGD, contributing to evaporative dry eye. Reduced blink frequency and incomplete blinks associated with lens wear can worsen MGD symptoms.

3. Conjunctival Health

Conjunctival Microtrauma: Contact lenses may cause conjunctival microtrauma, resulting in epithelial microcysts and papillary conjunctivitis. Proper lens fitting and material selection minimize microtrauma.

Limbal Stem Cell Deficiency (LSCD): Chronic contact lens wear can lead to LSCD, compromising corneal integrity and visual acuity. Regular monitoring and proper lens fitting are essential for preventing LSCD.

4. Inflammatory Responses

Giant Papillary Conjunctivitis (GPC): GPC is a common inflammatory reaction associated with contact lens wear, characterized by papillary hypertrophy and mucous discharge. Mechanical irritation from lens deposits contributes to GPC development.

Microbial Keratitis: Contact lens wear increases the risk of microbial keratitis, a severe corneal infection. Poor hygiene practices, extended wear, and microbial contamination of lenses contribute to microbial keratitis development.

Biomechanical Interactions: Contact lenses exert mechanical forces on the cornea, influencing its shape and biomechanical properties. Prolonged lens wear can induce corneal moulding, leading to changes in corneal curvature and refractive power. Biomechanical interactions also play a role in conditions such as corneal ectasia, where altered corneal biomechanics contribute to progressive corneal thinning and distortion.

Immune Response and Infection Risk**:** Contact lens wear increases the risk of microbial contamination and infection, posing a significant concern for ocular health. Bacterial, fungal, or viral pathogens may stick to the lens surface or infiltrate the cornea, causing infectious keratitis and other inflammatory conditions. Understanding the immune response to contact lenses and implementing proper hygiene practices are essential for minimizing infection risk and preserving ocular health.

Clinical Implications and Management**:** Clinicians must consider various factors when prescribing contact lenses, including corneal curvature, tear film dynamics, oxygen requirements, and patient lifestyle. Proper lens fitting, regular follow-up examinations, and patient education are essential for optimizing visual outcomes and minimizing complications. Additionally, innovation in contact lens materials and designs continue to improve comfort, safety, and efficacy for wearers.

5. Surface Properties:

Contact lenses interact with the ocular surface through their surface properties, such as water content, wettability, and surface roughness.

Hydrophilic contact lenses attract water molecules from the tear film, which helps maintain surface hydration and comfort. However, excessive water content can lead to lens dehydration and protein deposition.

Surface coatings and treatments are often applied to contact lenses to improve surface wetting and reduce friction with the ocular surface. These coatings help enhance comfort and reduce the risk of adverse reactions.

Factors Influencing Contact Lens Interaction:

1.Material and Design:

Material: Contact lenses are made from various materials, including hydrogels and silicone hydrogels for soft lenses, and polymers for rigid gas-permeable (RGP) lenses. Material properties such as oxygen permeability, water content, and modulus (softness or rigidity) impact comfort, oxygen transmission to the cornea, and durability.

Design: Lens design includes parameters such as base curve, diameter, thickness profile, edge design, and surface treatment. These factors affect fit, movement, tear exchange, and interaction with the ocular surface.

2.Fit and Size:

Base Curve and Diameter: Proper fitting involves matching the curvature (base curve) of the lens to the curvature of the cornea and ensuring an appropriate lens diameter that covers the cornea adequately without impinging on the limbus.

Lens Thickness and Edge Design: Thinner lenses with smooth edges enhance comfort and minimize interaction with the eyelids, while thicker or poorly designed lenses may cause discomfort, irritation, or papillary conjunctivitis.

3.Tear Film Dynamics:

Tear Film Stability: Tear film instability, as seen in conditions like dry eye syndrome, can lead to discomfort, fluctuating vision, and reduced lens wettability. Tear film instability may require management strategies such as artificial tears or specialty contact lens designs for improved lubrication and stability.

Tear Exchange: Efficient tear exchange beneath the lens is crucial for maintaining corneal health and oxygen supply. Factors influencing tear exchange include lens modulus, thickness, surface wettability, and blink dynamics.

4.Oxygen Permeability:

Dk/t Value: Oxygen permeability (Dk) and thickness (t) of the lens determine its ability to transmit oxygen to the cornea. Higher Dk/t values are associated with better corneal oxygenation and reduced risk of hypoxia-related complications such as corneal neovascularization and oedema.

Lens Modulus and Tear Exchange: Soft lenses with higher oxygen permeability and modulus allow for greater tear exchange and oxygen transmission, while rigid lenses provide optimal oxygenation through tear exchange beneath the lens.

5.Lens Care and Hygiene:

Cleaning and Disinfection: Proper cleaning and disinfection routines are essential to prevent microbial contamination, biofilm formation, and inflammatory reactions. Non-compliance with lens care instructions increases the risk of microbial keratitis, corneal infiltrates, and other infectious complications.

Replacement Schedule: Regular replacement of contact lenses reduces the accumulation of deposits, enhances comfort, and lowers the risk of adverse reactions. Daily disposable lenses offer the advantage of convenience and reduced risk of lens-related complications.

6.Environmental Factors:

Humidity and Temperature: Low humidity and high environmental temperatures can exacerbate dry eye symptoms and discomfort associated with contact lens wear. Environmental pollutants, allergens, and airborne particles may also contribute to ocular irritation and inflammation.

Occupational and Recreational Activities: Certain activities such as prolonged digital device use, swimming, or exposure to dusty or windy environments can affect tear film stability, lens wettability, and comfort during contact lens wear.

7.Individual Eye Anatomy and Physiology:

Corneal Shape and Health: Variations in corneal curvature, irregular astigmatism, and corneal irregularities influence the choice of contact lens type and design. Specialty lenses such as toric lenses for astigmatism or scleral lenses for irregular corneas address specific anatomical challenges.

Pupil Size and Position: Contact lens optics should account for variations in pupil size, position, and dynamic changes in lighting conditions to optimize visual performance and minimize visual aberrations.

8.Patient Compliance and Education:

Adherence to Instructions: Patient education regarding proper lens handling, wearing schedules, hygiene practices, and replacement intervals is critical for maintaining ocular health and preventing complications.

Follow-up Care: Regular follow-up visits with an optometrist allow for monitoring of ocular health, assessment of lens fit and visual performance, and adjustment of management strategies as needed.

Relationship of oxygen requirements of cornea with different types of contact lens.

The relationship between the oxygen requirements of the cornea and different types of contact lenses is crucial for maintaining ocular health and comfort during lens wear. Here's a detailed exploration:

1.Corneal Oxygen Requirements:

The cornea is avascular, meaning it doesn't have blood vessels. Instead, it relies on oxygen from the tear film and the atmosphere to meet its metabolic needs.

Adequate oxygen supply is essential for maintaining corneal health and transparency. Insufficient oxygen can lead to corneal hypoxia, characterized by swelling, neovascularization, and epithelial compromise.

2.Types of Contact Lenses and Oxygen Transmission:

Hydrogel Lenses: Traditional soft contact lenses are typically made of hydrogel materials. While they are comfortable to wear, their oxygen permeability is lower compared to other types of lenses. Prolonged wear of hydrogel lenses can restrict oxygen flow to the cornea.

Silicone Hydrogel Lenses: These lenses are designed to transmit more oxygen to the cornea than traditional hydrogel lenses. The incorporation of silicone allows for greater oxygen permeability, reducing the risk of hypoxia-related complications.

Rigid Gas Permeable (RGP) Lenses: RGP lenses are made of rigid, oxygen-permeable materials. They allow oxygen to pass through the lens material to nourish the cornea. Although they cover the cornea, they provide sufficient oxygen transmission to maintain corneal health.

Hybrid Lenses: Hybrid lenses combine a rigid gas permeable centre with a soft outer skirt. This design offers the oxygen transmission benefits of RGP lenses while providing the comfort of soft lenses.

3.Impact on Corneal Health:

Insufficient oxygen transmission can lead to corneal complications such as corneal edema, neovascularization, and epithelial breakdown.

Silicone hydrogel lenses and RGP lenses are associated with lower rates of corneal hypoxia compared to traditional hydrogel lenses due to their higher oxygen permeability.

Proper fitting and monitoring of lens wear are essential to ensure that the cornea receives adequate oxygen while wearing contact lenses.

4.Individual Considerations:

Factors such as wearing schedule, lifestyle, and ocular health should be considered when selecting contact lenses.

Some individuals may tolerate certain lens materials better than others, and personalized recommendations from an eye care professional are crucial.

In addition to considering the oxygen permeability, often denoted by the DK (oxygen permeability) and DK/t (oxygen transmissibility) values, several other factors influence the relationship between corneal oxygen requirements and different types of contact lenses:

5.Lens Material and DK Value:

The DK value represents the oxygen permeability of the contact lens material. Higher DK values indicate greater oxygen transmission.

Different materials have different DK values, with silicone hydrogel lenses generally having higher DK values compared to traditional hydrogel lenses. RGP lenses also have high DK values.

6.Lens Thickness and DK/t Value:

The DK/t value takes into account not only the oxygen permeability of the lens material (DK) but also the thickness of the lens (t).

Thinner lenses allow for better oxygen transmission to the cornea. Even if a lens material has a high DK value, if the lens is too thick, it may impede oxygen flow to the cornea.

7.Wearing Modality and Oxygen Requirements:

Extended wear lenses are worn continuously for an extended period, often overnight. These lenses must have high oxygen permeability to prevent hypoxia-related complications.

Daily wear lenses are removed nightly, allowing the cornea to receive oxygen during periods of lens removal. While they still require adequate oxygen transmission, the requirements may be lower compared to extended wear lenses.

8.Tear Film Dynamics:

The tear film plays a crucial role in oxygen delivery to the cornea. Contact lenses can affect tear film stability and thickness, which may impact oxygen availability.

Lens materials that interact well with the tear film and promote tear exchange are beneficial for maintaining corneal health.

9.Corneal Health and Tolerance:

Individual variations in corneal physiology and tolerance to lens wear influence the choice of contact lenses.

Some individuals may experience discomfort or adverse reactions with certain lens materials, even if they have high DK values. Personalized fitting and selection are essential to ensure comfort and ocular health.

10. Environmental Factors:

Environmental conditions such as humidity, temperature, and airflow can affect corneal oxygen requirements.

Patients who work in dry or dusty environments may require lenses that maintain hydration and provide adequate oxygen transmission to counteract environmental stressors.

DK and DK/t values are important indicators of a lens material's oxygen permeability, other factors such as lens thickness, wearing modality, tear film dynamics, corneal health, and environmental conditions also play significant roles in determining the relationship between corneal oxygen requirements and different types of contact lenses.

A comprehensive evaluation by an eye care professional is necessary to select the most suitable lens option for each individual.

Equivalent oxygen performance (EOP)

Equivalent oxygen performance (EOP) is a concept used to evaluate the oxygen transmissibility of contact lenses. It takes into account various factors that influence how much oxygen reaches the cornea while wearing contact lenses. Here's a detailed explanation of the components involved in EOP:

1. **Oxygen Permeability (Dk/t)**: This is a measure of how much oxygen can pass through a specific material over a given thickness. It's typically represented as Dk/t, where Dk is the oxygen permeability of the material, and t is the thickness of the lens. Higher Dk/t values indicate better oxygen permeability. Modern contact lenses, especially silicone hydrogel lenses, tend to have higher Dk/t values compared to older hydrogel lenses.

2. **Lens Material**: Different materials have different inherent oxygen permeability properties. Silicone hydrogel materials, for example, have significantly higher oxygen permeability compared to traditional hydrogel materials. This means they allow more oxygen to pass through to the cornea, promoting better ocular health.

3. **Lens Thickness**: Thicker lenses impede the flow of oxygen to the cornea. Even if a lens material has high oxygen permeability, if the lens is too thick, it may limit the amount of oxygen reaching the cornea. Therefore, thinner lenses or those with higher Dk/t values can provide better oxygen transmission.

4. **Lens Design**: The design of the contact lens can also influence oxygen transmission. Some designs allow for better tear exchange, which can help deliver more oxygen to the cornea. Additionally, certain lens designs may fit more securely on the eye, reducing the likelihood of oxygen deprivation.

5. **Wearing Schedule and Habits**: Factors such as how long the lenses are worn each day, whether they are worn overnight (extended wear), and how frequently they are replaced can affect oxygen transmission. Extended wear lenses, for example, need to have high oxygen permeability to support overnight wear without causing hypoxia.

6. **Corneal Physiology and Health**: The oxygen needs of the cornea can vary among individuals based on factors such as corneal thickness, tear film quality, and metabolic

rate. Eye health conditions like dry eye syndrome can also affect the cornea's ability to receive oxygen.

7. **Wearing Modality**: The wearing schedule and habits associated with the contact lenses play a crucial role in their oxygen performance. Extended wear lenses, designed for overnight wear, require higher oxygen permeability to support prolonged use without compromising corneal health. Daily disposable lenses, on the other hand, offer fresh, oxygen-permeable lenses with each wear, minimizing the risk of oxygen deprivation.

Conclusion:

In conclusion, the intricate interaction of contact lenses with the various layers of the eye constitutes a dynamic and multifaceted relationship that significantly influences both the visual experience and ocular health of individuals utilizing this corrective modality.

Throughout this chapter, we have explored the pivotal role played by each component of the eye in shaping the interaction with contact lenses. From the outermost layer, including the pre corneal tear film and conjunctiva, to the underlying cornea, lens, and retina, every anatomical structure contributes uniquely to the comfort, stability, and optical performance of contact lenses.

Understanding the complex interplay between contact lenses and the ocular environment is essential for clinicians and researchers alike. Material science advancements have led to the development of lenses with enhanced oxygen permeability, moisture retention, and biocompatibility, thereby minimizing adverse effects on the cornea and promoting long-term ocular health.

Moreover, individual variations in ocular anatomy and physiology necessitate a personalized approach to contact lens fitting and management. From selecting the appropriate lens type, design, and wearing schedule to optimizing lens care practices and addressing environmental factors, tailored strategies are indispensable for achieving optimal visual outcomes and patient satisfaction.

Looking ahead, ongoing research endeavours continue to deepen our understanding of the factors influencing contact lens interaction with the eye, paving the way for innovations that further improve safety, comfort, and efficacy. By fostering interdisciplinary collaboration and leveraging technological advancements, we can continue to enhance the quality of life of contact lens wearers.

In closing, the interaction of contact lenses with different layers of the eye underscores the intricate balance between vision correction, ocular physiology, and patient comfort. Through continued research, education, and clinical practice, we strive to uphold the highest standards of care and empower individuals to enjoy the benefits of clear and comfortable vision with confidence and peace of mind.

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12. Dry eye: why artificial tears are not always the answer

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Chapter 4: Materials of Contact Lens

Introduction

Contact lens materials are based on polymer- or silicone-hydrogel, with additional manufacturing technologies employed to produce the final lens. These processes are simply not enough to meet the increasing demands for contact lenses and the adding demands of contact lens users .

An advanced perspective on contact lens materials has been presented, with an emphasis on materials science employed in developing new contact lenses. The future trends for contact lens materials are to graft, incapsulate, or modify the classic contact lens material structure to provide new or improved functionality. Also, some of the fundamental material properties are discussed, and the outlook for related emerging biomaterials is presented.

Contact lens materials and lens types, treatment for contact lens andtearfilmcomplications,andmyopiacorrectionandcontactlenses for abnormal ocular conditions have been detailed . Current topics in this field are miniscleral lenses, keratoconus, corneal crosslinking, and pediatric, cosmetic and prosthetic contact lenses. Likewise, simulation programs for scleral lens fitting, sagittal values, soft toric mislocation, front vertex power, orthokeratology and rigid lens design are also taken into account.

Materials of Rigid Gas Permeable (RGP) Contact Lenses

Rigid Gas Permeable (RGP) contact lenses have revolutionized vision correction by offering a durable and breathable alternative to soft contact lenses. This comprehensive examination delves into the evolution, types, and specific materials used in RGP lenses, discussing their advantages, manufacturing processes, and considerations for users.

Evolution of Contact Lens(CL) matter

The journey of contact lenses began with glass lenses in the late 19th century, evolving to polymethyl methacrylate (PMMA) lenses in the 1930s. However, PMMA lenses, while durable, lacked oxygen permeability, leading to discomfort and potential eye health issues. The breakthrough came in the late 1970s with the development of RGP lenses made from materials that allowed oxygen to penetrate the cornea.

Types of RGP Materials

RGP lenses are primarily classified based on their oxygen permeability, which is measured in Dk units (the ability of a material to allow oxygen to pass through it). The materials used in RGP lenses can be grouped into several categories:

Low Dk Materials. : Early RGP lenses with Dk values ranging from 10 to 50.

Medium Dk Materials. : Lenses with Dk values between 50 and 100.

High Dk Materials. : Modern lenses with Dk values exceeding 100, providing superior oxygen permeability.

Key Materials Used in RGP Lenses

The primary materials used in the manufacturing of RGP lenses include:

Silicone Acrylate (SA)

Fluoro-Silicone Acrylate (FSA)

Hyper-Permeable Materials

Cellulose

Silicone acrylate was the first material to successfully combine the benefits of PMMA with improved oxygen permeability. The main components of silicone acrylate lenses are:

Siloxane Component: Provides excellent oxygen permeability, flexibility, and hydrophobicity. Siloxane (silicone) structures are composed of silicon-oxygen bonds, contributing to these desirable traits.

Acrylate Component: Offers good mechanical strength, hardness, and processability. Acrylate (derived from acrylic acid) structures enhance the rigidity and durability of the material.

Hybrid Nature: The combination results in a material that benefits from the flexibility and oxygen permeability of siloxane and the robustness and ease of processing of acrylates.

Key Characteristics

High Oxygen Permeability: Essential for applications like contact lenses, allowing sufficient oxygen to reach the cornea.Durability: Resistant to wear and tear, making it suitable for long-term use in various applications.

Hydrophobicity: Repels water, which can be beneficial in maintaining clarity and preventing deposit build-up in contact lenses.

Flexibility: Provides comfort in wearable applications, such as contact lenses, while maintaining shape and functionality.

Advantages

Biocompatibility: Suitable for use in medical and ophthalmic applications due to its compatibility with biological tissues.

Customizability: The properties of siloxane acrylate can be tailored by adjusting the ratio of siloxane to acrylate components, allowing for a wide range of applications.

Methyl Methacrylate (MMA) : Provides structural integrity and optical clarity.

Silicone. :It acts to enhances oxygen permeability but can lead to lens surface wettability issues.

Cross-Linking Agents. :It is involved in improving the material's stability and durability.

Advantages. :

- Good durability and optical clarity.
- Improved oxygen permeability compared to PMMA.
- Relatively easy to manufacture and fit.

Disadvantages. :

- Surface wettability issues due to silicone content.
- Prone to protein deposits, requiring rigorous cleaning.

Fluoro-Silicone Acrylate (FSA)

Fluoro-silicone acrylate materials incorporate fluorine into the silicone acrylate matrix, significantly enhancing the lens properties. The key components are:

Fluorine Compounds : Improve surface wettability and resistance to deposits.

Silicone : Continues to provide high oxygen permeability.

Methyl Methacrylate (MMA) : Maintains structural integrity.

Advantages :

- Superior oxygen permeability.
- Enhanced surface wettability and deposit resistance.
- Better comfort and longer wearing times.

Disadvantages. :

- Higher manufacturing costs compared to silicone acrylate lenses.

- Requires precise fitting and regular maintenance.

Hyper-Permeable Materials

The latest advancements in RGP lens materials focus on hyper-permeable compositions, offering exceptionally high Dk values. These materials blends various monomers to achieve the desired properties:

Silicone Macromers. : Large silicone molecules that significantly boost oxygen permeability.

Hydrophilic Monomers. : Improve lens wettability and comfort.

Fluorine Compounds. : Continue to enhance deposit resistance.

Advantages. :

- Exceptional oxygen permeability (Dk values over 150).

- High comfort and extended wear potential.

- Reduced risk of hypoxia-related complications.

Disadvantages :

- Very high cost.

- Potentially more complex fitting and adaptation period.

Cellulose Acetate Butyrate

Cellulose Acetate Butyrate (CAB) is a versatile thermoplastic polymer derived from cellulose. It is widely used in various industries due to its beneficial properties.

Here are the key aspects of CAB:Composition and ProductionCellulose Source: Derived from natural cellulose, commonly obtained from wood pulp or cotton linters.

Chemical Modification: Cellulose is reacted with acetic acid and butyric acid (and their anhydrides) in the presence of a catalyst, producing a butyrate-modified cellulose acetate.

PropertiesTransparency: CAB offers excellent clarity and transparency, making it ideal for optical and decorative applications.

Chemical Resistance: It has good resistance to a wide range of chemicals, including oils and greases.Durability: CAB exhibits good toughness and impact resistance.

Moisture Resistance: It has lower moisture absorption compared to pure cellulose acetate, enhancing its dimensional stability in humid environments.UV Resistance: It provides better UV stability than many other polymers, making it suitable for outdoor applications.

Processing: It can be easily processed using common thermoplastic methods such as extrusion, injection molding, and film casting.

ApplicationsCoatings: Used in lacquers and coatings for its excellent clarity, toughness, and weather resistance.

Plastics: Employed in the production of durable, transparent plastic parts and films.

Inks: Added to printing inks to enhance adhesion, gloss, and flexibility.Adhesives: Utilized in adhesive formulations for its strong bonding properties.

Automotive: Applied in automotive interior parts for its aesthetic qualities and durability.Packaging: Used in packaging films that require high transparency and strength.

Environmental ConsiderationsBiodegradability:

While CAB is derived from natural cellulose, the chemical modifications reduce its biodegradability compared to unmodified cellulose.Sustainability: Efforts are being made to improve the sustainability of CAB production by using more eco-friendly solvents and renewable raw materials.

Cellulose Acetate Butyrate (CAB) is a highly functional and adaptable polymer, prized for its clarity, toughness, and chemical resistance.

Manufacturing Processes

The manufacturing of RGP lenses involves several critical steps to ensure precision and quality. The primary methods include:

Casting. : Liquid monomers are poured into molds and polymerized, creating the lens shape. This method allows for precise control over lens parameters but can be costly.

Lathe-Cutting : Pre-polymerized lens blanks are machined to the desired shape using computer-controlled lathes. This is the most common method, providing high accuracy and flexibility.

Surface Treatment. : To address wettability issues, lenses may undergo surface treatments such as plasma coating or incorporation of hydrophilic agents.

Polishing and Inspection. : Finished lenses are polished to enhance comfort and inspected for quality control to ensure they meet all specified parameters.

Factors Affecting Lens Performance

Several factors influence the performance and suitability of RGP lenses for individual users:

Oxygen Permeability. : Higher Dk values ensure better corneal health and comfort, reducing the risk of complications occurring from long time wear.

Wettability. : Surface wettability affects comfort and visual clarity. Materials with good hydrophilic properties or surface treatments enhance this aspect.

Durability. : RGP lenses are more durable than soft lenses, but the specific material and manufacturing process impact their lifespan.

Deposit Resistance : Fluorine-enhanced materials are better at resisting protein and lipid deposits, maintaining clarity and comfort over time.

Flexibility. : While RGP lenses are generally less flexible than soft lenses, advancements in material science aim to improve their flexibility without compromising structural integrity.

Clinical Considerations

Optometrists consider various clinical factors when prescribing RGP lenses:

Patient History : Understanding the patient's ocular history, lifestyle, and previous lens use helps in selecting the right material and design.

Corneal Topography : Detailed mapping of the cornea aids in customizing the lens fit, especially for irregular corneas or conditions like keratoconus.

Tear Film Assessment. : The overall assessment of the tear film influence lens selection and the need for surface treatments to enhance wettability.

Lens Fitting. : Proper fitting is crucial for RGP lenses to ensure comfort and optimal vision. This involves trial lenses, fitting sets, and sometimes custom designs.

Patient Education. : Educating patients on lens care, handling, and the adaptation period is essential for successful RGP lens wear.

Benefits of RGP Lenses

RGP lenses offer several benefits over soft contact lenses:

Superior Vision Quality. : RGP lenses maintain their shape on the eye, providing clearer and more stable vision, especially for astigmatism and irregular corneas.

Durability and Cost-Effectiveness. : Despite higher initial costs, RGP lenses are more durable and have a longer lifespan, potentially reducing overall costs.

Ocular Health. : High oxygen permeability reduces the risk of hypoxia-related complications, making RGP lenses healthier for long-term use.

Reduced Risk of Infections : RGP lenses are less likely to harbor bacteria and other pathogens compared to soft lenses, lowering the risk of infections.

Customizability. : RGP lenses can be tailored to address specific visual needs and corneal shapes, providing a high degree of customization.

Challenges and Considerations

While RGP lenses have numerous advantages, they also come with challenges:

Initial Discomfort. : Many users experience discomfort during the initial adaptation period due to the lens rigidity.

Lens Care. : RGP lenses require cleaning and maintenance to ensure longevity and prevent complications.

Handling Difficulties. : Their smaller size and rigidity can make RGP lenses more challenging to handle, especially for user who are using it for first time.

Adaptation Period : Unlike soft lenses, RGP lenses require a longer adaptation period, during which users may experience fluctuating comfort and vision.

Higher Initial Cost. : The initial cost of the lens can be higher as compared to other types of lenses.

Soft contact lenses have made revolution since its invention,vision correction have improved majorly after their introduction, offering comfort and convenience that rigid lenses often can't match. The materials used to make soft contact lenses are a key factor in their performance, safety, and user experience. This comprehensive analysis explores the various materials used in soft contact lenses, their properties, benefits, and challenges

History and Development

The journey of soft contact lens materials began in the 1960s when Otto Wichterle and Drahoslav Lim developed the first hydrogel material. This material, known as hydroxyethyl methacrylate (HEMA), paved new ways to produce soft contact lenses. Over the years, advancements in polymer chemistry have led to the development of new materials that enhance lens performance and wearer comfort.

Types of Soft CL Matter

Soft contact lenses are primarily made from two types of materials: hydrogels and silicone hydrogels. Each type has unique properties that influence their performance and suitability for different users.

Hydrogel Lenses

Hydrogel lenses are made from water-absorbing polymers, which makes them soft and flexible. The key features of hydrogel lenses include:

High Water Content : Hydrogels can hold a significant amount of water, typically ranging from 38% to 75%. This water content is crucial for maintaining lens softness and adaptability.

Oxygen Permeability: The oxygen permeability of hydrogel lenses is proportional to their water content. Higher water content generally means better oxygen transmission to the cornea, which is essential for eye health.

Comfort: The high water composition and soft nature of hydrogel lenses make them comfortable to wear.

Key Hydrogel Materials

Poly (2-hydroxyethyl methacrylate) (pHEMA): This was the first hydrogel material used for contact lenses. It can hold up to 38% water and is known for its biocompatibility and ease of manufacturing.

Methacrylic Acid (MA): Used in combination with other monomers, MA increases the water content and hydrophilicity of the lens material.

N-vinyl Pyrrolidone (NVP): Adding NVP to the polymer mix increases the water content and flexibility of the lenses.

Glyceryl Methacrylate (GMA): GMA can increase water content and improve lens flexibility and comfort.

Silicone Hydrogel CL

Introduced in the late 1990s, silicone hydrogel lenses were developed to address the limitations of traditional hydrogel lenses, particularly in terms of oxygen permeability. Silicone hydrogel lenses merge with the water-loving properties of hydrogels with the oxygen permeability of silicone. Key features include:

High Oxygen Permeability: Silicone is highly permeable to oxygen, allowing more oxygen to reach the cornea. This reduces the risk of hypoxia-related complications.

Lower Water Content: Unlike hydrogels, silicone hydrogels generally have lower water content but still offer excellent comfort due to their advanced designs.

Durability: Silicone hydrogels are more resistant to dehydration and protein deposition, making them suitable for extended wear.

Key Silicone Hydrogel Materials

Siloxane: This is the main component that provides high oxygen permeability. It is used in various forms, such as tris(trimethylsiloxy)silylpropyl methacrylate (TRIS).

Fluorosilicone Methacrylate: Combines fluorine and silicone to improve wettability and oxygen permeability.

Silicone Macromers: Long-chain silicone molecules used to enhance flexibility and oxygen permeability.

Properties and Performance Metrics

When evaluating contact lens materials, several key properties are considered to ensure optimal performance and user comfort. These include:

1. Oxygen Permeability (Dk)

Oxygen permeability is a critical factor for maintaining corneal health. It is measured in units called Dk, where D indicate the diffusion coefficient and k indicate the solubility of oxygen in the material. Higher Dk values indicate better oxygen transmission.

Hydrogels: Dk values range from 8 to 40, depending on the water content.

Silicone Hydrogels: Dk values can exceed 100, making them suitable for extended and overnight wear.

2. Water Content

Water content affects lens softness, flexibility, and oxygen transmission. Higher water content generally means softer lenses and better initial comfort.

Hydrogels: Water content ranges from 38% to 75%.

Silicone Hydrogels: Water content ranges from 24% to 48%.

3. Wettability

Wettability is the ability of a lens surface to maintain a thin film of moisture, which is crucial for comfort and reducing dryness. It is often measured by the contact angle; lower contact angles indicate better wettability.

Hydrogels: Naturally hydrophilic, leading to good wettability.

Silicone Hydrogels: May require surface treatments or wetting agents to enhance wettability due to the hydrophobic nature of silicone.

4. Modulus of Elasticity

The modulus of elasticity refers to the stiffness of the lens material. A higher modulus means a stiffer lens, which can affect comfort and handling.

Hydrogels: Generally have a lower modulus, making them very flexible.

Silicone Hydrogels: Typically have a higher modulus, but newer formulations aim to balance flexibility and stiffness.

5. Biocompatibility

Biocompatibility ensures that the lens material does not cause adverse reactions in the eye. Modern materials are designed to minimize irritation and support healthy tear film and corneal function.

Innovations and Advancements

The field of contact lens materials is continually evolving with innovations aimed at improving wearer comfort, eye health, and convenience. Some recent advancements include:

1. Customizable Hydrogels

Advances in polymer chemistry allow for the customization of hydrogel properties to meet specific needs. For example, lenses can be tailored for higher oxygen permeability, enhanced wettability, or reduced dehydration.

2. Surface Coatings

To address the hydrophobic nature of silicone hydrogels, manufacturers use surface treatments and coatings to improve wettability. These coatings create a hydrophilic surface, enhancing comfort and reducing the risk of dryness.

3. Incorporation of Wetting Agents

Some modern lenses incorporate wetting agents directly into the lens material. These agents help maintain a moist surface, reducing dryness and improving comfort over extended wear periods.

4. Antimicrobial Coatings

To reduce the risk of infections, some lenses are now being developed with antimicrobial coatings. These coatings inhibit the growth of bacteria on the lens surface, enhancing safety for wearers.

5. Smart Lenses

Emerging technologies are leading to the development of smart contact lenses that can monitor health conditions, deliver medications, or even enhance vision beyond traditional correction.

Challenges and Considerations

Despite the advancements, there are challenges associated with soft contact lens materials:

1. Dry Eye

Dry eye syndrome can be exacerbated by contact lens wear, especially with lenses that do not retain moisture well. Innovations in wetting agents and surface treatments aim to mitigate this issue.

2. Hypoxia

Insufficient oxygen transmission can lead to corneal hypoxia, causing discomfort and potential long-term damage. Silicone hydrogel lenses have significantly reduced this risk, but ensuring adequate oxygen supply remains crucial.

3. Protein and Lipid Deposits

Protein and lipid deposits from tears can accumulate on lens surfaces, leading to discomfort and increased risk of infection. Regular cleaning and advanced materials that resist deposits are essential.

4. Cost

Advanced materials and treatments often come at a higher cost, which can be a barrier for some users. Balancing performance, comfort, and affordability is a key consideration for manufacturers.

5. Environmental Impact

The production and disposal of contact lenses and their packaging contribute to environmental waste. Biodegradable materials and sustainable practices are being explored to address this issue.

Future Directions

The future of soft contact lens materials looks promising with ongoing research and technological advancements. Potential future developments include:

1. Improved Comfort and Health

Continued innovation in materials and surface treatments will focus on enhancing comfort and maintaining eye health. This includes further reducing dryness and increasing oxygen permeability.

2. Multifunctional Lenses

Smart lenses that offer additional functionalities, such as health monitoring, UV protection, and drug delivery, are likely to become more prevalent. These lenses can provide added value beyond vision correction.

3. Personalized Lenses

Advances in 3D printing and customization technologies may lead to personalized contact lenses tailored to individual eye shapes and needs. This could significantly improve fit and comfort.

4. Sustainable Materials

The development of environmentally friendly materials and production processes will become increasingly important. Biodegradable lenses and eco-friendly packaging are areas of active research.

5. Enhanced Biocompatibility

Future materials will aim for even higher levels of biocompatibility, reducing the threat of allergic reactions and improving overall eye health.

Also,a method of producings of hydrophiliccast-moldedcontact lenses having enhanced surface quality is assessed. Such a method consists of :

Producing hydrophilic cast-molded contact lenses involves several steps that transform a liquid monomer mixture into a solid, transparent lens with hydrophilic properties. Here is an overview of the process:

1. Monomer Preparation

Monomer Selection: The process begins with the selection of hydrophilic monomers such as hydroxyethyl methacrylate (HEMA) or other suitable hydrophilic monomers.

Additives: The monomer mixture may include cross-linking agents, initiators, UV absorbers, and other additives to enhance the lens properties.

2. Mixing and Filtering

Mixing: The selected monomers and additives are mixed to form a homogeneous solution.

-Filtering: The mixture is filtered to remove any impurities or particles that could affect the clarity and quality of the lenses.

3. Molding

Mold Preparation: High-precision molds are prepared, usually made of metal or plastic. These molds define the shape and curvature of the contact lenses.

Filling: The monomer mixture is carefully injected into the molds. This step requires precision to ensure the correct amount is used and to avoid air bubbles.

4. Polymerization

Curing: The filled molds are exposed to a controlled environment where polymerization occurs. This can be initiated by UV light, heat, or a combination of both. The curing process solidifies the monomer mixture into a hydrogel.

Temperature and Time: The temperature and duration of the curing process are critical and are carefully controlled to ensure consistent quality.

5. Demolding

Lens Removal: After polymerization, the solidified lenses are removed from the molds. This step requires precision to avoid damaging the delicate lenses.

6. Hydration

Hydration Process: The lenses are immersed in a hydrating solution, typically saline, to absorb water and become soft and flexible. This step also ensures that the lenses attain their final hydrophilic properties.

7. Inspection and Quality Control

Inspection: Each lens is inspected for defects, clarity, and uniformity. Automated and manual inspection methods are used.

Quality Control: Lenses undergo rigorous quality control tests to ensure they meet industry standards and specifications.

8. Sterilization and Packaging

Sterilization: The lenses are sterilized using methods such as autoclaving or chemical sterilization to ensure they are safe for use.

Packaging: Finally, the lenses are packaged in sterile blister packs with a hydrating solution, labeled, and prepared for distribution.

Clear CL

Clear contact lenses are vision correction devices that are designed to be invisible when worn. Here are key points about them:

Purpose: Clear contact lenses correct refractive errors such as myopia (nearsightedness), hyperopia (farsightedness), astigmatism, and presbyopia, providing clear vision without altering the natural appearance of the eye.

Materials: They are made from hydrogel or silicone hydrogel materials, which are soft, flexible, and allow oxygen to pass through to the cornea.

Types

1. Daily Wear: These lenses are worn during the day and removed at night for cleaning and storage.

2. Extended Wear: Designed to be worn continuously, including overnight, for a specified period (up to 30 days).

3. Disposable: Available in daily, bi-weekly, or monthly disposables, these lenses are discarded after the recommended usage period to maintain hygiene and eye health.

Advantages

Aesthetic: Unlike glasses, clear contact lenses do not alter the appearance of the wearer.

Convenience: They provide a wider field of vision and are less affected by weather conditions (e.g., fogging up).

Comfort: Modern materials and designs enhance comfort and oxygen permeability, reducing the risk of eye dryness and irritation.

Care and Maintenance

Hygiene: Proper cleaning, disinfecting, and storing of reusable lenses are essential to prevent eye infections.

Replacement: Following the prescribed replacement schedule is crucial to maintain lens performance and eye health.

Clear contact lenses are a popular choice for vision correction due to their aesthetic appeal, convenience, and advancements in material technology that enhance comfort and eye health.

Bandage Contact Lenses

Materials of bandage contact lens

Bandage contact lenses are specialized contact lenses designed to protect and promote healing of the cornea. They are typically made from materials that offer high oxygen permeability, comfort, and safety. Here are the key materials used for bandage contact lenses:

Materials

1. Silicone Hydrogel

Oxygen Permeability: Silicone hydrogel lenses have high oxygen permeability, allowing significant amounts of oxygen to reach the cornea, which is essential for healing and maintaining corneal health.

Comfort: They provide enhanced comfort due to their soft and flexible nature.

Usage: Commonly used for extended wear, making them suitable for continuous use over several days or weeks if prescribed by an eye care professional.

2. Hydrogel

Water Content: Traditional hydrogel lenses have a high water content, which contributes to their softness and comfort.

Oxygen Transmission: While they have lower oxygen permeability compared to silicone hydrogels, they are still used for shorter-term bandage applications where oxygen needs are moderate.

Features

Sterility: Bandage contact lenses are packaged in sterile conditions to prevent infections.

Hydration: They help maintain a moist environment on the cornea, which is beneficial for healing and pain relief.

UV Protection: Some bandage lenses include UV-blocking agents to protect healing eyes from harmful ultraviolet light.

Thickness and Design: They are often designed thicker than regular contact lenses to provide additional protection and cushioning for the cornea.

Applications

Post-Surgery: Used after refractive surgeries such as LASIK or PRK to protect the cornea during the healing process.

Corneal Injuries: Applied to aid in the healing of corneal abrasions, ulcers, or other injuries.

Dry Eye Syndrome: Used in severe cases to provide a barrier against the drying effects of the environment.

Epithelial Healing: Promotes the healing of the corneal epithelium in conditions like recurrent corneal erosion.

Summary

Bandage contact lenses are primarily made from silicone hydrogel and hydrogel materials due to their excellent oxygen permeability, comfort, and protective properties. These lenses play a crucial role in corneal healing, providing a therapeutic benefit in various ocular conditions and post-surgical recovery.

Conclusion

The development and selection of materials for contact lenses have been pivotal in advancing eye care and improving the quality of life for millions of wearers. From the initial use of glass and PMMA (polymethyl methacrylate) to modern hydrogel and silicone hydrogel materials, the evolution of contact lens materials reflects significant strides in biomedical engineering and material science.

Key Takeaways:

Material Evolution: Early materials like PMMA provided the foundation but had limitations in oxygen permeability and comfort. The transition to hydrogels marked a major improvement, introducing soft, water-containing lenses that increased comfort but still had oxygen transmission challenges.

Silicone Hydrogels: The introduction of silicone hydrogels revolutionized contact lens technology by combining high oxygen permeability with the comfort of soft lenses. This advancement addressed the critical need for corneal health and extended wear possibilities.

Specialized Lenses: Bandage lenses, which are typically made from silicone hydrogel due to their superior oxygen transmission and comfort, demonstrate the specialized application of advanced materials for therapeutic uses.

Future Trends: Ongoing research continues to push the boundaries, with innovations aiming at enhancing lens performance, biocompatibility, and multifunctionality. Future developments may include lenses with drug delivery systems, enhanced UV protection, and materials tailored for individual eye conditions.

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Chapter 5: Soft Contact Lens Design & Fitting

Introduction

Soft contact lenses have revolutionized vision correction, offering a comfortable and convenient alternative to traditional eyeglasses. These lenses, made from a soft, flexible material, are designed to sit directly on the surface of the eye, providing clear vision while maintaining comfort throughout the day. Soft contact lenses come in various designs and materials, catering to different vision needs and preferences. They correct common refractive errors such as myopia (nearsightedness), hyperopia (farsightedness), astigmatism, and presbyopia (age-related near vision loss). Whether you're an athlete seeking clear vision without the hindrance of glasses, a professional looking for a more natural appearance, or someone with astigmatism or presbyopia, there's likely a soft contact lens option suitable for you.

The evolution of soft contact lenses has been remarkable. From the early hydrogel lenses introduced in the 1960s to the advanced silicone hydrogel lenses of today, there have been significant improvements in comfort, breathability, and optical clarity. Silicone hydrogel lenses, in particular, allow more oxygen to reach the cornea, promoting better eye health and enabling extended wear options.

Soft contact lens fitting assessment is most commonly undertaken practice but least discussed as it is straightforward exercise. Soft lens fitting not only related to finding the lens to fit patients eye but fitting soft contact lenses involves a thorough assessment by an eye care professional to ensure the lenses are tailored to your individual eye anatomy and vision requirements. This process considers factors such as corneal curvature, pupil size, and tear film dynamics to achieve an optimal fit and clear vision. Trial lenses are often used to assess comfort and vision quality before finalizing the prescription. Proper care and maintenance are essential for safe and successful soft contact lens wear. This includes following a recommended cleaning and disinfection routine, adhering to wearing schedules, and attending regular check-ups with your eye care provider. Fitting soft contact lens us equally challenging as rigid lens fitting with increase material choices, care regimes, wearing modalities which rely on the decision making of the clinician.

Every contact lens practitioner should aim to prescribe the appropriate material, lens size, and wearing modality to complement a wearer's ocular topography and lifestyle. Inappropriate lens selection or subpar fit can cause discomfort and/or have possible physiological effects, which can lead to people giving up using contact lenses.2. First-generation silicone hydrogel lenses with a greater modulus have taught us the value of a perfect fit.

There has been a contention that the expertise in contact lens fitting has shifted from the technical aspects of lens fitting to patient monitoring of ocular physiology. This is especially true with soft lens fitting, when practitioners' options are frequently restricted to "one-fit" lens designs.

Even if a large proportion of acceptable fits may be obtained with one-fit lenses, it's still important to know how to evaluate and optimize lens fit.

A number of myths about the fitting and design of soft contact lenses have been compiled in the literature.3.

An accessible synopsis of the main ideas behind soft contact lens fitting is given in this article. It doesn't deal with certain goods.

Silicone hydrogel materials are subject to the same criteria that govern hydrogel lens fitting.

Soft Lens Basic Principles :

Soft contact lenses are a popular form of vision correction and offer several advantages over traditional eyeglasses and hard contact lenses. Here’s a basic overview of their principles:

 Vision Correction:

- **Refraction**: Soft contact lenses correct refractive errors such as myopia (nearsightedness), hyperopia (farsightedness), astigmatism, and presbyopia by bending light rays to focus them properly on the retina.
- **Optical Power**: The lenses have a specific curvature and thickness, providing the necessary optical power to correct vision.

 Oxygen Permeability:

- The cornea requires oxygen from the air to stay healthy. Soft contact lenses are designed to allow oxygen to pass through the material to the cornea, preventing hypoxia (oxygen deprivation).

 Moisture Retention:

- The hydrophilic nature of soft contact lenses helps retain moisture, keeping the lenses comfortable and reducing dryness and irritation.

 Biocompatibility:

- Soft contact lenses are made from materials that are biocompatible, minimizing the risk of allergic reactions and ensuring comfort for extended wear.

Types of Soft Lenses:

Based on wearing schedule

- **Daily Wear:** These lenses are worn during the day and removed at night.
- **Extended Wear:** These can be worn continuously, even while sleeping, for up to a week or more, depending on the specific lens.

Based on replacement schedule

- **Disposable:** These lenses are designed for short-term use and are disposed of after a day, week, or month.
- **Conventional:** Conventional lenses are typically replaced every six months to a year, depending on the manufacturer's recommendations and the eye care professional's guidance.

Based on refractive correction

- **Spherical Lenses:** Correct standard vision problems like myopia and hyperopia.
- **Toric Lenses:** Specifically designed for astigmatism, with different powers in different meridians of the lens.
- **Multifocal/Bifocal Lenses:** These lenses help correct presbyopia by having multiple focal points for different distances.

Based on Material Composition

- **Hydrogel:** Traditional soft lenses are made from hydrogel, a water-containing polymer that remains flexible and soft.

- **Silicone Hydrogel:** These newer materials incorporate silicone to enhance oxygen permeability, which is crucial for corneal health.

Soft Contact Lens Design:

- **Back Optic Zone Radius (BOZR) or Base Curve (BC) :** The back optic zone radius (BOZR), also known as the base curve radius (BCR), is a crucial parameter in the design and fitting of soft contact lenses. It refers to the curvature of the posterior (back) surface of the lens. The BOZR is essential for ensuring that the lens fits properly on the cornea, providing both comfort and effective vision correction. Soft contact lenses typically have a BOZR ranging from 8.0 mm to 9.5 mm. Common standard values include 8.3 mm, 8.6 mm, and 8.9 mm. This is the curvature of the back surface of the lens, designed to match the curvature of the cornea. A proper base curve ensures the lens fits well and remains centered on the eye.
- **Diameter:** The overall size of the lens, typically ranging from 13.5 to 15 mm, which helps the lens cover the cornea properly and ensures stability.
- **Front Optic Zone Diameter (FOZD):** The diameter of the central optical zone on the front surface of the contact lens. It refers to the diameter of the central part of the front surface of the lens that contains the refractive power for vision correction. The FOZD is generally designed to be larger than the pupil size to ensure that the pupil is always within the optical zone, even in low light when the pupil dilates. The FOZD typically ranges from about 7.0 mm to 9.0 mm. An appropriately sized FOZD ensures that the wearer has clear and sharp vision across various lighting conditions. While FOZD primarily affects vision, it can also influence the overall fit and comfort of the lens. The overall diameter of the lens should be considered in conjunction with the FOZD to ensure proper fit and comfort.

- **Optic Zone/ Central Zone:** The central part of the lens that contains the prescribed refractive correction. It needs to be accurately crafted to correct specific vision issues like myopia, hyperopia, astigmatism, or presbyopia.
- **Peripheral Zone:** The surrounding area that transitions smoothly to the edge of the lens, contributing to the comfort and stability of the lens.
- **Lens Thickness:**

1. **Center Thickness:** Thinner lenses allow more oxygen to reach the cornea, improving comfort. However, the thickness can vary depending on the prescription, with higher prescriptions generally requiring thicker lenses.
2. **Edge Thickness:** The design of the edge can impact comfort. Smooth, tapered edges help reduce irritation to the eyelids and conjunctiva.

- **Water Content:**

1. **High Water Content:** Lenses with higher water content (up to 80%) tend to be softer and more comfortable, but can be more fragile and prone to dehydration.
2. **Low Water Content:** Lenses with lower water content (around 38-55%) are more durable and retain moisture better over extended wear.

- **Lens Edge:** The edge design of soft contact lenses is a crucial factor that significantly influences the comfort, fit, and overall performance of the lens. Various edge designs are used to ensure the lens remains stable on the eye, provides adequate oxygen transmission, and minimizes irritation to the eyelids and conjunctiva. The edge designs are - Tapered Edge Design, Round Edge, Beveled Edge Design, Blended Edge Design, Truncated Edge Design and Edge-Lift Design.

- **Oxygen Permeability:**

  Dk/t Value: This is a measure of how much oxygen can pass through the lens material. Higher Dk/t values indicate better oxygen transmission, which is crucial for maintaining corneal health, particularly for extended wear lenses.

- **Surface Treatment:**
  1. **Hydrophilic Coatings:** These coatings help the lens retain moisture and stay hydrated, enhancing comfort.
  2. **Antimicrobial Coatings:** Some lenses feature coatings to reduce bacterial growth, lowering the risk of infections.

The Ideal fit for soft contact lenses

It is necessary to assess both static and dynamic factors when judging the fit. The optimal fit for soft contact lenses should display the characteristics as follows :

1. Proper Size and Diameter

- **Lens Diameter**:
  - Soft contact lenses should cover the cornea completely and extend slightly onto the sclera (the white part of the eye) to ensure stability.
  - The typical diameter for soft contact lenses ranges from 13.8 mm to 15.0 mm, depending on the size of the eye.
- **Base Curve**:
  - The base curve (BC) of the lens should match the curvature of the cornea. This measurement ensures that the lens sits comfortably on the eye.
  - The base curve is usually measured in millimeters and typically ranges from 8.0 mm to 9.5 mm. A steeper cornea may require a lower base curve number, whereas a flatter cornea may need a higher number.

2. Lens Movement

- **Mobility**:
  - Proper lens movement is essential for tear exchange and debris removal.
  - The lens should move slightly (approximately 0.5 mm to 1.0 mm) with each blink and when the eye moves.
  - Excessive movement can cause discomfort and reduced vision stability, while too little movement can impede tear exchange and cause dryness.
- **Centering**:
  - The lens should center well on the cornea without drifting off to the sides.
  - A well-centered lens ensures consistent vision correction and minimizes the risk of irritation.

3. Comfort and Moisture Retention

- **Comfort**:

    - A properly fitted lens should feel comfortable, with minimal awareness of its presence.
    - The wearer should experience no irritation, redness, or discomfort during wear.
- **Moisture**:
    - The lens should retain moisture to prevent dryness and irritation.
    - Hydrophilic materials used in soft lenses help maintain a moist environment, enhancing comfort.

4. Vision Clarity

- **Optical Alignment**:
    - The optical center of the lens should align with the visual axis of the eye to ensure clear vision.
    - Misalignment can cause blurriness or ghosting.
- **Lens Stability**:
    - For toric lenses (used to correct astigmatism), rotational stability is crucial. The lens should not rotate excessively, which can lead to fluctuating vision.

5. Oxygen Permeability

- **Material Selection**:
    - High oxygen permeability is essential to keep the cornea healthy and prevent complications such as corneal hypoxia.
    - Silicone hydrogel lenses offer excellent oxygen transmission, supporting corneal health during extended wear.

6. Tear Exchange

- **Edge Fit**:
    - The edge of the lens should allow for adequate tear exchange beneath the lens.
    - This helps remove debris, provides nutrients, and maintains a healthy tear film.

Soft contact lens pre-fitting evaluation :

1. Patient History

- **Medical History**: Assess any medical conditions, such as diabetes, autoimmune diseases, or allergies, that might affect lens wear.
- **Ocular History**: Evaluate any previous eye conditions, surgeries, or issues with past contact lens wear. This includes a history of dry eyes, infections, or corneal conditions.
- **Current and Previous Lens Experience**: Gather information about previous contact lens wear, such as brand, type, wearing schedule, and any problems encountered.
- **Lifestyle Needs**: Understand the patient's lifestyle and daily activities to recommend lenses that match their needs, such as lenses suitable for sports or extended wear.
- **Allergies**: Identify any allergies to materials or solutions that could affect lens choice.

2. Vision Assessment

- **Refraction Test**: Conduct a thorough refraction test to determine the precise prescription needed for vision correction, including assessing for myopia, hyperopia, astigmatism, and presbyopia. For refractive power more than ±4.00D need to calculate vertex distance compensation.

  Vertex distance (VD) is typically around 12-15 mm for eyeglasses. Contact lenses sit directly on the cornea, so the vertex distance is essentially 0 mm.

  Formula

  For **spherical powers**, the formula for conversion is:

  CL Power=Spectacle Power1−(Vertex Distance×Spectacle Power)\t(CL Power)

  CL Power=1−(Vertex Distance×Spectacle Power)Spectacle Power

  Where:

  CL Power = Contact Lens Power

  Spectacle Power = Power of the spectacle lens in diopters

  Vertex Distance = Distance in meters (usually around 0.012 to 0.015 meters)

- **Visual Acuity**: Measure distance and near visual acuity to ensure lenses will provide the desired vision correction.

3. Ocular Health Examination

- **Slit-Lamp Examination**: A slit-lamp biomicroscope is used to examine the anterior eye structures, including the cornea, conjunctiva, and eyelids, to identify any abnormalities or contraindications for lens wear.

- **Tear Film Assessment**: Evaluate the tear film stability and production using tests like the Schirmer test or tear breakup time (TBUT) to determine if the patient has dry eyes or other tear-related issues.

- **Corneal Health**: Assess the cornea for any signs of irregularity, scarring, or conditions such as keratoconus that might affect lens fitting.

- **Conjunctival Health**: Examine the conjunctiva for signs of inflammation or allergic reaction.

- **Eyelid Condition**: Check for eyelid conditions like blepharitis or meibomian gland dysfunction that could impact lens comfort and hygiene.

4. Corneal Measurements

- **Keratometry**: Measure the curvature of the cornea to determine the appropriate base curve of the lens. This helps ensure that the lens will fit well and be comfortable.

  Calculate the average K reading if given two values:

  Average K (D)=K1+K2\2

  Determine the Base Curve

  Use the average keratometry reading to determine the base curve. The typical relationship between the corneal curvature and the base curve for soft contact lenses is as follows:

  Flatter Corneas (K: 40.00 - 42.00 D or 8.00 - 8.50 mm): Base curve ~ 8.6 - 9.0 mm.

  Average Corneas (K: 42.00 - 45.00 D or 7.50 - 8.00 mm): Base curve ~ 8.4 - 8.6 mm.

  Steeper Corneas (K: 45.00 - 48.00 D or 7.00 - 7.50 mm): Base curve ~ 8.0 - 8.4 mm.

Recommended Base Curve: For an average K of 7.76 mm, select a base curve around 8.4 mm.

- **Corneal Topography**: For more detailed mapping, corneal topography provides a comprehensive view of the cornea's surface, identifying any irregularities or unique shapes that need consideration.

- **Pupil Size**: Measure the pupil size in different lighting conditions to ensure proper lens selection, especially for multifocal or toric lenses. Pupil size determines the back optic zone of soft contact lens.

- **Corneal Diameter**: Measure the horizontal visible iris diameter (HVID) to aid in selecting the correct lens diameter.

  Diameter of soft contact lens = HVID + 1.5 mm

5. Lifestyle and Needs Assessment

- **Wearing Schedule**: Discuss the patient's preferences for wearing schedules, such as daily wear, extended wear, or occasional use, to guide lens selection.

- **Occupation and Activities**: Consider the patient's occupation, hobbies, and activities to recommend lenses that accommodate specific needs like UV protection, comfort for screen use, or sports performance.

- **Cosmetic Preferences**: Some patients may prefer colored lenses or those with specific cosmetic features.

6. Patient Education and Expectations

- **Lens Options**: Educate the patient about different types of lenses available, including daily disposables, bi-weekly, monthly, toric, and multifocal lenses.

- **Hygiene and Maintenance**: Explain the importance of proper lens care, cleaning, and maintenance to prevent infections and complications.

- **Cost Considerations**: Discuss the cost of lenses, solutions, and any ongoing expenses related to contact lens wear.

- **Realistic Expectations**: Set realistic expectations about vision correction, comfort, and potential adaptation time.

Initial Lens Selection :

Based on the pre-fitting evaluation, select a suitable trial lens considering:

A. Lens Parameters

- **Base Curve:** Choose a base curve that closely matches the patient’s corneal curvature. The base curve of soft contact lenses usually ranges from 8.0 to 9.0 mm.
- **Diameter:** The lens should cover the cornea adequately and extend slightly onto the sclera. Common diameters are between 13.8 and 15.0 mm.
- **Material:** Select a lens material suitable for the patient’s needs, such as silicone hydrogel for higher oxygen permeability.
- **Optical Power:** Ensure the lens power matches the patient’s prescription, adjusted for vertex distance if necessary.
- **Lens Type:** Choose between daily disposables, bi-weekly, monthly, toric (for astigmatism), or multifocal lenses based on the patient's needs.

B. Trial Lenses

Insertion: Properly insert trial lenses and allow them to settle on the eyes for 10-15 minutes before evaluation.

Evaluation of Lens Fit :

Once the trial lenses are in place, evaluate the fit through the following steps:

A. Lens Movement and Positioning

- **Movement on Blink:** The lens should move slightly (0.5 to 1.0 mm) with each blink to ensure adequate tear exchange and debris removal.
- **Centration:** The lens should center well on the cornea, with no tendency to decenter or drift off to the side.
- **Coverage:** The lens is in its original position with the eye in primary position full coverage of the cornea should be demonstrated before, after, and throughout the process. and approximately 1 mm of conjunctival coverage

- **Edge Lift:** Ensure there is an appropriate edge lift for tear exchange without causing irritation.
- **Push up test:**

  Lens fit assessment is a measure of the fit of the lens to the eye. It is the most effective way to assess the dynamic fit of the lens. The practitioner moves the lens vertically, applying pressure to the lower eyelid with his or her fingers. The lens is allowed to refocus while the practitioner observes. The practitioner assesses the relative ease with which the lens is moved and the speed with which it returns to its original position. A percentage has been suggested, with 100 percent representing a lens that cannot move and 0 percent representing a lens that has detached from the cornea without eyelid support. A perfectly fitted lens would register at 50 percent.

B. Comfort Assessment

- **Patient Feedback:** Ask the patient about initial comfort, noting any irritation, dryness, or awareness of the lens.
- **Adaptation:** Explain that slight discomfort might occur initially but should improve with regular wear.

C. Vision Assessment

- **Visual Clarity:** Check visual acuity with the lenses on, ensuring they provide clear vision at all required distances.
- **Stability:** Ensure stability of vision, especially for toric lenses, as rotational movement can affect astigmatic correction.

4. Follow-Up Evaluation

Conduct follow-up visits to ensure continued comfort and vision quality:

A. Scheduled Follow-Ups

- **Initial Follow-Up:** Typically scheduled within a week of lens fitting to assess adaptation and make adjustments if needed.
- **Ongoing Monitoring:** Regular follow-ups every 6-12 months to monitor eye health and lens performance.

Conclusion :

The successful design and fitting of contact lenses require a comprehensive approach that considers individual patient needs, ocular health, and lifestyle. By carefully selecting lens materials, designs, and fitting parameters, eye care professionals can provide personalized solutions that enhance comfort, vision quality, and overall satisfaction.

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Chapter 6: Soft Toric Contact Lens Design & Fitting

6.1 Introduction

Soft contact lenses that are specially designed to provide correction to astigmatism termed as "toric" contact lens. Astigmatism normally occurred when the corneal curvatures have become irregular with different curvature value. Unlike regular soft contact lenses, which are spherical in shape, toric contact lens is made up of in such a way to have also different diopter value in different curvature to do the correction of the irregular surfaces.

The characteristics of toric lenses are flexible, breathable materials that is capable to allow oxygen transmission within the lens to supply it to cornea may provide more comfortable with stable vision correction. Contact lenses are available in market can be classified as per use and wearing shedule like daily wear and disposable, Bi-weekly and now monthly disposable is also beneficial as per long duration use.

Before prescribing soft toric lenses, an eye it is mandatory to do a gross clinical observation and checkup to make sure about ocular health stability to be adjusted with contact lens without any other clinical complication. The exact prescription needed to correct the individual's astigmatism and other refractive errors. Proper fitting and alignment of the lenses are crucial for optimal visual acuity and comfort.

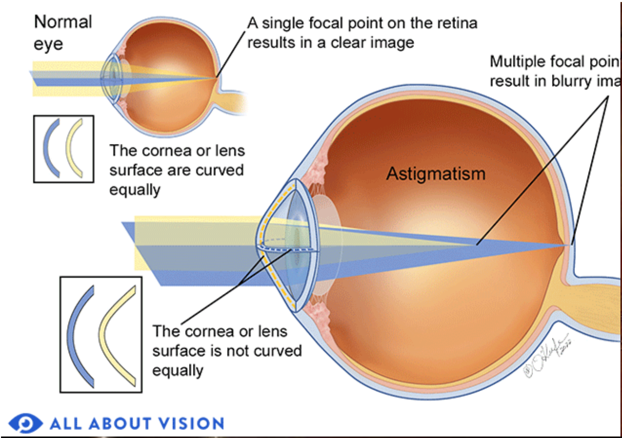
Overall, soft toric contact lenses offer a convenient and effective solution for individuals with astigmatism, providing clear vision and comfort for daily activities

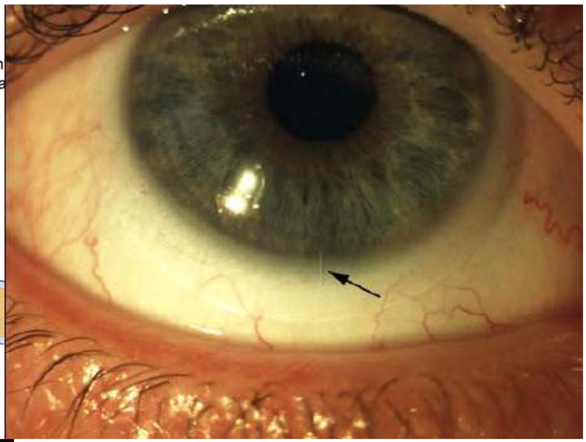
6.2 **Anatomy of eye including impacts of astigmatism**

Astigmatism is type of common refractive error which happens normally when cornea or crystalline lens bear two different curvatures in different meridians, when one meridian is considered as 90 degrees apart from the other.

To understand its anatomy, let's break down the relevant parts:

> →Cornea: This is the clear, outermost layer of the eye. In case of astigmatism one meridian will become flatter or steeper than the other meridian located 90 degrees apart from each other responsible for forming irregular refraction that may cause blurred vision.





Lens: Behind the cornea, the lens further refracts light onto the retina. In astigmatism, the lens may also contribute to the uneven focusing of light due to its irregular shape.

Retina: Located at the back of the eye, the retina receives the focused light and sends signals to the brain through the optic nerve, allowing us to see. In astigmatism, the uneven focus of light can result in blurred or distorted vision.

Understanding these structures helps in diagnosing and treating astigmatism, often through corrective lenses such as glasses or contact lenses, or in some cases, surgery to reshape the cornea.

6.3 **Procedure of Correction of Astigmatism with Soft Toric Contact Lens:**

→ Step one: Complete assessment of refractive error of the patient. Then the refractive power conversion to be made by using power conversion table or with vertex correction formula that is spectacle power to be converted in to corneal power.

The formula is:

Compensated power that means corneal power = F (Spectacle's Sphere Power / 1- d (Vertex Distance) ×F (Spectacle's Spherical Power).

The trial toric contact lenses to be chosen closest to the vertex compensated power.

→Step Two:

To measure the different parameters of the eye Refractive Power along with that is a) Base Curve, b) Corneal Diameter, c) Palpebral aperture, d) Pupillary Aperture etc. After measuring all these the actual trial lens to be selected.

→Step Three:

After inserting the trial lens inside the eyes over the cornea and wait for 10 minutes so that it can be adjusted with patient's eye including its rotation and stability also that is helpful for correcting errors to form the clear vision.

→Step Four:

The next step is performed to check about contact lens parameters and quality adjustment such as the uniform coverage over the corneal surface, proper centration, movement, lens position over the cornea after blinking in different gazes. In case of toric lens fitting also lens marking is also important to find the rotative angle with directions.

→Step Five:

Now to check visual acuity. If it is found that the visual acuity improves and optimum with over refraction then be sure that the other parameters are all right then the existing trial lens will be the prescription lens.

If there is any problem appears in visual acuity, lens rotation, movement then check the lens rotation and axis compensation to be provided. Angle Of rotation and compensation to be done according to LARS/ CAAS rules that is Left Add and Right Subtract or Clock wise Add and Anti Clock wise subtract).

In such a way trial contact lens to be selected with proper axis and prescription purpose.

If the rotation of contact lens on the eye towards Left that means new rotative angle to be added with the present axis for next trial lens selection and if the angle of rotation towards right or anti clock wise that means rotative angle need to be subtracted from existing angle to do the final prescription.

After completing the all above procedure new trial lens to be selected and inserted to the patient's eye with modified axis and over refraction should be done. Now Patient should be observed and if the patient's vision becomes optimum then the modified power and axis of the trial lens will be the final contact lens power and to be ordered.

→Step six

For example,

Power of Right Eye:-3.0 DSph/-1.25 DCylX 180°

Power of Left Eye: -3.0 DSph/-0.75 DCylX 180°

BE Base Curve 7.75 mm (Mean K)

BE Diameter (Cornea) 11.5 mm

So, in Right Eye Refractive Power can be find as

-3.0Ds/-1.25x180 when base curve is 7.75mm.Overall diameter is 11.5mm.

Trial contact lens power selected as -3.00/-1.25x180, V/A 6/6

After inserting the contact lens observed the patient after 15 minutes (time given to be settled) with blink lens rotated anti clockwise that is towards practitioners right and after that axis of the lens which should have come to 180 degrees but returned to 10degree. Visual equity 6/6 (partial) this was not very good acceptance. Now to correct for this 10-degree rotation subtracted 10 degrees from the spectacle cylinder for new lens.

So final prescription which to be ordered is for the right eye -3.0Ds/ -1.25 X 170. Now in left eye refractive power is -3.0 diameter so spherical/ -0.75x 180.

Base curve is 7.75-millimeter visual acuity 6/6. Overall diameter 11.5 millimeter mean overall diameter.

Trial contact lens power is -3.0Ds/ -0.75x 180. After inserting the trial contact lens on the left eye and observed after 15 minutes (time given to be settled the trial contact lens on the cornea) with blink lens rotated clockwise that is towards practitioners left and after that the axis of the lens which should have come to 180 degrees but returned to 170 degrees.

In this position the visual equity become 6/6 partial which was not very good acceptance. Now to correct for this 10-degree rotation need to add 10 degrees on spectacle cylinder for new toric contact lens.

So, the final prescription which to be ordered is

Left eye: -3.0Ds/-0. 75x10.V/A 6/6

Now the final toric contact lens prescription

RE -3.0/-1.25x170, 6/6

LE -3.0/-0.75 x 10, 6/6

6.4 Types of Soft toric soft CL (Contact lens)

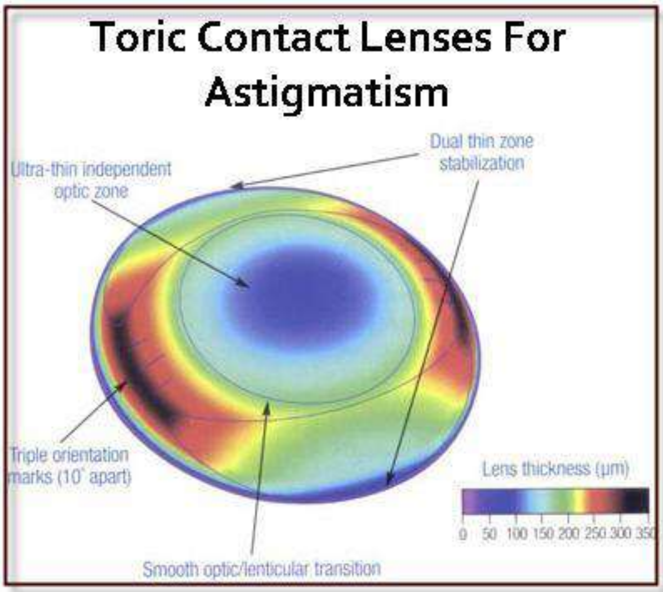
→Front Toric Soft CL

→Back Toric Soft CL

→ Bi Toric Soft CL

6.5 Design of Toric Soft CL

The soft toric contact lens is designed and engineered in such way to overcome refractive errors that happening from the irregular corneal or refractive surface that responsible for blurry and distorted vision.



Below is a simplified explanation of their design:

→Material Selection:

Soft toric lenses are typically crafted from hydrogel or silicone hydrogel materials. These materials offer comfort, breathability, and moisture retention, which are essential for long-term wear.

→Stabilization Technology:

Correcting astigmatism requires lenses to maintain a specific orientation on the eye. To achieve this, soft toric lenses utilize various stabilization technologies. One common method is known as "ballast" or "prism ballast," where the lens is slightly thicker at the bottom to ensure correct orientation.

→Toric Geometry:

Toric lens geometry has the dissimilarity with the spherical contact lens normally has same curvature and diopter value in all the meridian but toric lens consists of different dioptric value in different meridian to correct astigmatism. So, it composed two distinct different power in different meridians to correct both the astigmatic and spherical meridian at a time.

→Axis and Cylinder:

These lenses feature markings that indicate the axis and cylinder power to ensure proper alignment and orientation on the eye. The axis determines the location of the more curved meridian of the lens, while the cylinder power corrects the astigmatism.

→Moisture and Comfort:

Soft toric lenses prioritize moisture retention and comfort, often incorporating features such as high-water content, surface treatments to resist protein buildup, and UV protection.

→Customization: Soft toric lenses can be customized to fit individual eye shapes and prescriptions, guaranteeing optimal vision correction and comfort.

Daily Wear and Replacement Schedule: Depending on the specific brand and type, soft toric lenses may be designed for daily wear or extended wear, with replacement schedules ranging from daily disposables to monthly or longer.

Overall, the design of soft toric contact'- lenses aims to provide individuals with astigmatism clear and stable vision, while also prioritizing comfort and eye health.

6.6 Patient education and care instructions

Dos:

- Prior to handling the lenses, always wash hands to avoid using soap with lotion to prevent leaving a hazy film.

- Before inserting, carefully inspect each lens for any damage and ensure it is not inside-out.

- Clean each lens daily by gently rubbing it for 10 seconds on each side, then rinse before storing.

- Use only the solution recommended by the Eye Care Practitioner.

- Change the solution on a daily basis.

- Keep the storage case clean and replace it every 3 months.

Don'ts:

- Do not sleep while wearing contact lenses unless approved by the Eye Care Practitioner.

- Avoid swimming or using a hot tub while wearing the lenses. During swim with contact lenses need to consult with the doctor for the best approach.

- Never use tap water to clean the lenses.

- Not to use medicated drops with contacts unless approved by the Eye Care Practitioner.

6.7 Common issues and troubleshooting with soft toric contact Lenses:

→Discomfort:

In case of discomfort, ensure the lenses are clean and properly inserted. If discomfort persists, consult eye care professional to check the fit.

→Blurry Vision:

Blurriness may indicate the lenses aren't sitting properly on eyes. Make sure they're positioned correctly, and if the problem persists, need to consult eye doctor.

→Rotation:

Toric lenses need to stay in the correct orientation to effectively correct astigmatism. If they rotate may cause vision may blur. If rotation is an issue needs to ask contact lens practitioner about lenses with a higher stabilization design.

→Dry Eyes:

Astigmatism can exacerbate dry eye symptoms. Use lubricating eye drops recommended by eye doctor to keep ocular surface moist.

→Tearing:

If eyes have watering excessively, the lenses may not be fitting properly. Consult eye care professional for a proper assessment.

→Lens Deposits:

Protein and lipid deposits can build up on toric lenses, leading to discomfort and blurred vision. Need to clean lenses as directed and replace them as recommended.

→Incompatibility with Activities:

Some toric lenses may not be suitable for certain activities like swimming or intense sports. Need to discuss eye care professional for recommendations based on lifestyle.

→Prescription Changes:

If prescription parameters changes toric lenses may no longer provide optimal correction. Regular eye exams are essential to ensure patient's prescription is up to date.

6.8Advancement in toric contact lens technology

Advancement of Toric contact lens technology:

Use of contact lens has come a long way since early 1900. It has been used for a device which corrects the simple refractive errors for visual problems. Now this device turns into a versatile tool for enhancing vision and as therapeutic purpose also. Due to advancement in technology, contact lenses have become more comfortable, durable and easily wearable. So many innovative works have done on contact lens to enhance vision.

-->As now vision becomes sharp and comfortable, durable simple contact lens become torque lens which can correct the astigmatism and also able to solve refraction problem due to the irregular corneal surface and perform the smooth refraction.

-->Beside this colored contact lenses used for enhancement of vision with cosmetic purpose. They are being able to enhance natural eye color and create a beautiful look.

-->UV blocking properties in simple and toric contact lenses:

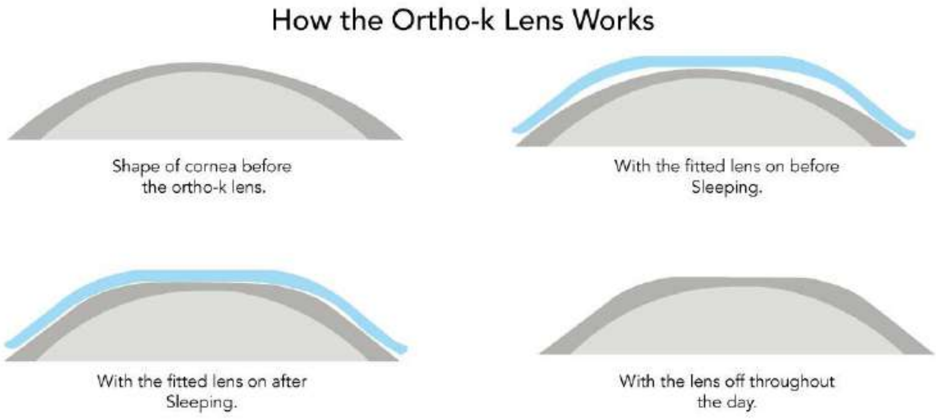
This property in contact lens protects the eyes from harmful effect of UV radiation. The complications in the eyes like cataracts, macular degenerations, etc. A special coating is applied over the lens surface that may block UV rays from entering into eyeballs. Disposable contact lens which have a great value to reduce the rate of infection and very easy to handle the material made up of Silicon hydrogel. In silicon hydrogel material, the transmissibility of oxygen is near about 100% by the hypoxic conditions of the cornea has reduced into 0% after wearing the silicon hydrogel toric lens from morning to night.

-->Multifocal contact lens which bears multiple zones through which the person who wears such lens can seen clearly at any distances where the person wants to see.

-->Telescopic contact lens is the recent development in this age. This type of contact lens helps to see clearly the persons those who are suffering from age related macular degeneration. Telescopic contact lenses can magnify images and project them in the healthy part of the retina and help them to improve the vision.

→Orthokeratology (Ortho-k):

Ortho k lens is such type of contact lens which can reshape the corneal shape. By wearing such type of contact lens overnight and remove in the morning, after that the person who worn the contact lens overnight will be able to see clearly throughout the day without using any other corrective spectacle and contact lens.



--> **Smart contact lens:**

These are the new type of contact lenses which can monitor various health matrixes like blood glucose level, intraocular pressure with enhancing visual acuity and also providing real time health information's also.

6.9 Future directions and innovations in soft toric contact lenses

In future contact lens as well as toric contact lens will bring the revolutionary changes in this field. The change has already started and we are getting now the benefits of that research and development activities with new generation toric silicon hydrogel contact lenses.

-->Stability improvement:

The present days, design of the toric lanes have been changed and developed so the stability of contact lens over the corneal surface is also improved and rotation becomes less. Clarity of vision is also enhanced with eye motility and blinking. Developmental works is also continued to develop the parameters to enhance the qualities.

-->Improvement of material:

The material of contact lens has been developed as per corneal physiology so oxygen permeability, oxygen transmissibility and other parameters can be maintained properly with enhancing corneal moisture for lowering discomforts. The patient now having the optimum comfort throughout the day with contact lens correction and also with special contact lens with overnight wear without any complications and compromising ocular health.

-->Customized lens project:

Innovation of customization and personalized updated lenses has given extreme comfort to overcome the unwanted irregularities of the lens.

-->Smart lenses: Improvement of technology such as monitoring eye health or built in filters for protection against a harmful blue rays is also under research and development to make this more standard. In future and the field of toric lenses also.

-->Biocompatibility:

The innovation and compatibilities developed according to the physiology of the eye to reduce discomfort and the risks of complications. Special type of lenses like that new innovations for correction the special issues of cornea and eyeball. Ortho Keratology lenses now a day's successfully dispensing and using by patients for correcting with slower growth of myopia by reshaping corneal surface. Overnight use of Ortho K lens can modify corneal refractive surface so that during the daytime patient can see the clean and clear vision without any other type of corrective spectacle and contact lens.

-->Scleral lens: In Keratoconus or in post surgical astigmatism. Such type of lenses is very useful which provides stable vision in case of irregular refractions that happening from the irregular cornea.

-->Hybrid contact lens: Another special type of lenses that is combination of soft and rigid gas permeable material which are very useful to correct astigmatism.

-->Non corrective benefits: Toric lens have the additional features beyond vision correction such as material which water gradient material and biomimetic colligent technology, which is very useful to resist the bacteria and minimize the protein lipid deposition to enhance quality of contact lens from other cell debris over the lens. Drug applications with contact lenses are also helpful for treatment of mild and moderate glaucoma cases and ocular hypertension. Nowadays also, photo chromatic toric lens is also playing vital role in contact lens practice field specialized to correction glare issues.

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Chapter 7: RGP Contact Lens fitting & Management

Introduction :

RGP contact lenses are made up of durable and hard plastic material, but it allows oxygen transmission so that reduce chances of hypoxia due to contact lens wear for the prolong time. Previous Generation hard contact lenses are made of PMMA that stands for polymethyl meth-acrylate but not have properties to pass oxygen within the lens material. About the characteristics; it has differences from the soft contact lens that made up of silicon hydrogel material. Tear reserved formed within the space between lens and corneal surface helps to correct refractive errors and provide good visual equity with free from deposits. Tear reserved formed within the space between lens and corneal surface helps to correct refractive errors and provide good visual equity with free from deposits. Tear reserved formed within the space between lens and corneal surface helps to correct refractive errors and provide good visual equity with free from deposits but soft contact lenses are comfortable due to its soft nature. Rigid permeable lenses have a smaller diameter than the soft contact lens that allows more tear exchange capacity while blinking may provide stable and clear vision.

Basic differences between RGP & Soft contact lens :

Normally soft lenses that made up of silicon hydroxyl are soft in nature and overall diameter fitted over the corneal surface softly and diameter is also larger than the corneal diameter.

On the other hand, RGP lenses have this shorter diameter compared to corneal diameter that allows fresh tear exchange during blinking and oxygen transmission. Proper rigid lens fitting depends on apical alignment and proper base curve selection. Tear lens located between the lens posterior surface and anterior corneal surface. Tear lens power can be find by the calculation of difference between the corneal curvature and the contact lens base curve. Proper contact lens fitting allows easy tear exchange during the eyelid and ocular movement. In case when rigid contact lens base curve measurement properly match with corneal surface that fitted over that can be termed as proper apical fitting. If the corneal base curve is shorter than the corneal surface with short radius of curvature compared to cornea may be responsible for this steeper fitting. If the contact lens base

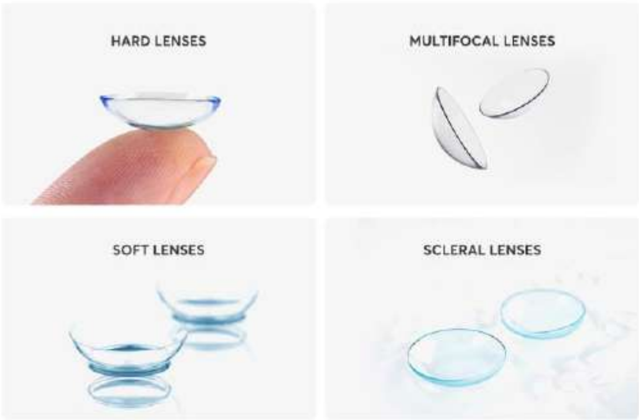


Figure 1(different types of contact lens)

Curve is larger than the corneal surface with larger anterior radius of curvature compared to cornea may be responsible for the flat or loose fitting alignment. Beside this for the proper lens fitting lens upper edge should be located under upper lid margin so that it may allow adequate lens movements with adequate tear flow.

Clinical significance and use of RGP:

Gas Transmission: RGP contact lens can transmit oxygen to reduce hypoxia of cornea normally occurred from continuous contact lens wear. Beside this it is smaller in size so cover less area of cornea to allow more water flow to circulate moisture with more oxygen breathing.

Customized shape: In case of rigid contact lens dispensing, it is mandatory to do customization about its size, shape, base curve according to patient's cornea so that it is comfortable for wearing and with proper correction of refractive error.

Refractive to error correction: Adequate fitting with apical alignment and clearance allows proper tear lens circulation with spreading moisture and tears to correct refractive errors occurring from an irregular corneal surface. Beside this toric RGP is also used in case of lenticular astigmatism.

Less Chance of deposition: Due to rigid property with its smooth surface there is less chance of deposition and bacterial infection growth within the lens. For this purpose it is more safe and healthy to use with lasting for a long time period.

Myopia control properties: It has been seen that rigid lenses can slow the progression of myopia due to its reshaping characteristics and reverse geometry. It is useful for the pediatric patient to slow the myopia progression. In case of orthokeratology treatment, RGP lenses are used broadly in the field of contact lens practice.

Correction of astigmatism:

In case of irregular cornea keratoconus cases, RGP lens have the properties to correct the refractive error with sharp vision quality and astigmatism correction. Tear lens properties is able to correct corneal astigmatism cases.

Expenses:

In case of long term use, RGP lenses are beneficial due to its rigid properties. It has lower chance of tearing like the soft contact lens and also easier to maintain and cleaning for that purpose. It can provide stable vision with long lasting quality for a year or more than one year.

→In case of keratoconus treatment, RGP lens is recommended, but it is very tough to find the ideal fitting over the corneal apex. In keratoconus condition corneal apex is sharper but posterior surface are flatter than the apex area. But RGP contact lens normally fit over the apex so for the proper alignment then tri-curve and multi-curve peripheral design needed with special characteristics for the trial purpose and perfect fitting

Tear lens Properties

Tear lens properties: Tear lens located between the lens posterior surface and corneal anterior Surface to correct the corneal astigmatism and irregularities. Spherical RGP lens with help of tear lens formation helpful for correction Irregular and irregular astigmatism as it fills the space between lens and cornea can correct irregularities in such a way.

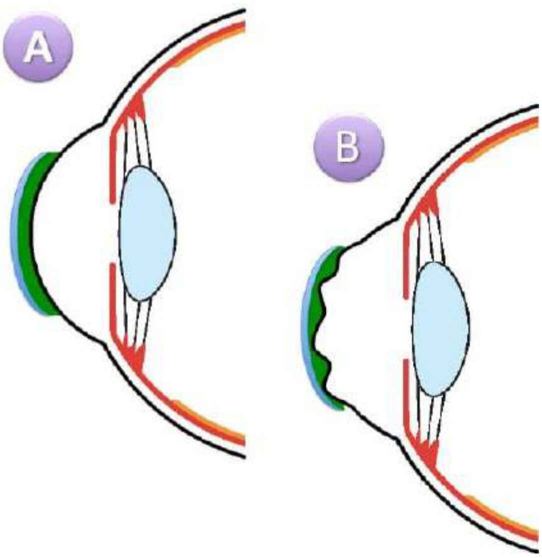


Figure 2: Tear lens properties

In the picture green mark substance marked as the tear lens and in the diagram b it is correcting corneal irregular surfaces and maintaining smooth refraction. Normally cornea has the Refractive index as 1.376.

Tear lens refractive index almost same as the water that is 1.336.So due to tear lens location over the corneal surface it can mask optical properties from the corneal surface area. As tear film properties depends on the contact lens surface characteristics so if the posterior contact lens surface is spherical may be responsible for forming the tear lens anterior surface with spherical properties. In such a way it can correct 90% astigmatism with regular or irregular characteristics. About the power calculation flattest area power is taken and termed as the spherical value with noted it as minus cylinder form. Toric RGP lens with toric properties in the backside of lens is used to correct residual astigmatism. Tear lens power can be calculated as the difference between the corneal curvature (K) measurement and contact lens base curve. It is it is found that tear lens power is 0.25 Diopter as calculated based on the contact lens base curve and corneal surface curvature difference in every time when 0.05 millimeter radius of curvature generated. So it can say that 0.05 millimeter of radius of curvature difference generated between the corneal curvature and contact lens base curve may be responsible for forming the tear lens power as 0.25D. This power can be generated with more value if the corneal anterior radius of curvature is steeper than the value 7.00mm.

When the contact lens base curve is become steeper than the corneal curvature is responsible for forming the tear lens with the diopter value found as plus power.

When the base curve of rigid lens is flatter than that of corneal curvature may be responsible for forming the tear lens power with minus power properties.

Contact lens fitting parameters :

Parameters that need to be justified by practitioners regarding RGP Contact lens fitting can be listed as

-> BOZR that stands for back optic zone radius.->BVP stands for back vertex power.

->BVD stands for back vertex distance.

->TD stands for total diameter

-> BOZD stands for back optic zone diameter.

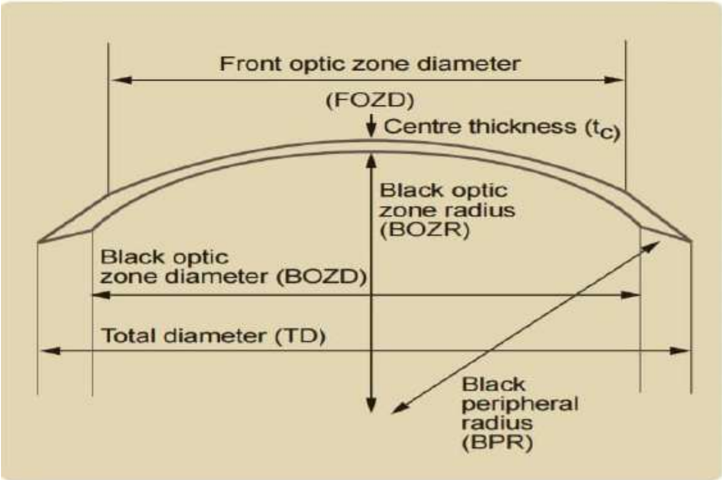


Figure3 Contact lens parameters

->BOZR: It is determined as the distance between the back optic zone centers of curvature to the pole of the back optic zone curvature. ->Back vertex power: BVP is the power of contact lens after compensating the back vertex distance. That means the power from the spectacle power to contact lens power fitted over corneal anterior surface part.

-> Back vertex distance: BVD is concerned about the distance between the central most posterior parts of spectacle lens to the anterior central apex part of cornea.

->Total diameter: TD stands for distance between the two poles through the centre of the circle.

->Back optic Zone diameter: It is the diameter of the two opposite pole of the optic zone curvature from the posterior as the line crossing through the centre of the optic zone curvature circle.

Base curve selection for RGP lens:

->To select the base curve we need to find the Keratometric value of the cornea which will be aligned with the posterior curvature of the contact lens.

->Normally corneal average anterior radius of curvature range is 7.74 to 7.76 millimeter which will be aligned with the posterior curvature of selected contact lens.

->We can averagely find the mean value of horizontal and vertical curvature Keratometric value and take that as anterior radius of curvature corneal curvature to select the base curve.

-> In case of irregular astigmatism, cornea became irregular also so that the different meridian also has the difference in curvature value.

->In such cases, practitioner prefers to select the flatter meridian as part of base curve selection and write that in the form of minus cylinder format.

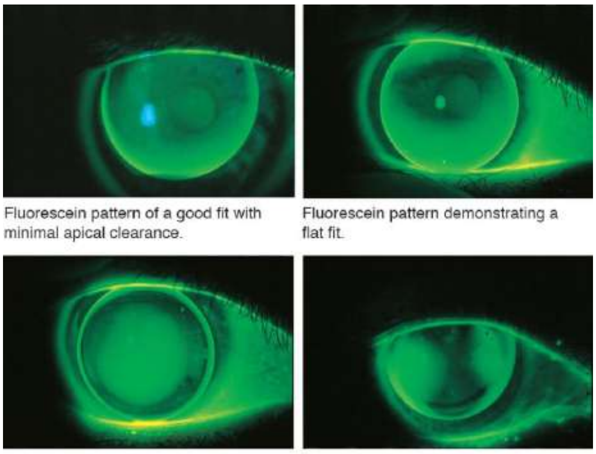
->In case of minus power, more diopter power value is responsible for performing steeper meridian and less power value for the flatter meridian. On the other hand for the plus value, more diopter power value is responsible for the flatter meridian compare to the less power value considered as the steeper meridian.

-> Total diameter of the selected trial lens should be 1.5-2mm less than HVID value.

Contact lens fitting assessment:

RGP lenses are normally hard in nature so it may cause foreign body sensation with excess tearing with blinking unlike the soft contact lens that is smooth and very quickly adapted by patient.

-> To become comfortable with RGP lens it will take at least 30 minutes with wearing that, but after 30 minutes if patient feels uneasy with the lens then lens all parameters need to be checked again for the correction if in case of residual astigmatism RGP can be needed to stable the vision quality.



Fluorescein pattern of a good fit with minimal apical clearance.

Fluorescein pattern demonstrating a flat fit.

Fluorescein pattern showing a steep fit.

Against-the-rule astigmatic band.

(Figure 4 Contact lens fitting assessment)

->To check the other fitting parameters we need to check about

the lens movement, tear exchange with blinking, rotation or displacement to make sure about steep or loose fitting.

->Contact lens fitting evaluation technique can be classified as static and dynamic.

->As per Static procedure we can find adjustment of contact lens with corneas as it is loose fit or flat feet can be judged according to the tear pulling and apical touch.

->As per dynamic assessment we can find contact lens fitting properties about its movement with blinking and proper Centration etc.

-> Simply we can say that static stands for the stability of lens with proper fitting and dynamic deals with lens movement with blinking to evaluate high or low riding properties (tight or loose fitting).

According to the static assessment Proper fitting can be determined after applying the fluorescence under slit lamp observation as three touch point condition.

->Three point touch stands for

a) Central part,

b) Mid peripheral part, and

c) Peripheral part.

-> In case of tight fit condition Central deposition can be seen under slit lamp observation when central part of cornea not touched with contact lens but mid periphery and the peripheral part of contact lens touched with the cornea while blinking very slow movement can be seen and also very sluggish while pushing.

->In case of flat feet, central part touched with cornea and mid peripheral part also same in condition, but peripheral area pulling can be seen more than 0.50 millimeter. While blinking if it is reported, clear vision after blink then become blurry gradually may be symptoms of tight fitting and while blinking if it becomes blurry and gradually clearer may be symptoms of flat fit.

->In case of increasing BOZR may cause loose fit and increasing amount of diameter may cause flat fit condition.

Hybrid lenses:

This type of lenses designed with both combination of soft and RGP lenses.

->Soft lenses are easy to adapt because that comfortably fitted over the cornea.

->RGP lenses are rigid lenses but it allows oxygen transmission and it can correct irregular astigmatism to provide sharper vision. Due to its rigid nature, it may cause foreign body sensation for some patients and it takes time to be adjusted with fitting. But after 30 minutes of wearing patient will have smooth lens fitting, movement with sharp vision. It also form tear lenses that solve refractive errors from the irregular corneal surface and provide very sharp visual equity.

(Figure 5 Hybrid contact lens)

->Hybrid lenses designed for the patients both need sharper vision that can be corrected by RGP lenses with comfort fit as like soft lens.

-> Central part of the lens are rigid and it has the capabilities to breathe the oxygen and supply it to cornea with properties of tear lens formation to provide clean and sharper vision from irregular corneal surface quality. Peripheral edges are designed as soft lens combination that helps patients with comfortable fitting and lesser chance of foreign body sensation.

->Hybrid lenses are used for myopia, hypermetropia, post lasik cases, keratoconus, irregular astigmatism etc.

Contraindications:

->Normally RGP lenses are highly contraindicated for the patients have corneal pathology, high allergic sensitivity, excessive blink rate, excessive dry eye symptoms, infection status, etc. In some cases during pregnancy period it also prohibited from wearing and for use due to ocular complications related with pathological changes.

->Mentally unstable persons are also capable to handle the contact lens carefully or maintained in a proper way. So this lens is not recommended for them.

->Patients have disorders related with naso-lachrymal drainage due to any infections contraindicated for RGP lens wearing.

-> Severe dry eyes with infection status like blepharitis, corneal pathology, Scleral or episcleral infections, nerve disorders, ulcer, uveitis, corneal degeneration etc. are highly contraindicated.

Conclusion:

For proper RGP lens practice and dispense, so many clinical criteria's and parameters need to maintain. Nowadays it's becoming more developed and becoming easier to dispense contact lens with providing more comfortable wear and adaptation with lesser infection chances. Beside this free from deposits, long lasting properties also help to lower expenses in long duration use of contact lens. Patients are suffering from uncorrected or not properly corrected refractive error due to corneal irregularities, keratoconus, high refractive errors, headache, myopic progression etc that all can be managed by RGP contact lens dispensing with proper measurements and fitting.

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Chapter 8: Contact Lens Care & Maintenance

Objective

The objective of this chapter is to provide comprehensive guidance on the appropriate care and maintenance of contact lenses to ensure optimal ocular health, comfort, and lens longevity. By detailing daily cleaning routines, storage practices, handling techniques, and troubleshooting common issues, this chapter aims to equip contact lens users with the knowledge and best practices needed to minimize the possibility of developing any ocular infection and other complications. The ultimate goal is to help users maintain clear vision and enjoy the benefits of contact lenses safely and effectively.

Introduction

Contact lenses are a convenient and beneficial means of vision correction, however, their benefits come with the responsibility of diligent care and maintenance to ensure eye health and lens longevity. This chapter provides a comprehensive guide on appropriate CL maintenance and care, covering cleaning routines, storage tips, handling techniques, and troubleshooting common issues. By following these guidelines, you can maximize both the comfort and lifespan of your contact lenses while minimizing the possibilities of developing any ocular infections and other complications. One of the clinical study on CL by A.E.Fick recognized the crucial component of lens maintenance, as a matter of course, he boiled the liquid to sterilize it before using it and thoroughly cleaned the little glass shells.

Maintaining the integrity of RGP CL or hydrogel is more intricate process than maintaining the integrity of PMMA lens material. Maintenance system need to be more efficacious in terms of their anti-microbial activity and at the same time the elements that are used for the maintenance system should be nontoxic materials.

1.1 Importance of Proper Contact Lens Care

In addition to providing the hydration essential to complete the physical construction of the lenses, solutions are needed for both disinfecting and maintaining contact lenses (especially hydrogel lenses). Reminding patients of the need to follow standard cleanliness guidelines during lens maintenance is also important for better results and safety.

Proper contact lens care is crucial for several reasons:

1. **Preventing Infections:** Inadequate cleaning can lead to the accumulation of bacteria and other microbes on the lenses, raising the level of danger of eye infections such as keratitis and conjunctivitis.

2. **Ensuring Comfort:** Clean lenses are more comfortable to wear. Debris and protein deposits can cause discomfort and irritation.

3. **Maintaining Lens Integrity:** Proper care helps maintain the structural integrity of the lenses, preventing scratches and tears.

4. **Prolonging Lens Life:** Regular and correct maintenance can extend the lifespan of your contact lenses.

1.2 **General Guidelines for Contact Lens Care**

1.2.1 **Essential steps to maintain the contact lens care regimen include:**

1.2.1.1 **Hand Hygiene:**

In advance of handling your contact lenses, always wash and pat dry your hands. After using a mild soap, rinse and dry your hands with a lint-free towel.

This prevents transferring dirt, oils, and microorganisms to the lenses. Regarding hand hygiene and CL wear, there are a few other things to take into account. It is suggested that you wash your hands with soap and running water rather than using wipes or rubs that contain alcohol. [2]

1.2.1.2 **Cleaning:**

This is the process of cleaning the lens by rubbing it against the palm of your hand with a finger to remove surface deposits as well as debris.

1.2.3 **Rinsing:**

An essential step in the cleaning and disinfection procedure is rinsing a contact lens. When cleaning and rinsing are combined, the lens is free of almost 99 percent of microorganisms. Rinsing also gets rid of any leftover cleaning solution and weakly bonded material from the surface, which could cause pain when inserting lenses.

1.2.1.4 **Disinfection:**

The term refers to the elimination of microorganisms, which may or may not include bacterial spores. Therefore, cleaning is an essential part of maintaining both type of CL. It has been demonstrated that a major contributing component to the aetiology of microbial keratitis is failure to disinfect.

It has been strongly encouraged to create standards for the testing and categorization of contact lens products by the International Organization for Standardization (ISO):3. The current standard, ISO 14729, establishes both basic and secondary disinfection criteria based on the test microbes that are chosen, which are two fungi and three bacteria, as shown in the Table 1 (below) [3]. Currently, this standard does not contain Acanthamoeba.

Table. 8.1

Microorganism	Type	ATCC Strain
Staphylococcus aureus	Bacteria	6538
Pseudomonas aeruginosa	Bacteria	9027
Serratia marcescens	Bacteria	13880
Candida albicans	Yeast	10231
Fusarium keratoplasticum (formerly known as *F. solani*)	Mold	36031

1.2.1.5 **Sterilization:**

The complete elimination of all living microorganisms, including spores, is known as sterilization. Sterilization is the regular manufacturing procedure, that is done before dispatching. The most popular method of sterilization is autoclaving, which involves heating the product to a specific temperature and holding it there for a predetermined amount of time—usually 30 minutes at 115–118°C.

1.2.2 <u>Additional steps to maintain the contact lens care regimen include:</u>

1.2.2.1 **Periodic protein removal:** Periodic protein removal is essential for maintaining the cleanliness and comfort of contact lenses, particularly for those who use weekly or monthly disposable CL or extended wear CL. Protein deposits, which accumulate from natural tear proteins, can lead to discomfort, reduced visual clarity, and increased risk of eye infections if not properly managed. The enzymatic cleaning process is procced by breaking the bond of disulphide in protein structure. The loosely bonded protein will be removed easily.

- **For SCL** protein removers' tablets mainly contains: Pancreatin (Alcon Opti-Free Enzymatic Cleaner), Subtilism A (Bausch + Lomb Ultrazyme Enzymatic Cleaner or Alcon Opti-Free SupraClens Daily Protein Remover) or Subtilism B, Papin.

- **For GP** lenses the protein removers, which are used are not necessarily to be enzymatic, Example: Progent (Menicon),

1.2.2.2 Re-wetting/Lubricating eye drops: Patients who wear CL often complain about dryness or watering issues. These lubricating or rewetting drops are necessary to maintain or enhance an individual's wettability standards. To get rid of dust or any other foreign particles from the ocular surface, lubricating the eyedrops is useful. It can also be used while wearing a CL . It will be better if an individual uses only the recommended lubricating drops.

1.2.2.3 **Contact lens case maintenance:** The CL case should be cleaned regularly to prevent contamination:

✓ **Daily cleaning:**

- Spin off all additional solution from the case and disinfect with sterile saline or MPS.
- Using fresh tissue, gently rub dry.
  (fibre free tissue or towel)
- Air dry case & lids upside-down on clean tissue

✓ **Weakly cleaning:** Scrub weekly with a new, clean toothbrush (hard/firm rather than soft) & CL CLEANING solution. Weekly clean case using baby shampoo.

✓ **Replacement schedule:** Replace regularly (at least 3 monthly)

✓ Consider to the instructions given by your eye care specialist concerning when to change and wear your lenses. Such schedules consist of:

- **Daily Wear Lenses:** Worn all day and taken off right before bed.
- **Extended Wear Lenses:** Can be worn overnight for a specified period, but require careful monitoring to avoid complications.

- **Disposable Lenses:** Daily, weekly, or monthly disposables must be replaced as per their designated schedule to maintain eye health.

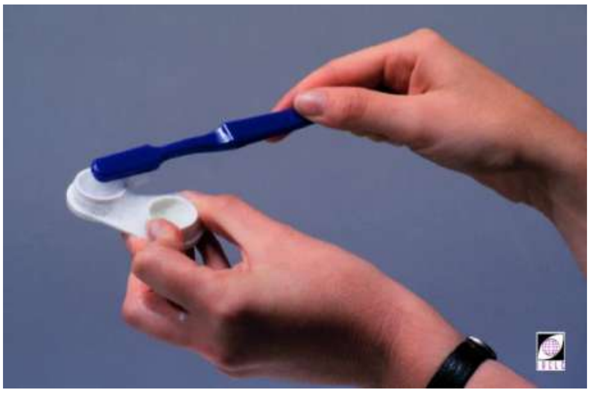

Figure. 8.2(a)

Figure. 8.2(b)

8.3 **Solution properties:**

For patient comfort and ocular health maintenance, all lens care products that come into direct or indirect contact with the eye must be chemically and physically balanced. Understanding a solution's general characteristics is crucial for recommending distinct products to patients who may be having specific issues. Consideration should be given to the following general properties:

Tonicity: It refers to the osmotic pressure of a solution relative to the osmotic pressure of the body's cells. In the context of contact lens solutions, tonicity is a critical property that ensures the solution is compatible with the natural fluids of the eye. The human tear film has an osmolarity range of 300–350 m mol/kg, with an average of 320 m mol/kg. This corresponds to 0.9% of sodium chloride. Contact lens solutions need to have a tonicity similar to the tear film when the lenses are inserted to the eye in order to minimize pain. Conjunctival hyperaemia is expected to increase and comfort will decrease as solution tonicity increases. [5,6]

- **Acidity/ Basicity: It** refers to the pH level of a contact lens solution, which indicates whether the solution is acidic, neutral, or basic (alkaline). The pH level measures the concentration of hydrogen ions (H^+) in a particular solution. A pH of 7 is termed as neutral, below 7 is acidic, and above 7 is basic. A proper pH balance prevents the solution from causing stinging, burning, or irritation to the eyes.[7] A pH-balanced solution mimics the natural pH of the eye's tears, ensuring comfort during lens wear. It also ensures the solution is gentle and safe for the eyes, reducing the risk of adverse reactions.
- **Buffering agent: It** is the substances, added to contact lens solutions to maintain a stable pH level, ensuring that the solution remains consistent and comfortable for the eyes. It also helps to maintain the solution's pH within the optimal range, typically around 7.4, which matches the natural pH of the eye. Examples of Buffering agents are: Sodium Borate, Sodium Phosphate, Boric Acid.

  Viscosity: It refers to the thickness or resistance to flow of a liquid. In the context of contact lens solutions, viscosity is an important property that affects the solution's performance and user comfort. Solutions with appropriate viscosity provide better lubrication, ensuring that lenses are more comfortable to wear by reducing friction between the lens and the eye. It helps the lens move easily on the eye, lessening discomfort and enhancing wearer comfort. It helps in keeping the lenses hydrated for extended periods, which is particularly beneficial for those with dry eyes. Examples of ingredients influencing viscosity are: Hyaluronic Acid, Polyethylene Glycol (PEG), Carboxymethylcellulose (CMC).
- **Disinfecting agents:** Any CL solution that has been sealed off is prone to microbes' contamination. Except, presentations meant for a single usage, must therefore be maintained. Each solution is consisting of antimicrobial agents and preservatives to reduce the risk of microbial activity. Antimicrobial activity refers to the ability of a substance to kill or inhibit the development of microbes, such as bacteria, fungi, and viruses etc. In markets commonly used antimicrobial agents are:

- **Biguanides:** Such as polyhexamethylene biguanide (PHMB), effective against a broad spectrum of microorganisms.
- **Quaternary Ammonium Compounds:** Such as benzalkonium chloride, which are potent disinfectants.
- **Polyquaternium-1:** A polymeric quaternary ammonium compound that is gentle on the eyes but effective against microbes.

Surfactants: These are the compounds that lower the surface tension between two substances, such as a liquid and a solid, or between two liquids. In contact lens solutions, surfactants play a crucial role in the cleaning process. Surfactants help to loosen and lift away dirt, debris, and deposits from the surface of the contact lenses, making it easier to rinse them off. They break down and remove protein and lipid deposits that accumulate on lenses, which can cause discomfort and reduce vision clarity. It also makes the lens surface wettable in addition, ensuring that the solution spreads evenly across the lens and retains moisture, which enhances comfort for the wearer. By efficiently removing deposits and contaminants, surfactants help maintain the cleanliness of the lenses, which is essential for clear vision and eye health. The examples of surfactants use in contact lens solutions are: Tetronic, Poloxamine, Pluronic.

By combining these properties, contact lens solutions play a crucial role in maintaining lens hygiene, ensuring wearer comfort, and protecting eye health.

8.4 **Avoiding Common Mistakes:**

8.4.1 **Patient education**: A proper education should be given to the patient for handling contact lenses, provided by the eye care practitioner. [8]

8.4.2 **Water Exposure:** Never expose your contact lenses to water, including tap water, swimming pools, or hot tubs. Water can harbour microorganisms that can adhere to your lenses and cause severe eye infections.

8.4.3 **Reusing Solution:** Never reuse old solution. Always use fresh solution to clean and store your lenses. Reused solution can become contaminated and ineffective.

8.4.4 **Sleeping in Contacts:** Only sleep in contact lenses if they are specifically designed for overnight wear and you have been instructed by your eye care professional to do so. Sleeping in regular contacts increases the risk of eye infections.

8.7 **Troubleshooting:**

Patient compliance, or the degree to which the patient adheres to the guidelines required for safe contact lens wear, is possibly one of the most important factors in CL care. An example of the human belief model is a flowchart that a patient uses to determine whether or not to follow a procedure. Figure 3 is showing the schematic representation of the model.

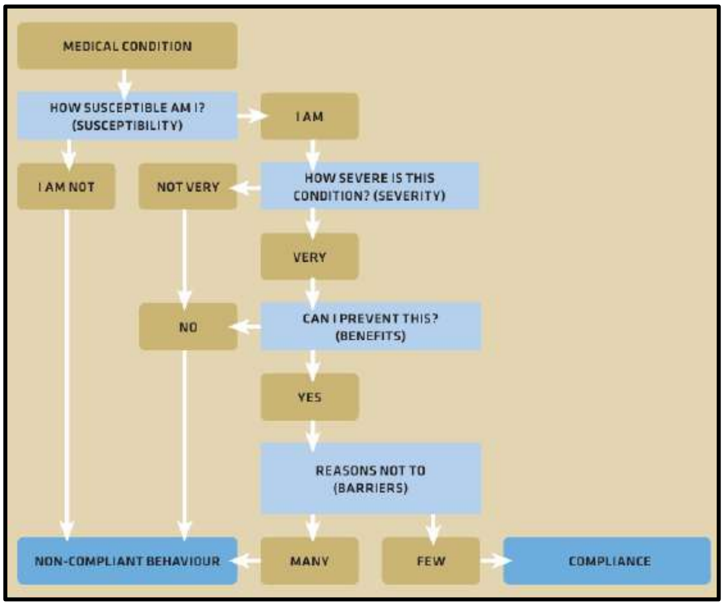

Figure. 3[9]

8.8 Conclusion:

Appropriate CL care should be provided with great concern about evaluation procedures. Proper contact lens care is essential for maintaining eye health and ensuring the longevity and comfort of your lenses. By adhering to the guidelines provided in this chapter, you can reduce the risk of complications and enjoy the benefits of clear, comfortable vision. Always follow the instructions given by your eye care professional and keep abreast of any updates in contact lens care practices.

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Chapter 9: Contact Lens Complications

INTRODUCTION

Contact lenses (CL) are often recommended for addressing vision issues that glasses can't correct, such as aphakia, keratoconus, an irregular cornea, and significant anisometropia. They also serve as an alternative to glasses for managing straightforward vision errors. Additionally, CLs are beneficial in treating dry eye conditions associated with Stevens-Johnson syndrome or Sjogren syndrome, aiding in recovery after refractive surgery, and healing persistent epithelial defects. The aesthetic appeal of CLs has also gained considerable popularity in recent times (1).

CLs have enhanced people's lives not only by rectifying vision inaccuracies but also by offering an improved aesthetic and fewer limitations in daily activities. Regrettably, complications can arise from CL use, which can be disheartening for users, compelling them to transition from their usual method of vision correction to alternative options, which may not always be straightforward or free from complications (2).

Discomfort from Wearing CLs

The Tear Film & Ocular Surface Society (TFOS) describes CL uneasiness as a state where the wearer experiences intermittent or constant unpleasant feelings in the eye linked with the usage of CLs. These feelings may or may not be accompanied by a disturbance in vision. The root cause of this discomfort is the lack of harmony between the CL and the surroundings of the eye (3).

This issue can result in the wearer reducing the duration of lens wear or even completely stopping the use of contact lenses. The symptoms of this condition should appear after the initial adjustment period to the lenses and should lessen or disappear once the lenses are removed. In addition, contact lens discomfort may present physical signs such as redness of the conjunctiva, or it may be identified solely based on the wearer's account of uneasiness (4).

CL related issues	Definition	Frequency	Type of CL	Influential Factors	Management

Contact Lens Discomfort (CLD)	Episodic or chronic adverse ocular sensations related to CL usage.	50-75%	All types	Tear film instability, poor fit, material incompatibility	Optimizing lens fit, using rewetting drops addressing underlying dry eye or ocular surface disease
Dry Eye Disease (DED)	A problem when tears are either not produced enough or excessive evaporation of tears.	20-50%	All types	Tear film instability, environmental factors, lens material	Artificial tears modifying lens material, improving ambient humidity
Corneal Edema	Swelling of the cornea due to inadequate oxygen supply.	2-5%	Low oxygen permeability (PMMA, some Hydrogels)	Extended wear, overnight use	Switching to high oxygen-permeable lenses reducing wear time
Giant Papillary Conjunctivitis (GPC)	Inflammation of the upper eyelid's conjunctiva causing itching and mucous discharge.	1-5%	Soft, Extended wear	Protein deposits, mechanical irritation	Discontinuing lens wear, using anti-inflammatory drops, switching to daily disposable lenses

Infectious Keratitis	Corneal infection leading to redness, pain, and potential vision loss.	0.04-0.2% (Soft) 0.01-0.05% (RGP)	All types	Poor hygiene, extended wear, contaminated solutions	Immediate discontinuation of lenses antibiotic treatment, medical evaluation
Corneal Neovascularization	Growth of new blood vessels into the cornea due to chronic hypoxia.	2-10%	Low oxygen permeability (PMMA, some Hydrogels)	Extended wear, improper fit	Switching to higl oxygen-permeable lenses reducing wea time
Contact Lens-Induced Acute Red Eye (CLARE)	Sudden redness, pain, and tearing associated with contact lens wear, often overnight.	1-3%	Extended wear	Overnight wear, lens contamination	Discontinuing lens wear, using anti-inflammatory o antibiotic drops improving hygiene
Solution-Related Discomfort	Discomfort or allergic reaction to contact lens solutions.	5-15%	All types	Preservatives in solutions, sensitivity to ingredients	Switching t preservative-free solutions, rinsing lenses thoroughly
Lens Deposits	Accumulation of proteins, lipids, and other substances on the lens surface	30-50%	All types	Poor lens hygiene, extended wear, tear film composition	Regular lens cleaning, using enzymatic cleaners, switching to daily disposables

	causing discomfort.				
Mechanical Abrasion	Physical damage to the corneal or conjunctival surface due to improper lens fit or handling.	1-5%	All types	Poor fit, improper handling, long fingernails	Proper len fitting, carefu handling, educating o proper insertion/remova techniques

Epidemiology

The prevalence of Contact Lens Discomfort (CLD) among individuals reporting symptoms related to contact lenses exhibits considerable variability, ranging from 23% to 94%. This wide range underscores the significant burden associated with this issue. Factors contributing to this variability include variations in testing method, the severity of evaluated steps, sampling methodologies, intrinsic traits of the investigated population, and the timing of studies (4,5).

CLD results from a multifaceted interaction of contact lens-related and surrounding factors.

CL Factors:

- **Material:** Lens materials with lower lubricity or water content can contribute to dryness and discomfort.
- **Design:** Sharp edges, inappropriate base curves, or aspheric designs may cause irritation.
- **Fit:** Poorly fitting lenses can lead to excessive movement or tightness, both of which can be uncomfortable.
- **Wearing Schedule:** Exceeding the recommended wear time increases the risk of deposits and discomfort.

- **Care System:** The chemical composition of cleaning solutions and adherence to proper care routines can impact lens comfort.

Environmental Factors:

- **Ocular Surface Condition:** Dry eye syndrome and tear composition imbalances can worsen CLD.
- **External Environment:** Low humidity, wind, and extreme temperatures can contribute to lens drying and irritation.
- **Occupational Factors:** Working environments with computer screens, bright lights, or high altitudes can exacerbate CLD symptoms.
- **Medications:** Certain medications can affect tear production and contribute to dryness.
- **Compliance:** Failure to follow proper lens care and hygiene routines can increase the risk of CLD.
- **Individual Factors:** Age, gender, pre-existing eye conditions, psychiatric conditions, and seasonal allergies can all influence CLD susceptibility.

Research has indicated that a number of factors, including age, gender, allergies that are seasonal, low tear quality, and psychological issues, certain medications, low room humidity, wind, and activities that alter blink rate are clinically linked to a higher prevalence of CLD (4).

Management

The suitable and sufficient period of daily wear that would provide for the intended purposes and is wanted by patients can vary between individuals. Therefore, evaluating factors that predispose to contact lens discomfort is best commenced from the first visit and fitting. These result in the fact that an estimation of the risk of CLD will require an extensive history of the patient, a slit-lamp examination, and tests to evaluate tears. Before starting to wear CLs, conditions including blepharitis, meibomian gland dysfunction (MGD), and DED should be treated as they are predisposing factors to CLD (6).

CLs and their care systems used by those patients who experience a CLD due to inherence or under the effect of environmental factors should be more eye-friendly. Preventive strategies for CLD in severely at-risk patients would include a daily wearing timetable, more frequent lens replacement, a hydrogen peroxide-based care system, adherence to the care of CLs, and regular use of lubricating drops. A full medical history helps identify the source of CLD in those who exhibit symptoms. It is essential to comprise the timing and progression of complaints throughout the day, the type of CL and care system, the timetable for lens use and exchange, hygiene, and compliance attitude, several ophthalmic or systemic disorders and allergies, current ophthalmic and systemic remedies, and individual and ecological influential factors. Every other ocular and systemic disease not associated with contact lens wear will be managed as necessary. For example, chemically induced irritation of the eye, or ocular medicamentosa, may be confused with CLD but is often secondary to the toxic agents of topically administered eye drops, especially those with preservatives or cosmetics. CL usage can exacerbate ocular illnesses such conjunctivochalasis, pinguecula, and pterygium. These conditions can cause discomfort to the eyes. Ocular illnesses such Salzmann nodules, corneal dystrophies, and recurrent corneal erosion (induced by prior injury or corneal dystrophies) are uncommon causes of CLD. These disorders will be easier to recognise with a detailed slit-lamp examination. Patients with various pathological or anatomical disorders who wish to wear CLs must have these issues treated surgically or medically. Lubricating drops may help these patients. Firstly, it is good to consider those controllable environmental factors. Increasing the room's humidity, avoiding the front of the air conditioning, and breaking the near task with a distant fixation break while changing the tilt of the screen are some considerations with minimum change in those controllable environmental variables. Negligence on the part of the patient to follow the recommendations is one of the most easily preventable causes of CL Discomfort. Patient education and assistance, together with reminders via mobile devices, can help address low adherence with the required frequency of CL replacements (7,8,9).

Non-compliance to the CL care system can be overcome by re-education of the CL users regarding the importance of lens rubbing. The ecological and working factors that can be controlled have to be managed. Lubricating eye drops helps in the reduction of CLD in its mild form. Effective treatments reported for diseases causing dry eye: Use of punctual plugs, ocular anti-histamine drops like Olopatadine and Epinastine decrease CLD symptoms in the past allergic conjunctivitis patients (10). Even when there is no symptom, consumption of oral omega-3 fatty acids has shown effectiveness in reducing symptoms of dry eyes. Further lens type changes may be a realistic attempt to address concerns for patients with an established clinical profile (11,12). These concerns may include improved surface wettability and a more frequent replacement schedule, for which daily disposables may offer advantages (13, 14).

Table 1: Clinical Practice Guide for Managing Contact Lens Discomfort (CLD)

Understanding CLD Definition: A condition causing intermittent or constant eye discomfort linked to CL use, possibly with visual disturbances.
Symptoms: Arise post-adjustment period and diminish upon lens removal.
Signs: Red conjunctiva, ocular surface staining, or subjective discomfort reports.

Epidemiology Snapshot

Prevalence: 23% to 94%, influenced by assessment variability and population traits.

<u>**Contributing Factors**</u>

Contact Lens-Related:
***Material**:* Low lubricity/water content → Dryness.
Design: Sharp edges, incorrect base curves → Irritation.
Fit: Poor fit → Excessive movement/tightness.
Wearing Schedule: Extended wear → Deposit buildup.
Care System: Solution chemicals + care routine → Comfort impact.

Environmental:
Ocular Surface: DED, tear imbalances.
External: Low humidity, wind, extreme temps.
Occupational: Computer use, bright lights, high altitudes.
Medications: Tear production reduction.
Compliance: Poor lens care/hygiene.
Individual: Age, gender, eye conditions, psychiatric conditions, allergies.

<u>**Management Strategies**</u>

Initial Assessment

Comprehensive History
Slit Lamp Examination
Tear Evaluation Tests

Address Pre-existing Conditions

Treat Conditions: Blepharitis, meibomian gland dysfunction, dry eye.

Preventive Measures

Daily Wear Schedule: Prefer daily disposables.
Care System: Hydrogen peroxide-based solutions.
Lubricating Drops: Regular use.

Patient Education & Environment Adjustments

Compliance Emphasis: Replacement schedules, care routines.
Environmental Control: Increase humidity, avoid direct AC airflow, adjust computer angles.

Symptom Management

Identify Root Causes: Comprehensive history.
Manage Concurrent Diseases: Address unrelated ocular/systemic diseases.
Use Lubricating Drops: Early-stage CLD relief.
Switch Lens Types: Better wettability, frequent replacement.

Medications

Ocular Antihistamines: For allergic conjunctivitis.
Omega-3 Fatty Acids: Dry eye relief.

Advanced Treatments

Punctal Plugs: For dry eye disease.

Patient Tips

Routine Check-ups: Regular eye exams.
Adherence: Follow wear/care instructions.

Hydration: Use lubricating drops.
Educational Tools: Reminders, compliance apps.

Corneal Neovascularization

Corneal neovascularization extends new blood vessels into the avascular cornea and may be set off by stimuli such as hypoxia, inflammation, or trauma. The clearness of the cornea is highly essential for the process of vision, and the blood vessels can impair the clarity of the cornea. Thus, vision loss or blindness can potentially develop if not cared for. Studies indicate that of all the cases diagnosed with corneal neovascularization, 10-30% are people who wear CLs. Among CL users, corneal neovascularization is exhibited in 1-20% of users. Users of rigid gas permeable (RGP) or poly-methyl methacrylate (PMMA) lenses have a lower incidence of this condition. This condition is more commonly encountered in users of soft CL, particularly in users for more prolonged periods.

Risk Factors: Lenses have certain intrinsic factors that render them responsible for corneal neovascularization. Problems like severe myopia and astigmatism might change the peripheral thickness of hydrogel-based Soft CLs, limiting future oxygen transport and physically increasing peripheral friction. Soft CL wearers are at potential risk of peripheral hypoxia or mechanical trauma due to poor lens-to-cornea alignment in a patient with an overly flat or overly steep cornea. Problems such as poor fitting of lenses are not so rare because of insufficient base curves of soft CLs (15, 16, 17).

Causes: Herpes simplex stromal keratitis and corneal transplantation are two conditions that can lead to corneal neovascularization. Refractive errors resulting from herpetic corneal scars can be treated with CLs; however, it increases the frequency of herpetic outbreaks. Thus, clinicians treating such patients with CLs should always bear in mind the possibility of recurrent corneal herpetic ulcers and manage them wisely. Patients with a history of penetrating keratoplasty (PK) are more susceptible to corneal neovascularization, even in the absence of ongoing inflammation, if they have a large recipient bed, active blepharitis, or suture knots in the host stroma. Therefore, it is important to take into account how the CL especially one that fits poorly, contributes to the advance of corneal neovascularization in these individuals (18,19).

Management: Use a CL of higher oxygen permeability after removing the current lens; change it from extended wear to daily wear; use RGP lenses instead of soft CL; and discontinue the use of CLs when active, new, progressive corneal new vessels are present (20,21). Corticosteroids and nonsteroidal anti-inflammatory agents, whether subconjunctival or in stromal therapy, also prove beneficial when active neovascularization threatens the survival of a corneal graft or the health of the ocular surface. In treating new vessels, severe cases warrant surgical interventions such as laser photocoagulation, photodynamic therapy, electrocoagulation, and stem cell transplantation (22-24).

Important for CL Practice

- Corneal Neovascularization (CNV) can occur in 10-30% of CL wearers. It's crucial to educate patients about the clinical features of CNV and advise them to seek instant medical care if these occur.

- The material composition and oxygen permeability of lenses can contribute to the onset of CNV. Therefore, choosing the right type of lens is essential.

- Severe myopia and astigmatism can affect the peripheral thickness of hydrogel Soft CL, leading to reduced oxygen transmission and increased peripheral mechanical friction. Regular eye examinations can help detect these conditions early.

- Misalignment between the lens and cornea can cause peripheral hypoxia or mechanical injury in soft CL wearers. Proper lens fitting is crucial to prevent this.

- In cases of active progressive corneal new vessels, it's suggested to cease the use of CLs.

- Regular follow-ups with CL users can help detect any complications early and prevent the progression of conditions like CNV.

Tips

- Consider replacing the current lens with one that allows more oxygen to pass through if a patient is diagnosed with CNV.

- Alter the wearing schedule from extended to daily wear to reduce the risk of CNV.

- Opt for RGP lenses over soft lenses as they have a lower incidence of CNV.

- Be vigilant about recurrent corneal herpetic ulcers in patients with herpes simplex stromal keratitis and address them promptly.

- Consider the potential role of the CL, particularly poor fitting, in the advance of corneal neovascularization in patients who have undergone PK.

CL associated corneal inflammation

Contact Lens-Related Peripheral Ulcer (CLPU):

Definition: Unlike corneal ulcers, CLPU is characterised by epithelial excavation and infiltration while maintaining the integrity of the Bowman layer. Instead of doing a histological test, clinical criteria are usually used to distinguish between CLPU and corneal ulcers. Microbial keratitis (MK) tends to be more acute and severe, and overlapping characteristics can sometimes lead to misdiagnosis. Mild, confined conjunctival injections and focal infiltrations at the peripheral cornea, generally measuring less than 1.5 mm, circular or a little elliptical in form, and white or white-gray in colour, are the hallmarks of CLPU. In contrast to MK, CLPU may have punctuate epithelial erosions or epithelial deficiencies (25).

Causes: The occurrence of CLPU is frequently associated with bacterial infection, especially from the Staphylococcus species. This infection typically affects one side and is prevalent among individuals who use their CLs for prolonged durations. Additional factors contributing to this condition include an ill-fitting lens, inadequate lens cleanliness, and diseases affecting the eyelid margin (26,27).

Incidence: The rate of symptomatic Contact Lens-Associated Infiltrative Events (CIEs), encompassing CLPU, ranges from 0.5% to 3.3% for daily usage and between 2.5% and 6% for overnight usage. The frequency of asymptomatic CIEs is significantly higher, varying from 10% to 25% (28).

Management: The resolution of CLPU is generally spontaneous upon the removal of the CL. However, it is crucial to closely monitor the condition for 24 hours to rule out the possibility of an infected Microbial Keratitis (MK). If the lesion is centrally located, exceeds 1mm, and causes pain, it should be approached with caution. It is advised to discontinue lens usage until the epithelium completely covers the lesion, which could take up to two weeks. The use of ocular lubricants can help prevent the eyelid from rubbing against the affected area and dilute bacterial toxins (29).

Important for CL Practice

- CLPU is a condition characterized by epithelial excavation and infiltration, with the Bowman layer remaining intact. It is typically distinguished from corneal ulcers based on clinical features rather than histological examination.

- The occurrence of CLPU is frequently associated with bacterial infection, especially from the Staphylococcus species. This infection typically affects one side and is prevalent among individuals who use their CLs for prolonged durations.

- Additional factors contributing to this condition include an ill-fitting lens, inadequate lens cleanliness, and diseases affecting the eyelid margin.

Tips

- The resolution of CLPU is generally spontaneous upon the removal of the CL. However, it is crucial to closely monitor the condition for 24 hours to rule out the possibility of an infected Microbial Keratitis (MK).

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- It is advised to discontinue lens usage until the epithelium completely covers the lesion, which could take up to two weeks.

- The use of ocular lubricants can help prevent the eyelid from rubbing against the affected area and dilute bacterial toxins.

Microbial Keratitis (MK)

Definition: MK refers to an active inflammation in the cornea, which is typically induced by microorganisms like bacteria, viruses, or parasites. The primary risk factor associated with this condition is the usage of CLs (30).

Causes: Multiple factors related to CL usage can cause Keratitis. These factors include hypoxia (insufficient oxygen) induced by CLs, minor injuries or microtrauma to the eye, and contamination of the CL or its cleaning solution. Moreover, handling CLs with dirty hands can introduce microorganisms into the eye, causing Keratitis. The risk increases up to 20-fold with extended wear schedules, which worsen corneal hypoxia. It is noteworthy that silicone hydrogel CLs cause punctate epithelial erosions in the corneal epithelium due to mechanical microinjury, even though they have a greater oxygen permeability. A compromised epithelial barrier greatly raises the risk of developing infectious Keratitis (31).

Management: The most effective way to combat infectious keratitis is through proper CL care. Eye care professionals play a crucial role in educating patients about lens hygiene, verifying their understanding and adherence to these practices, and providing educational materials in various formats. Utilizing weblogs, email reminders, social media platforms, and mobile apps can be valuable tools for ongoing patient education and reinforcement of safe lens care practices.

Management Strategies:

If, despite these preventive measures, infectious keratitis develops, a multi-pronged approach is essential:

1. **Eradicating the Infection:** Identifying and eliminating the causative organism is the top priority. This typically involves targeted antimicrobial therapy.
2. **Controlling Inflammation:** Managing inflammation is crucial to prevent disease progression, potentially saving the eye and vision. This may involve anti-inflammatory medications.
3. **Antimicrobial Treatment:** Selecting and administering appropriate antimicrobial agents based on the identified organism is vital.
4. **Treatment Adjustments:** Close monitoring of the infection's course allows for adjustments to the treatment plan as needed.
5. **Surgical Intervention:** In severe cases unresponsive to optimal medical management, surgical intervention might become necessary. This could involve situations like impending corneal perforation, progression to scleritis or endophthalmitis.

Referral for Complex Cases:

Certain situations warrant immediate referral to an ophthalmologist specializing in managing infectious keratitis. These include:

- Central corneal ulcers of serious depth
- Ulcers >3 mm in diameter

- Immunosuppressive agents, immunocompromised patients, diabetics
- Patients with monocular infections
- Rapidly progressive infections
- Primary treatment failure
- Suspected acanthamoebal or fungal infections

By prioritizing prevention through education and proper lens care, and implementing a comprehensive management strategy for diagnosed cases, we can minimize the risk and impact of infectious keratitis for CL wearers.

Important for CL Practice

-MK involves active infection of the cornea, often caused by microbes such as bacteria, viruses, or parasites. The primary contributing factor to this condition is the use of CLs.

-Various factors related to the use of CLs can contribute to Keratitis. These factors include reduced oxygen supply due to the lenses, minor eye injuries or microtrauma, and contamination of the lenses or their cleaning solutions.

-Handling CLs with dirty hands can introduce microorganisms directly into the eye, leading to Keratitis. The risk is significantly increased with extended wear schedules, which worsen corneal oxygen deficiency.

-Although silicone hydrogel CLs offer better oxygen permeability, they have been linked to mechanical damage to the corneal epithelium, resulting in small areas of erosion. A compromised epithelial barrier significantly increases the likelihood of developing infectious Keratitis.

Tips

- The most effective way to combat infectious keratitis is through proper CL care. Eye care professionals play a crucial role in educating patients about lens hygiene, verifying their understanding and adherence to these practices, and providing educational materials in various formats.

- If infectious keratitis develops, a multi-pronged approach is essential: Eradicating the Infection, Controlling Inflammation, Antimicrobial Treatment, Treatment Adjustments, and Surgical Intervention.

- Certain circumstances necessitate immediate referral to an ophthalmologist specialized in treating infectious keratitis. These include severe central corneal ulcers, ulcers larger than 3 mm in diameter, ulcers in immunocompromised individuals, patients with only one functional eye, cases with rapid disease advancement, resistance to initial intervention, and suspected fungal or acanthamoebal infections.

Bacterial Corneal infection

Definition: Bacterial keratitis is an inflammatory condition of the cornea caused by bacterial infection. It often leads to pain, redness, blurred vision, and discharge from the eye. Prompt diagnosis and treatment are crucial to prevent severe complications, including vision loss (32).

Incidence: The frequency of Bacterial Keratitis is not constant, with reported cases fluctuating between 2.5 and 799 per 100,000 individuals annually. It’s noteworthy that the incidence among those who wear CLs is said to be 4-5 times greater than those who do not (33).

Causes: Bacterial Keratitis primarily originates from bacterial infection, especially from the species Staphylococcus, Streptococcus, and Pseudomonas. The use of CLs, particularly for extended periods, is a major risk factor. Other factors that contribute to this condition include poor hygiene practices, insufficient cleanliness of the lens and its storage case, and prolonged lens usage (35,36).

Management: When keratitis is suspected, immediate removal of the CL is critical. It's advisable to obtain smears and cultures from the infiltration site, the CL, and the lens container separately. If clinical symptoms fail to clearly distinguish between fungal and acanthamoeba keratitis, a confocal corneal scan may provide valuable information.

Starting broad-spectrum antibiotic treatment is essential to fully treat both Gram-positive and Gram-negative bacteria. Based on smear results and clinical presentation, treatment should focus on the most likely organisms, with modifications made in accordance with culture and antibiogram findings.

A single treatment with topical fluoroquinolones may be enough for minor peripheral infiltrations. However, in severe cases, a more aggressive approach involving fortified topical antibiotics and potentially hospital admission or frequent visits is advisable. The choice of antibiotics may vary among institutions, influenced by factors such as microbial resistance patterns, keratitis epidemiology, and drug availability (37).

Important for CL Practice

- Bacterial Keratitis is an inflammatory condition of the cornea caused by bacterial infection. It often leads to pain, redness, blurred vision, and discharge from the eye. Prompt diagnosis and treatment are crucial to prevent severe complications, including vision loss.

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- Bacterial Keratitis primarily originates from bacterial infection, especially from the species Staphylococcus, Streptococcus, and Pseudomonas. The use of CLs, particularly for extended periods, is a major risk factor. Other factors that contribute to this condition include poor hygiene practices, insufficient cleanliness of the lens and its storage case, and prolonged lens usage.

Tips

- In instances where keratitis is suspected, it's crucial to remove the CLs immediately. It's recommended to collect a smear and culture from the site of infiltration, the CLs, and the lens case separately.

-Initiating broad-spectrum antibiotic treatment is crucial to encompass all potential Gram-negative and Gram-positive microorganisms. Tailoring treatment to the most likely organisms, as indicated by smear results and clinical presentation, is paramount. Antibiotic regimens may need adjustment based on culture and antibiogram findings.

- A single treatment with topical fluoroquinolones may be enough for minor peripheral infiltrations. However, in severe cases, a more aggressive approach involving fortified topical antibiotics and potentially hospital admission or frequent visit is advisable.

-The selection of antibiotics may vary among healthcare facilities, influenced by factors such as microbial resistance patterns, keratitis epidemiology, and drug availability.

Acanthamoeba Keratitis

Definition: Acanthamoeba Keratitis is a severe infection of the eye, specifically the cornea, which is the clear, dome-like surface at the front of the eye. This infection is caused by a tiny, free-living amoeba known as Acanthamoeba. It's a relatively rare condition that can result in permanent damage to the eye or even loss of vision.

Causes: The condition is most commonly seen in individuals who wear CLs. The infection is primarily caused by specific species of Acanthamoeba, namely A. castellanii and A. polyphaga. These amoebae are typically found in a variety of environments, including swimming pools, hot tubs, tap water, shower water, and even in CL solutions. The risk factors for this condition include wearing CLs, exposure to the amoeba (usually through contaminated water), and trauma to the cornea (38).

Risk Factors: The main risk factor for Acanthamoeba Keratitis (AK) is wearing CLs. This condition should be considered in any CL wearer presenting with keratitis. Symptoms of AK can include pain, sensitivity to light, a ring-like stromal infiltrate, an epithelial defect, radial perineuritis, and eyelid swelling. The clinical presentation can vary at various phases of the disease, with the classic ring-shaped infiltration typically found in progressive phases (38).

Diagnosis of AK requires a confocal scan of the cornea or specialized culture and staining techniques. A delayed diagnosis can result in worse visual consequences, a weaker response to therapy, and more severe invasion. Typically, individual amoebae enter the lens container through tap water or air, rapidly multiply in the lens if the container isn't cleaned properly and regularly, and then attach to the CL and contaminate the eye (39).

Users of multipurpose solutions who wear soft CLs are more vulnerable because acanthamoeba sticks very well to the hydrophilic plastic in these lenses. Furthermore, the majority of people use soft CLs, whether they are cosmetically coloured glasses for social occasions or infrequent wearers (once a week for sports, for example). These usage habits put people at risk for not taking proper care of their CLs (40).

Water from the tap should not be used to prevent any kind of infectious keratitis, including AK. After manually cleaning the lens container, let it air dry. Lens containers should be changed at least every three months (ideally monthly), and CLs should be properly cleaned and kept. Anti-acanthamoeba medications like polyhexamethylenebiguanide (PHMB) are a common component of multifunctional treatments, while further research is needed to demonstrate their efficacy in a therapeutic environment. The two-step hydrogen peroxide systems are still the finest disinfection technology available. Moreover, the parasite Acanthamoeba can be effectively eradicated with heat sterilisation (40).

Management: Treatment for Acanthamoeba Keratitis typically entails medical intervention and consistent monitoring. When keratitis is suspected, prompt removal of the CL is imperative. Initial treatment often consists of broad-spectrum antibiotic therapy to target a wide range of potential microorganisms. Selection of antibiotics may be modified according to culture and antibiogram results. Severe cases may necessitate surgical intervention. Close monitoring of disease progression is essential, allowing for adjustments to the treatment regimen as needed (41,42).

Important for CL Practice

- Acanthamoeba Keratitis is a severe infection of the eye, specifically the cornea, caused by a tiny, free-living amoeba known as Acanthamoeba. It's a relatively rare condition that can result in permanent damage to the eye or even loss of vision.

- The condition is most commonly seen in individuals who wear CLs. The infection is primarily caused by specific species of Acanthamoeba, namely A. castellanii and A. polyphaga. These amoebae are typically found in a variety of environments, including swimming pools, hot tubs, tap water, shower water, and even in CL solutions.

- The primary risk factor associated with Acanthamoeba Keratitis (AK) is the use of CLs. It's crucial to consider this condition in any individual who wears CLs and presents with keratitis. Symptoms of AK may include pain, sensitivity to light, a ring-like stromal infiltrate, an epithelial defect, radial perineuritis, and swelling of the eyelids.

Tips

-Diagnosing AK requires either a confocal scan of the cornea or specialized culture and staining techniques. A delayed diagnosis can result in worse visual consequences, a weaker response to therapy, and more severe invasion.

-Individuals who wear soft CLs and use multipurpose solutions are at a heightened risk, as acanthamoeba adheres particularly well to the hydrophilic plastic of these lenses.

-To prevent any form of infectious keratitis, including AK, it is advised to avoid using tap water. -The lens container should be cleaned through hand rubbing and then left to air-dry. CLs should be cleaned and stored using an appropriate method, and lens container should be replaced every three months at least (preferably monthly).

-Treating Acanthamoeba Keratitis typically involves medical intervention and regular follow-ups. Upon suspicion of keratitis, the CL should be promptly removed. Treatment

usually commences with broad-spectrum antibiotic therapy to address all potential microorganisms. The selection of specific antibiotics can be adapted based on the results of culture and antibiogram tests. In severe cases, surgical intervention may be necessary.

Giant Papillary Conjunctivitis (GPC)

Definition: GPC, also recognized as Contact Lens-Induced Papillary Conjunctivitis (CLPC), is a regular problem linked with CL usage. Discomfort, itching, redness, decreased lens acceptance, increased lens movement (especially superior dislocation), and excessive discharge of mucous are common symptoms. Hyperemia and a papillary response more than 0.3 mm in the superior tarsal conjunctiva are noteworthy signs.

Incidence: The occurrence rate of CLPC varies widely, ranging from 1.5% to 47.5%. The incidence is around 4.6% among users of silicone hydrogels from the first generation.

The prevalence of CLPC tends to be greater in individuals wearing silicone hydrogel CLs compared to those using hydrogel CLs, likely due to the increased mechanical irritation caused by the relatively high modulus of silicone hydrogel lenses. A reduction in CLPC incidence has been noted among wearers of disposable lenses (43,44,45).

Risk Factors: CLPC is frequently linked with specific CL types and materials. It is more commonly observed with soft CLs (85%) compared to rigid CLs (15%). Mechanical injury may contribute to its development. Additionally, a background of hyper-sensitivity and atopy may be evident in most CLPC cases (46,47,48)..

Management: It is suggested to examine the likelihood of this consequence during each patient visit. Early identification and management, even in asymptomatic instances, can often prevent the need to discontinue lens use. Early symptom relief can occasionally be achieved by following lens care instructions and using lubricating drops on a regular basis. It is advised to stop using lenses until symptoms and signs go away in both localised and widespread forms of CLPC, or to switch to a different lens. Changing to a daily wear schedule or daily disposable could be helpful if complaints persist. In cases of widespread conditions, the use of mast cell stabilizers, including 2% sodium cromoglycate, 0.05% ketotifen fumarate, 0.025% levocabastine hydrochloride, or 0.1% olopatadine HCL, can be effective in controlling ongoing symptoms and repeated flare-ups.

Important for CL Practice

- GPC, also referred to as CLPC, is a typical issue linked to the use of CLs. Symptoms typically include discomfort, redness, itching, reduced lens tolerance, excessive lens movement, and increased mucous discharge.

-The incidence of CLPC varies greatly, ranging from 1.5% to 47.5% in reported cases. Among users of first-generation silicone hydrogels, the incidence is approximately 4.6%. Patients using silicone hydrogel lenses are more prone to CLPC compared to those wearing hydrogel lenses.

-CLPC is often linked with specific lens types and materials, with a higher occurrence observed in users of soft CLs compared to rigid ones. Mechanical trauma may play a role in its development. Additionally, many CLPC cases are associated with a history of allergy and atopy.

Tips

-It is advisable to be vigilant about the potential for Giant Papillary Conjunctivitis (GPC) during every patient visit. Early identification and management, even in cases without symptoms, can often prevent the need to stop using CLs.

-Following lens care recommendations diligently and using lubricating drops regularly can sometimes resolve the issue in its initial phases.

-For both localized and generalized forms of GPC, it is recommended to halt CL wear until characteristic features diminish, or switch to a different type of lens. If symptoms persist, transitioning to a daily disposable or daily wear schedule may prove beneficial.

-In cases of generalized GPC, mast cell stabilizers can be employed to manage persistent symptoms and recurrent episodes.

Fungal keratitis

Fungal Keratitis, a serious complication linked to CL use, is characterized by a distinct grayish-white infiltration with feathery edges and deep penetration. Satellite lesions, a hallmark sign, and hypopyon are commonly observed. Diagnosis typically relies on microbiological tests, with confocal biomicroscopy aiding in differentiation from other infections and monitoring treatment response (49,50).

Incidence: Fungal keratitis comprises a significant portion of microbial keratitis cases, particularly in countries like India and Nepal. CL wear has been noted in 21% of fungal keratitis patients, with a reported rate of around 10% in other regions. Fungal pathogens, notably Candida, Fusarium, and Aspergillus, account for up to 4.8% of contact lens-related keratitis cases. The 2006 global outbreak of fungal keratitis was linked to the ReNuMoistureLoc solution. While the rate of Fusarium keratitis declined post-recall, an increase in contact lens-related fungal keratitis cases was reported in 2007 and 2008 (51,52).

Risk factors: CL wear, especially extended wear schedules, is the primary influential factor for fungal keratitis, particularly those caused by yeast-like fungi. RGP CLs have a minimal risk, while hydrogel CLs with extended usage have a greater risk than silicone hydrogel. Additional influential factors comprise injury, especially involving vegetative substance, topical steroids, and underlying systemic illnesses (52).

Management: Treatment typically involves topical medications like natamycin (5%), amphotericin B (0.15–0.30%), topical voriconazole (1%), and miconazole (1%). When deep infiltrative lesions are present, systemic treatment may be applied. Surgical interventions, ranging from debridement and superficial keratectomy for small lesions to PK for large lesions, are necessary for cases unresponsive to medical treatment or in patients with severe thinning at risk of perforation (53).

Important for CL Practice

-Fungal Keratitis presents a serious complication associated with CL use, displaying a distinct grayish-white infiltration with feathery edges and deep penetration. Notable signs such as satellite lesions and hypopyon are frequently present.

-Diagnosis typically relies on microbiological tests, with the aid of confocal biomicroscopy to differentiate these infections from different sources and monitor effectiveness of the treatment

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-In certain countries like India and Nepal, fungal keratitis constitutes the majority of microbial keratitis cases. CL wear has been recorded in 21% of patients diagnosed with fungal keratitis.

-Fungal pathogens have been identified in up to 4.8% of contact lens-related keratitis cases, with Candida, Fusarium, and Aspergillus being the most commonly isolated organisms.

-The primary influential factor for fungal keratitis, especially those triggered by yeast-like fungi, is CL wear, particularly with extended wear schedules. Other influential factors include injury, especially involving vegetative substance, topical steroids, and underlying systemic illnesses.

Tips

-Treatment of fungal keratitis typically includes topical medications such as natamycin (5%), amphotericin B (0.15–0.30%), topical voriconazole (1%), and miconazole (1%).

-In cases with deep infiltrative lesions, systemic treatment may be considered as an adjunct.

-Surgical interventions, including debridement and superficial keratectomy for minor lesions and PK for large lesions, are necessary for cases showing inadequate response to medical therapy or in individuals at risk of severe thinning leading to puncture.

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