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**CONTACT LENS FITTING: A GUIDE AND  
METHODOLOGY OF CONTACT LENS FITTING**

# Contact Lens Fitting: A Guide and Methodology of Contact Lens Fitting

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## Abstract

**Purpose:** The objectives of this thesis are to provide fellow Optometrists a guideline on the importance of contact lens fitting, with a focus on its advantages and disadvantages. Topics to be discussed include:

- a) Types of lenses that can be prescribed to patients.
- b) Consultation with the patient and fitting techniques.
- c) Confronting difficulties on contact lens fitting.
- d) The importance of proper contact lens fitting to avoid undesirable effects such as injuries and infections.
- e) Theories and practices that Optometrists are advised to follow by accredited professors in the field.

**Methods:** This master thesis focuses on the importance of contact lenses and on ways various problems can be prevented. Several approaches are discussed on how vision rehabilitation and comfort can be achieved. The guide outlined in this thesis is based on new research, accredited books and articles on indications for use of contact lenses and their proper fitting.

**Results:** Herein, we discuss further that contact lenses are used not only to correct refractive errors, but also to help deter myopia progression in the case, for example, of the Ortho-k lenses. We discuss further that contact lenses are of utmost importance in the management of aphakia. They do not only help to prevent amblyopia in childhood, but also eliminate patients' discomfort by reducing aniseikonia and anisometropia. The evaluation of the right contact lens fit is performed by observing lens centration, movement and whether the lens has ideal position on the cornea. Finally, the use of contact lenses for vision improvement in different cases of corneal ectasia is discussed as well.

**Conclusions:** This thesis aims to serve as a guide for Optometrists outlining the proper steps to follow for safe contact lens fitting and optimal care of patients with various conditions and ailments.

## Introduction

Vision is the ability to distinguish shapes and colors. The human eye receives an image and transfers it to the brain. Optometrists examine the eyes to detect disease or refractive errors such as myopia, hyperopia, presbyopia and astigmatism; then the physician proceeds with an anterior and posterior segment examination to diagnose potential disease processes, prescribes eye glasses and/or contact lenses and in some cases recommends eye surgery [1]. The work of the Optometrist is not restricted only to diagnosis and refraction; each case is treated differently and Optometrists also provide advice on disease prevention and eye health protection. For example, Optometrists counsel patients on how to use contact lenses properly in order to avoid eye injury, how to perform certain eye exercises and, in general, they provide physical and mental support. [2].

In 1887, Adolf Fick created the first contact lens, made of glass, to correct irregular astigmatism. However, these lenses could not be worn for a long period of time because they were quite uncomfortable. Contact lenses became convenient for the patients when optical instruments were created that could measure the curvature of the cornea [3] (Figure 1).



**Figure 1:** Photograph of two contact lenses [4].

A significant number of patients with refractive errors prefer to substitute eyeglasses with contact lenses for aesthetic reasons. Furthermore, patients with high refractive errors prefer contact lenses because contact lenses improve the quality of their peripheral vision.

In the mid-1900s, plastic-based contact lenses were introduced. This type of hard contact lenses could only be used for a short period of time because of irritation of the ocular surface with long term wear. The spherical design of these contact lenses aimed to alter the shape of the cornea in order to correct refractive errors. "In the 1970s, gas-permeable rigid contact lenses were developed that allowed much more oxygen to pass through to the corneal surface, thus increasing comfort and wear time." [3].

In the 1970s, soft contact lenses, known as hydrogels, were developed. Hydrogel lenses allow oxygen to enter the ocular surface, thus making them even more comfortable. Another advantage of these contact lenses is the fact that they cannot be easily lost due to their size. The disadvantages are that the material is more sensitive; they need to be taken care of systematically and they are not that effective in correcting astigmatism [3].

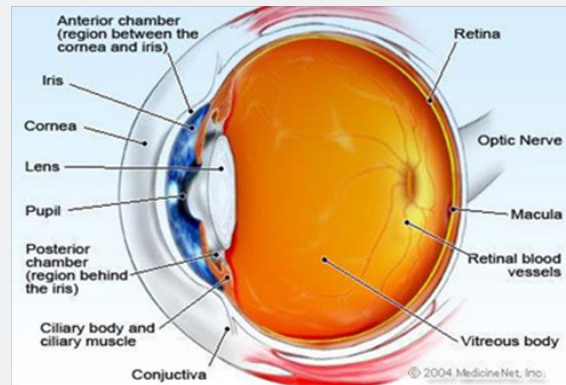
According to Davson & Perkins [2], "In 2005 hybrid lenses were developed that are gas-permeable and rigid and surrounded by a soft ring. These lenses provide the comfort of a soft lens with the visual sharpness of a hard lens." (Encyclopedia Britannica) (Figure 2).



**Figure 2:** Contact lens being inserted in the eye (Encyclopedia Britannica, Contact Lenses, 2017).



## I. Anatomy (Figure 3)



**Figure 3:** The eye is our organ for sight. The eye has a number of components which include but are not limited to the cornea, iris, pupil, lens, vitreous, retina, choroid and optic nerve [5].

- A. **Cornea:** Clear front window of the eye that transmits light and contributes (along with the lens) to light focusing on the retina.
- B. **Iris:** Colored part of the eye that helps regulate the amount of light that enters the eye.
- C. **Pupil:** Dark aperture in the iris that determines how much light is let into the eye.
- D. **Lens:** Transparent structure inside the eye that focuses light rays onto the retina.
- E. **Retina:** Nerve layer that lines the back of the eye, senses light, and creates electrical impulses that travel through the optic nerve to the brain.
- F. **Macula:** Small central area in the retina that contains special light-sensitive cells and allows us to see fine details clearly.
- G. **Optic nerve:** Connects the eye to the brain and carries the electrical impulses formed in the retina to the visual cortex of the brain.
- H. **Vitreous:** Clear, jelly-like substance that fills the middle of the eye [6].

Just behind the iris and pupil lies the lens, which helps the light to focus onto the retina. Most of the eye is filled with a clear gel-like substance called the vitreous. The inside lining of the eye is covered by special light-sensing cells that are collectively called the retina. The retina cells convert light into electrical impulses. Behind the eye, the optic nerve carries these impulses to the brain. The macula is a small extra-sensitive area in the retina that is responsible for central fine-detail vision. The “color” of the eye is determined by the amount and type of pigment in the iris.

## II. Eye Treatments

- A. **Contact lenses and glasses:** They correct common eye problems like nearsightedness, farsightedness, and astigmatism.
- B. **LASIK (Laser-Assisted In-Situ Keratomileusis):** A doctor creates a thin flap in the cornea and then uses a laser to reshape it. This procedure improves nearsightedness, excessive farsightedness and astigmatism.
- C. **Radial Keratotomy (RK):** The doctor makes a series of small incisions in the cornea to reshape it. Once a common treatment for nearsightedness, it's rarely used today.
- D. **Photorefractive Keratectomy (PRK):** The doctor rubs surface cells off the cornea, then uses a laser to improve nearsightedness, farsightedness, or astigmatism. The cells grow back, and the eye heals the same way it would if it was scratched.
- E. **LASEK (laser epithelial keratomileusis):** It's similar to PRK. The doctor peels back the upper layer of cornea cells and uses a laser to reshape it. The doctor may replace or remove the flap afterwards.
- F. **Artificial tears:** These eye drops are a lot like the natural tears. They can help treat dry or irritated eyes.
- G. **Cyclosporine eye drops:** This anti-inflammatory eye drop can treat dry eye caused by inflammation.
- H. **Laser photocoagulation:** A doctor uses a laser on parts of the retina with poor circulation or to treat abnormal blood vessels directly. It's often used for diabetic retinopathy but can also seal a retinal tear.
- I. **Cataract surgery:** The doctor removes the cloudy cataract and replaces the natural lens with a man-made version [7].

## Theme 1. Contact Lenses Correct Refractive Errors

- a. Contact lenses correct refractive errors that occur in patients. The light rays travel from the cornea, pass through the lens and land on the retina. The electrical impulses formed in the retina travel via the optic nerve to the brain's visual cortex, which turns them

into an image. This case of no refractive error is called emmetropia. In the presence of refractive errors, the light does not focus on the retina [8].

- b. Myopia is a condition of blurry far vision. The patients are nearsighted, as they can see very clear in close distance. In myopia the light rays focus in front of the retina instead of on the retina and the axial length of the eye is longer in size.
- c. Hyperopia is when the light rays focus on the back of the retina instead of on it. These patients are farsighted with good far vision and blurry near vision. In cases with high hyperopia, far vision will be blurry too.
- d. Astigmatism is the refractive error in which the light fails to focus on the retina due to the curvature of the cornea. Regular astigmatism types are:
  - i) With-the-rule, when the meridian of the astigmatism is vertical
  - ii) Without-the-rule, when it tends towards the horizontal
  - iii) Oblique, when the meridian is between  $30^\circ$  -  $60^\circ$  and  $120^\circ$  -  $150^\circ$
- e. Irregular astigmatism is when the curvature varies in different parts of the same meridian. Lenticular astigmatism comes from the crystalline lens. Astigmatism can occur by itself and with other refractive errors like myopia, hyperopia and presbyopia.
- f. Presbyopia arises at about 40 years of age and blurry near vision occurs. The near addition, according to the patient's age, begins at about +0.75 D and reaches up to +3.50 D addition. This ADD power is calculated depending on the far refractive error [9].
- g. In younger ages, the lens changes shape easily for near vision and this is called accommodation. In presbyopia, accommodation decreases because of the natural hardening of the lens that occurs with aging.
- h. Prescription for contact lenses is based on subjective refraction, binocular balance, the vertex formula and spherical equivalent calculation. Subjective over refraction should be evaluated after contact lens fitting. This technique evaluates refractive errors that have remained when testing patients that are wearing contact lenses. This also applies to children; retinoscopy over the contact lens aims to detect differences that occur from inappropriate vertex correction.
- i. Contact lens fitting may take several appointments until the proper contact lens is found. Optometrists give the patients guidelines as to how to insert and remove the lens. Moreover, physicians give tips about the routine wash, the proper care and the storage of the contact lenses. [10].
- j. The examiner must have the patient's medical history as it has great diagnostic value. Information that should be collected in contact lenses wearers includes stability of prescription, glasses, presence of eye diseases, history of operations, environment in which lenses will be worn, allergies and family eye diseases. A full eye examination is then performed [11].

A complete eye examination includes the following:

## A. Slit Lamp Examination

Slit lamp examination and biomicroscopy are used as equivalent terms. Slit lamp examination has several built-in magnification lenses that help verify contact lens fitting. Both an anterior and a posterior segment examination should be performed [12].

- i) The anterior segment is located in the front of the eye and includes the eyelids, conjunctiva, cornea, limbus, sclera, iris, anterior chamber, crystalline lens and anterior vitreous.
- ii) The posterior segment is tested using biomicroscopy lenses. Evaluation of the optic nerve, retina, macula and posterior vitreous is undertaken.

A Goldman 3-mirror lens can be used for examination of the retina, vitreous and anterior chamber angle of the eye. Gonioscopy is crucial in the evaluation of glaucoma as it permits direct visualization of the anterior chamber angle [13].

Also, with slit lamp biomicroscopy physicians can check tear film stability by measuring the breakup time (BUT). A value of BUT below 5 seconds may indicate dry eye syndrome and a poor tear film [14].

Goldmann tonometry can be attached to the slit lamp to measure the eye pressure. The eye pressure is also known as intraocular pressure (IOP). Patients with high intraocular pressure could develop glaucoma with irreversible optic nerve damage and visual field loss. This eye disease usually occurs when the IOP is high, but it may occur in eyes with normal IOP as well [13].

Contact lens fitting is estimated with the white light or with fluorescein light and the cobalt blue filter. The examiner observes if there are areas of staining using fluorescein and prior contact lens wear. Afterwards, the examiner uses contact lenses to observe color patterns. This method points out where the contact lens touches or does not touch the cornea. Patients with meibomian gland dysfunction (MGD) are not good candidates for contact lenses.

## B. Topography

Topography images the surface of the cornea and helps Optometrists determine the types of astigmatism that the patient has. Also, it assesses the shape and power of the cornea. The topography map estimates how flat or steep the cornea is and detects the astigmatism meridian [15]. Measurements can be conducted using Javal keratometer. The average keratometer measurements are used to select the base curve and diameter for contact lens fitting.

## C. Contact Lens Fitting

The examiner checks for lens movement in order to assess a flat or steep contact lens fitting. First, the patient looks straight ahead and blinks; in this way the Optometrist observes not only if the lens is in the center, but also evaluates for lens movement. Then, in the slit lamp the contact lens movement in the vertical and horizontal positions is evaluated by having the patient look up, down, right and left. An ideal movement in all positions should be about 0.2 mm to 0.4 mm. The same test is applied for toric lenses and Optometrists have to detect if the lens's mark is stable. The contact lens should be centered in the middle of the cornea and the lens has to cover the entire cornea.

The "push up test" is another way to estimate contact lens movement and indicates how loose or tight the lens is fitted. This method works when the patient looks up, blinks repeatedly, and then the Optometrist pushes the lens on the lower eye lid using his/her thumb. In this way, the lens movement can be assessed: when the lens has a lot of movement the result is 0% and when it falls out of the eye, there is no movement, so the result is 100% [16].

Other examinations include: cover uncover test to detect any phoria or tropia, accommodation test, convergence test, subjective refraction, cycloplegic retinoscopy, measurement of pupil size, Schirmer tear test, measurement of base curve, keratometry, corneal thickness, corneal diameter and axial length.

## Theme 2. Soft Spherical and Soft Toric Lenses

Soft contact lenses are made of a flexible hydrophilic or modern silicone-hydrogel material and are very comfortable. The lenses have high oxygen permeability and there are many types in the market; some provide more oxygen than others. Soft contact lenses correct the refractive errors of myopia, hyperopia, presbyopia and astigmatism. Soft lenses have a wide spherical and toric power range and are comfortable for the patient. These lenses have a steep or flat base curve depending on keratometry measurements.

### a) Types of Soft Contact Lenses

- i. Daily Spherical Contact Lenses
- ii. Daily Toric Contact Lenses
- iii. Multifocal Contact Lenses
- iv. Daily Colored Contact Lens
- v. 1-2 Week Spherical Contact Lenses
- vi. 1-2 Week Toric Contact Lenses
- vii. 2-Week Multifocal Contact Lenses
- viii. Monthly Spherical Contact Lenses
- ix. Monthly Spherical Contact Lenses for Astigmatism
- x. Monthly Multifocal Contact Lenses
- xi. Monthly Multifocal Toric Contact Lenses
- xii. Monthly Colored Contact Lenses
- xiii. 6-month up to 12-month Soft Contact lenses
- xiv. Extended Wear Soft Contact lenses

These lenses are very easy to adjust to and have a larger diameter than rigid gas permeable contact lenses with great stability. Soft contact lenses correct irregular astigmatism and have a large range of power but in advanced stages of keratoconus, in pellucid marginal degeneration and in keratoglobus Optometrists can recommend other types of lenses [17]. Keratoconus, pellucid marginal degeneration (PMD) and keratoglobus are non-inflammatory eye disorders. The cornea gets thinner and the eye loses the normal round shape, which causes vision loss. In pellucid marginal degeneration (PMD) an inferior peripheral cornea ectasia gradually develops.

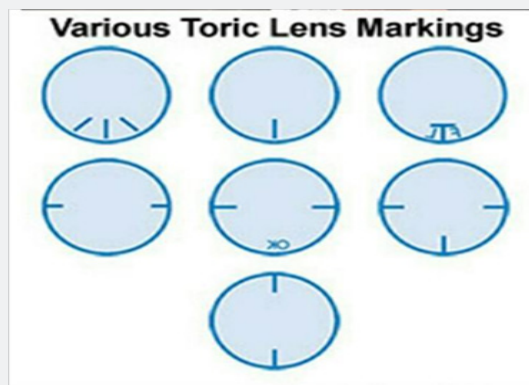
Toric contact lenses are available in soft and rigid gas permeable material. Soft lenses correct astigmatism and they have a laser mark orientation at the 6 o' clock position to check the contact lens fitting with a slit lamp examination. After 30 minutes of adaptation, Optometrists check the lens centration and lens movements with the push up test and horizontal and vertical lag. In this case, subjective



refraction is suggested to correct refractive vertical changes [18]. Prisms balance bifocal, multifocal and toric lenses with a vertical base-down prism for the contact lens position and orientation to provide the best visual acuity [19]. This design helps to keep the lens from rotating and the meridian to stay at the correct position. Toric contact lenses correct simultaneously myopia, hyperopia, presbyopia together with astigmatism in different meridians and powers. Toric lenses usually have a vertical 6 o' clock laser mark, though in the market, there are different types of laser marks.

## b) Different laser marks in toric contact lenses (Figure 4)

Toric lenses have a front toric design, a back toric design and a bi-toric design. The front design corrects both corneal and phakic astigmatism up to 4.50 D whereas the back design corrects higher astigmatism up to 6.00 D. Bi-toric design contact lenses have a front and back curve and correct small amount of astigmatism of up to 2.50 D [21]. Research about tips for toric lens fitting states that when the lens settles down, usually after 30 minutes, then the lens rotation can be estimated [22]. This evaluation can be accomplished with the slit lamp and the laser mark of the toric lens. According to Quinn [23], when fitting toric contact lenses, Optometrists should follow the LARS rule and "if the lens rotates left add to the axis and if it rotates right subtract from the axis". In this way lens rotation can be corrected for up to 8 degrees [24]. In clinical practice, sometimes, this is difficult, so different applications are used to help us with this task. For example, Optometrists can download the toric lens application of Bausch and Lomb for iPads or smartphones. This smart phone application calculates the rotation and gives the correct contact lens prescription. There are many similar applications that are used in clinical practice which follow a similar principle. First, the lens prescription is inserted and then the mark is moved at the position that the lens is stable at the slit lamp. This will calculate the correct toric lens prescription.



**Figure 4:** Various toric lens marking [20].

## Theme 3. Contact Lenses for Presbyopia

Presbyopia is a condition in which near vision decreases and is associated with aging. Accommodation decreases at the age of about 40 years old and most people start having near vision problems. The crystalline lens gets harder after some years and loses the ability to change shape and focus in near distance. This is called presbyopia and is a normal condition that occurs with aging. The firsts symptoms are blurry near vision; for example, patients move a book further away in order to have a clearer image. Common symptoms are headaches, fatigue and blurry vision, while better lighting is needed for reading. The addition power increases with advancing age and it depends on the patient's preferences and activities. The addition power for near vision in the early stages of presbyopia starts at about +0.75 D and can reach up to +3.5 D as the patient gets older. The addition power is calculated over the far subjective refractive error and can correct both presbyopia and astigmatism. In clinical practice, it is required to note the working distance that the patient needs. There are a variety of materials and designs for presbyopia contact lenses. Contact lenses play a primary role in correcting presbyopia depending on the patient's needs. Also, presbyopia contact lenses are desired by patients because they can put aside their near glasses. Patients usually do not want to correct only presbyopia with contact lenses, they want to be able to see clearly both close and far. Several options can be tested to create a comfortable setting for both far and near correction. Material options in presbyopia are rigid gas-permeable (RGP) and soft contact lenses.

### A. Types of Presbyopia Contact Lenses for Far and Near Vision

- i) Near vision contact lenses and far vision spectacles
- ii) Distance contact lenses and near vision spectacles
- iii) Monovision with contact lenses
- iv) Bifocal contact lenses
- v) Multifocal contact lenses
- vi) Myopia progression with multifocal contact lenses

- vii) Contact lenses after cataract operation
- viii) Contact lenses in aphakia

In the case that presbyopia is corrected binocularly, with contact lenses, the patient will see blurry in far distance and it will be necessary to use far distance glasses. Contact lenses for distance vision and reading spectacles over such contact lenses can be used to correct presbyopia in early stages. More often than not, patients do not prefer these methods because they want to be spectacle-independent both for near and far.

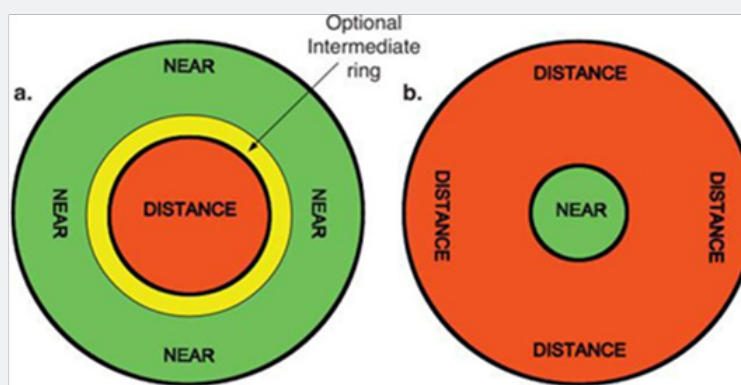
Another well-known technique is monovision. Using this method, the dominant eye is corrected for far and the non-dominant eye for near vision. This solution is favorable in the early stages of presbyopia with up to +1.75 D difference in addition between the two eyes.

The dominant eye evaluation technique is appropriate in other conditions such as poor visual acuity with multifocal contact lenses. Multifocal contact lenses are a good idea, but sometimes they do not provide perfect vision for both far and near vision. The dominant eye in modern design multifocal contact lenses can correct far distance with a lower addition power and the non-dominant eye can correct near vision with a higher addition power. Multifocal contact lenses have a modern design and correct areas of far, intermediate and near distance. Both bifocal and toric lenses have a vertical base-down prism for the contact lens position and orientation to acquire the best visual acuity [19]. In both bifocal and multifocal lenses, pupil diameter should be tested in normal light as well as lens centration and it is preferable to use a flatter fit contact lens [24].

Another technique of monovision, which is used by Optometrists, is applying different types of contact lenses to each eye. In one eye the Optometrist inserts a spherical or spherical contact lens with astigmatism to correct far distance and in the other eye a multifocal lens is used to correct near vision. Also, multifocal contact lenses can correct spherical and astigmatic refractive errors providing best vision. Optometrists prefer soft contact lenses with an aspherical design.

Hodd [25], mentions the following multifocal designs:

- a. With a distance center and near periphery
- b. Near center with a distance periphery
- c. The concentric ring of distance and reading. (Figure 5).



**Figure 5:** a) The center of this contact lens corrects distance vision and the periphery provides near correction, b) This lens has a near center and a distance peripheral correction [26].

A similar monovision technique is the following: the distance center is corrected at the dominant eye and the near center is chosen at the non-dominant eye. Kassalow [27] mentions, multifocal lenses such as “AIR OPTIX AQUA Multifocal contact lenses are made from a silicone hydrogel material (lotrafilcon B) that provides both high oxygen transmissibility (with a Dk/t of 138 @ -3.00D) and a low lipid-depositing surface” and are available in LOW, MEDIUM and HIGH range addition powers for presbyopia.

Optometrists should examine the patient at the beginning with a trial lens and test the patient’s visual acuity binocularly for far and near vision. Over contact lenses refraction will be estimated in presbyopia with +/- 0.25 D or +/-0.50 D binocular flippers or trial lenses [25]. Perfect eye-sight in both far and near distance sometimes cannot be accomplished. Some negative aspects are difficulties in binocular fusion and dizziness, especially with monovision and high-power addition. Blurry near vision occurs in patients undergoing a cataract surgery and in aphakia, because the crystalline lens is replaced or removed. In some occasions in cataract surgery, the physician chooses a monovision technique or a multifocal lens implantation. In such a case, patients generally cover their needs with glasses. Aphakic patients should wear contact lenses because they are more stable and provide better quality vision than aphakic spectacles. This is especially important in children to avoid amblyopia. Contact lenses are necessary to be used; this helps to avoid aniseikonia and anisometropia in cases of monocular aphakia. Aphakia in adults and children is usually corrected with extended wear contact lenses. Otherwise, multifocal contact lenses are a good option for patients who need prescription for near and far distance.

Multifocal contact lenses are used for myopia control on a daily lens wear schedule. Follow up examination should be planned within two consecutive weeks of wearing them. This means that these lenses are appropriate for 8 hours up to 14 hours wear a day. These contact lenses reduce myopia progression in children and in the early teens [28].

## Theme 4. Extended Wear Contact Lenses

Extended wear soft contact lenses are worn continuously at night and day for up to 30 days followed by 1 night without lens wear. This means that these lenses can be worn while sleeping and have to be removed once a week for cleaning with contact lens solution. This continuous wear increases the risk of corneal infections [29]. These lenses are suitable for patients with an active life.

Patients with a history of cornea infection or inflammation are not good candidates for extended contact lens wear. Suboptimal effects occur more often with hydrogel than silicone hydrogel material such as, for example, vascular changes and endothelium polymegathism from chronic hypoxia. Kaplan [30] reports that “epithelial cells originate at the limbus and travel across the cornea before sloughing off at the ocular surface a process that might be affected by covering the cornea with a contact lens, possibly inducing hypoxia”. This study clarifies that extended wear contact lenses decrease oxygen permeability and demonstrates that epithelial thinning leads to infections. At times, these lenses are required for therapeutic reasons in cases of corneal diseases and corneal dystrophies. Some examples are: Fuchs’ dystrophy, bullous keratopathy, trauma and after some corneal surgeries [30].

Extended wear lenses can also be used in cases of corneal scarring and injuries. These lenses correct refractive errors like myopia, hyperopia, astigmatism and presbyopia. Follow up examinations are necessary one week after the trial session, then after two weeks and finally after six months [21].

## Theme 5. Rigid Gas Permeable Contact Lenses

Rigid gas permeable contact (RGP) lenses are smaller in size. RGP lenses are fitted within the cornea and the movement of the lens does not cross 1mm of the limbus onto the sclera. In clinical practice, tears are provided under the lens as oxygen transmissibility occurs.

RGP contact lenses are a safe option to recommend for patients to use. They can correct refractive errors such as astigmatism-irregular astigmatism, myopia, hyperopia and presbyopia. RGP contact lenses provide a better or sharper vision in high diopters than soft lenses, especially in cases of irregular astigmatism and keratoconus. The adaptation to these lenses is more complicated than to soft lenses because it takes longer for patients to feel comfortable using them [32].

RGP lenses are comfortable after a period of few days of adaptation. In general, they become as comfortable as soft contact lenses for the patients. They also last longer than soft contact lenses. Contact lens fitting sessions are required, so patients can learn the procedure of inserting and removing the contact lens through a mini-course in hygiene. This is especially important for patients that have never worn contact lenses.

The following list presents a summary of the recommendations for the patients when soft or RGP contact lenses are fitted for the first time:

### Inserting Soft Contact Lenses and RGP Lenses

- i) The patient must wash his/her hands with soap.
- ii) The patient should be in front of a mirror.
- iii) The middle finger of the opposite hand will hold the top eyelid of the eye.
- iv) The middle finger of the other hand will hold the bottom eyelid to prevent blinking.
- v) In RGP lenses the patient looks straight ahead in the mirror and inserts the lens in the middle of the cornea.
- vi) In soft lenses, it will be difficult to insert the lens in the center of the cornea because these lenses are larger in diameter. The lens should touch the sclera and following several eye movements it will position itself at the center of the cornea.

### Removal of Soft Contact Lenses and RGP Lenses

- a) The patient must hold the top and bottom eyelid wide open with their finger.
- b) Using one finger from one hand to hold open the upper eyelid and one finger from the other hand to hold open the lower eyelid. When the patient presses the lids, the RGP lens will pop out.
- c) Soft contact lenses are removed easier by holding wide the lower eyelid. The patient must touch the edge of the contact lens and then gently drag the lens to the bottom of the eyelid. Lastly, the lens will easily be removed from the cornea.
- d) Contact lenses are cleaned with drops of solution on the lens. Patients gently rub the end of the fingertip, where the lens is placed, and rinse with solution or saline. Then contact lenses are maintained in a case with fresh solution and the case should be replaced every month.

## Theme 6. Scleral Contact Lenses

Scleral contact lenses are large diameter lenses that are made of gas permeable material [33]. They are appropriate for patients with high refractive error such as high myopia, high hyperopia and high regular or irregular astigmatism. These lenses provide stability and less contact lens movement. Lipson [34] reports that scleral lenses are recommended to patients with the following conditions “keratoconus, pellucid marginal degeneration, post penetrating keratoplasty (post-PKP), corneal scarring and irregularities following refractive surgery and ocular surface disorders”.

## Theme 7. Hybrid Contact Lenses

The design of hybrid contact lenses is a combination of a soft and rigid gas permeable contact lens. The center of the lens has RGP material and the periphery soft material. These are large diameter contact lenses. This contact lens corrects irregular astigmatism and is comfortable because of the soft peripheral skirt. Also, they are recommended in keratoconus and provide good quality vision [35].

### Hybrid Contact Lenses Using New Technology

- a) SynergEyes A for astigmatism
- b) SynergEyes multifocal for presbyopia
- c) SynergEyes KC for keratoconus
- d) SynergEyes PS for postoperative conditions [36].

## Theme 8. Cosmetic and Prosthetic Contact Lenses

These contact lenses are used for cosmetic reasons after eye diseases, color and iris abnormalities such as iris coloboma. Also, a person's eyesight may deteriorate due to trauma, injury and eye infection. The 'eye care practitioner' can order custom-made lenses to conceal the defaulted eye and to give the impressions that it is a normal eye [37]. The majority of these cosmetic and prosthetic contact lenses can be purified and sanitized using solution. These lenses are hybrid or soft lenses and also correct refractive errors [38].

## Theme 9. Therapeutic Contact Lenses

Therapeutic contact lenses are used as a bandage to protect the cornea. These are soft contact lenses and used as a treatment after cornea injuries, refractive surgeries and other intraocular surgeries [39]. They are also used in binocular problems, strabismus, diplopia, amblyopia and for occlusion [19]. Kalaiyarasan [40] reports that therapeutic contact lenses are used for “corneal dystrophies such as bullous keratopathy and in the management of corneal ulcers”.

## Theme 10. Colored Contact Lenses

Colored contact lenses allow wearers to change the color of their eyes. These lenses can be used for cosmetic reasons alone or both for cosmetic and for refractive correction such as myopia and hyperopia. In cases of astigmatism calculation of the spherical equivalent is required because toric colored contact lenses are difficult to find and they are available only in a limited toric range. New technology colored contact lens are Air Optix Colors with high Dk and silicone hydrogel material [41].

## Theme 11. Contact Lens Fitting in Aphakic Patients

When the lens of the eye loses its transparency a cataract is formed and vision declines. People with cataract see through a cloudy lens and, thus, experience disturbances such as blurry vision, sensitivity to glare, poor night vision, monocular diplopia and halos around lights [42]. Cataract formation occurs most commonly because of increasing age; other causes of cataract formation include diseases such as diabetes, drugs (corticosteroids, antibiotics), eye injury, and radiation. There are several types of cataracts such as cortical, nuclear and posterior subcapsular. The presence of a cloudy lens at birth is called congenital cataract. The cataractous lens continues to become cloudier over the first year of life. Congenital cataracts may be related to hereditary and/or metabolic disorders and might appear in a large number of syndromes and injuries [43].

Surgical removal of the cataract is accompanied by the implantation of an artificial lens in its place, called intraocular lens. The patient, thus, becomes pseudophakic. Removal of the cataract lens without inserting another results in aphakia. Aphakia is the absence of the crystalline lens in one or both eyes because it has been surgically removed [44].

Gaballa et al. [45] state that the power of the intraocular lens to be implanted depends on different measurements of “the axial length (AXL), keratometry, anterior chamber depth (ACD) and lens formulas”. Hamburg [46] explains that in some cases, it is better not to implant an intraocular lens because it may “induce either fatal inflammations or complications necessitating other surgical interventions” causing undesirable results. Also, complications during the surgery may prevent inserting the intraocular lens.

In children over 2 years of age primary IOL implantation was found to be safer than aphakia with secondary IOL implantation at an older age. Specifically, patients that underwent IOL implantation secondarily developed glaucoma. In this study, the Hoffer Q II formula is used for children to avoid future refractive errors and a suitable target for a 1-year-old will be +4.00 D hyperopia, a target for a 2-year-old will be +3.50 D, and for a 3-5-year-old the target should be +2.50 D preventing IOL power changes [47].

# Contact Lens Fitting: A Guide and Methodology of Contact Lens Fitting

Aphakia in children should be treated with spectacles or contact lenses in order to manage amblyopia and, thus, improve visual acuity. Contact lenses provide a better optical result, minimizing prismatic effects during eye movements, especially in monocular aphakia where the use of eyeglasses can cause a difference in the perceived size of images (aneisokonia) or diplopia. These may occur due to anisometropia and cause difficulty with peripheral images thus progressing suppression and increasing the risk of amblyopia [48]. In cases where the child cannot accept contact lenses or spectacles over 2 years of age secondary surgery and an intraocular lens implantation is recommended because, until this age, axial length increases very fast [49]. Patients with aphakia have total loss of accommodation and that is why it is proposed that patients should wear glasses over contact lenses for near vision or multifocal contact lenses depending on the refractive error, especially in binocular aphakia. If amblyopia occurs due to refractive errors, patients will also need patching for 2 hours a day of the non-amblyopic eye. It is recommended that patients do near vision activities to prevent or confront amblyopia. This possibility of correcting amblyopia is until the first decade of the child's life [50].

Strako [51] suggests that the appropriate material of contact lenses for children is silicone hydrogel with high Dk (Oxygen Permeability); for example, "Bausch and Lomb Silsoft Super Plus" with Dk 340, Dk/t (Oxygen Transmission) 71, Base curves: 7.5 mm, 7.7 mm and 7.9 mm, Diameter: 11.3, Power +23.00 D to +32.00 D (in 3.00 D steps)". These lenses are designed for aphakia for adults or children and can be worn overnight either for a daily wear or extended wear fitting. Also, silicone hydrogel lenses for aphakia in adults are SilSoft Aphakic with the same Dk values and Base Curves: 7.5 mm, 7.7 mm, 7.9 mm, 8.1 mm, 8.3 mm Powers: +11.50 D to +20.00 D (1.00 D steps).

The fitting process should start one week after the cataract removal operation and Optometrists may begin for instance with a steep base curve of 7.5 mm and a high spherical power +29.00 D. Taking into account steeper fitting, Optometrists can correct corneal astigmatism with spherical power contact lenses. Checking the contact lens movement is an important step. If the contact lens moves away from the center of the cornea, it means that the contact lens is too flat. Furthermore, detecting bubbles under the lens indicates that this contact lens is possibly too steep. A good idea for determining changes in the contact lens power is over-refraction contact lens retinoscopy in every session [51].

Contact lens fitting for aphakic patients depends on the health of the aphakic eye. A full examination is appropriate bearing in mind the patient's age. It is necessary to consider medical-family history, visual acuity, manifest and cycloplegic refraction, slit lamp examination of the cornea, intraocular pressure (IOP), keratometry, color vision, topography, BUT test, Schirmer test and testing of the eyelids. Harrell [48] indicated that there are a variety of lens materials, "Soft, Silicone, Rigid Gas Permeable and Hard (PMMA)". The choice in each case is different and it depends on the corneal steepness, diameter and refractive power. To achieve best visual acuity, Optometrists prefer daily wear of hard lenses (PMMA) with good oxygen permeability and a central thickness of 0.05 mm. Additionally, children are good candidates for extended wear hydrophilic lenses, with a 0.5-1.5 mm contact lens movement during blinking and in different eye movements. Also, in cases of an unsuccessful fitting of the hard lens (PMMA) extended wear lenses are suggested and in a failed extended wear fitting daily wear of soft, silicone or gas permeable lenses is recommended [52].

Hydrophilic lenses for aphakia are extended wear 'soft' contact lenses worn continuously providing comfort and have proven to be safe with frequent follow up examinations to avoid complications [53]. These lenses are appropriate for children because parents do not have to insert or remove the contact lens from the child. Also, these lenses do not correct corneal astigmatism, so glasses can be used for the remaining uncorrected astigmatism. Adults tend to be affected with dry eye symptoms and poor-quality tear film and must change their lenses after a year of use.

The problems that occur with hydrophilic continuous wear contact lenses in aphakia are infections, lens deposits and irregularity of the tear film. A solution to this problem is choosing a flattened peripheral curve to attain more edge lift fitting [54]. Lorenz & Worle [55] explain that hydrophilic extended wear contact lens material is "polymethymethacrylate cross-linked with vinylpyrrolidone" and diameter of optical zone 6 mm, aspherical edge and suggest "rigid-flexible edge than thin edges for better tear exchange". The diameter of hydrophilic contact lenses is chosen based on the values of the iris diameter, for example, for corneas of 12.00 and 12.50 mm diameter a lens diameter of 13.5 mm is chosen. In order to evaluate the lens, the movement in up gaze, the horizontal lag, and the Josephson eyelid push-up recovery speed test is assessed. This allows Optometrists to have a clear perspective of the contact lens fitting [56].

Rigid gas permeable contact lens material is silicone of fluoropolymers which allows oxygen through the cornea. These lenses provide better vision and benefits for patients with astigmatism or ocular trauma. GP lenses cover 75% of the cornea floating on a tear layer allowing more oxygen to reach the cornea. They also tend to last longer than soft contacts lenses [57].

Hard contact lens material is plastic called polymethymethacrylate (PMMA) and they are rarely used today. PMMA lenses had to be made relatively small in size and oxygen cannot pass through a PMMA contact lens. Wearing contact lenses without proper care may put the eyes at risk for developing complications and infections such as keratitis, corneal irritation, soreness, redness, reduction in visual acuity and inflammation. If one of the aforementioned symptoms occurs, the contact lens must be removed, and the patient has to be examined. Also, in some cases, antibiotic therapy is required without taking off the lens. The best way to avoid eye infections is to follow proper lens care guidelines as prescribed and contact lens fitting teaching sessions. In cases of children with aphakia, parents must be informed that they should practice contact lens fitting to the child. I would like to emphasize that there are patients who have difficulty or cannot insert or remove their contact lenses [58].



## Theme 12: Contact Lens Fitting in Orthokeratology

Orthokeratology or corneal refractive therapy is a specialty contact lens fitting method where a gas permeable (GP) contact lens is worn overnight to change the corneal curvature and thus modify the corneal refractive power [59]. The ortho-k lenses, for instance, are worn while sleeping and are not worn in the daytime, allowing patients to see clearly without contact lenses or glasses during the day [60]. In other words, it is a temporary, reversible and alternative option to refractive surgery procedures and is described as a treatment for reducing myopia, rather than curing it. Patients need to continue to wear the lenses to maintain the effect [61].

According to Newman [62] ortho-k contact lenses are “gas permeable of high Dk (Oxygen Permeability) with a reverse geometry design and refractive correction that reaches full correction within two weeks”. They work with the tear layer to flatten and reshape the front surface of the cornea reducing myopia, astigmatism or both. For this reason, according to Sun et al. [63] they “reduce the refractive error in myopia with central corneal flattening, thickening of the midperipheral cornea, and thinning of the central corneal epithelium”.

Ortho-k lenses are recommended for:

- a. Patients with refraction up to 4.00 D of myopia and up to 1.50 D of corneal toricity [64].
- b. Patients who need good visual acuity due to occupation, hobbies and activities.
- c. Both children and adults.

Moreover, orthokeratology lenses for myopia control in children and teenagers until 18 years old are thought to slow the progression of myopia [64]. Another technique for myopia control with good results is atropine eye drops of 0.5%.

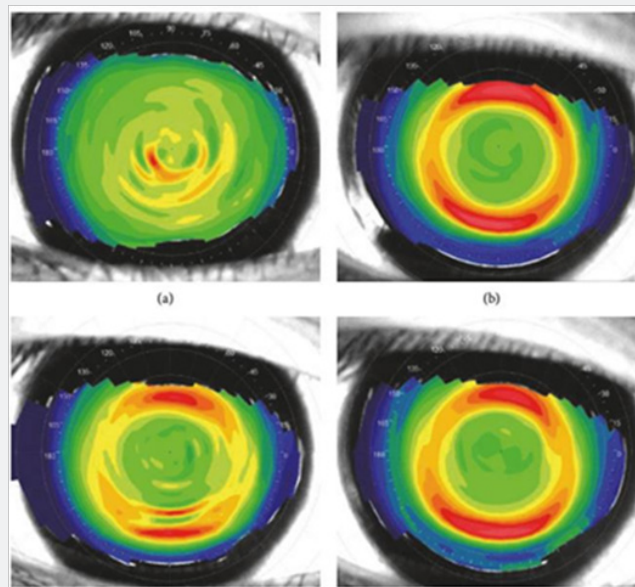
Overnight ortho-k lenses are suggested for patients with a small pupil diameter when the pupil diameter increases from <3 to 6 mm. For example, a patient with pupil size at normal light over 5mm is not a good candidate [65].

Potential risks of orthokeratology include corneal ulceration, microbial keratitis, acanthamoeba infection, and central corneal staining [66]. Meszaros [67] mentions that the most common pathogen in treatment with ortho-k contact lenses is “pseudomonas aeruginosa”.

Collecting necessary data is necessary with a full eye examination and baseline measurements before and after orthokeratology fitting. Furthermore, measurements include manifest and cycloplegic refraction, visual acuity, corneal topography, tear film evaluation, intraocular pressure (IOP), axial length measurement with the IOL Master, lens fitting movement of about 1-2 mm during blinking, pupil size measurement, slit lamp examination and anterior segment evaluation (ciliary body, cornea, iris and lens). Using the corneal topographer, we can optimize the corneal elevation profile and corneal wavefront data calculations [68].

Patients need routine appointments with their physicians to monitor the progress of the orthokeratology practice:

- a) The first appointment after the fitting visit will be the next day.
- b) The second appointment will be one to two weeks later.
- c) One month follow up examination, three months and six months after fitting ortho-k lenses.
- d) And every six months thereafter [69]. (Figure 6).



**Figure 6:** This figure shows us the corneal surface shape at baseline (a), 1 month after orthokeratology (b), 3 months after orthokeratology (c) and 6 months after orthokeratology (d). [70].

On one hand, studies of contact lens fitting with orthokeratology have reported an increase in wavefront high order aberrations. Specifically, in spherical aberration and coma aberration, the patients' optical vision quality improves [71]. On the other hand, statistically significant changes that have been observed include a decrease in Contrast Sensitivity Function after orthokeratology contact lens treatment in follow up visits [72].

Ortho-k contact lenses were approved by the United States Food and Drug Administration (FDA) in 2002 as an overnight wear type of corneal reshaping termed Corneal Refractive Therapy (CRT) [73].

### **Theme 13. Contact Lens Fitting in Children**

Soft contact lenses or soft extended wear contact lenses are used for therapeutic reasons so that children do not develop amblyopia [74]. Also, contact lenses provide comfort to patients that have anisometropia and aniseikonia. In this situation, there are differences in refractive errors between the two eyes. This occurs after cataract surgery with primary IOL implantation or in aphakia; contact lenses correct refractive errors and improve binocular vision.

A lot of children have difficulties in sports because they do not have adequate eye vision that is mandatory to have good performance. Additionally, children are very sensitive with their external appearance and do not want to wear spectacles. Parents should have in mind the risks that accompany the use of contact lenses [75].

Another reason for a child to wear contact lenses is for myopia control, i.e. to slow down the progress of myopia with multifocal and ortho-k contact lenses. Children have to be examined regularly in follow up sessions. Parents and children have to participate in contact lens fitting sessions and to be well informed of how take care of the lenses.

### **Theme 14. Contact Lens Fitting in Patients with Corneal Ectasia**

#### **a) Pellucid Marginal Degeneration**

Pellucid marginal degeneration (PMD) is a rare non-inflammatory ectatic disorder characterized by bilateral peripheral thinning of the inferior cornea. This leads to myopia and irregular astigmatism; as a result it affects the visual acuity [76]. This corneal thinning occurs about 1–3 mm from the limbus in the 4–8 o'clock position. Pellucid marginal degeneration appears from the age of 20 to 40 and, unfortunately, the etiology of this disease is unknown. PMD is treated with rigid gas permeable contact lenses, cross-linking (CXL) therapy, intracorneal ring segment implantation and keratoplasty [77].

#### **b) Keratoglobus**

Keratoglobus is a rare non-inflammatory corneal ectasia and causes irregular astigmatism. The first type of keratoglobus is congenital, which appears from birth, due to several syndromes. The second type develops in teenagers from the existing eye disease keratoconus or pellucid marginal degeneration. The etiology is unknown; other theories about the appearance of keratoglobus in older patients are thyroid ophthalmopathy, injuries, corneal dystrophies and many other syndromes. The negative effects of keratoglobus are poor vision, pain, tearing, photophobia and loss of endothelial cells. Keratoglobus leads to high myopia and high irregular astigmatism. Visual acuity rehabilitation, when applying modern scleral contact lenses, results in better vision than with spectacles. No exact studies or literature is written about patients with keratoglobus regarding contact lens fitting. The use of contact lenses in patients with keratoglobus is controversial because of the serious risks and trauma that contact lenses can cause in this situation by the insertion and removal of the lens. When a Descemet tear occurs the treatment involves patching the eye to protect the cornea or bandage contact lens and cycloplegics to reduce the edema. Keratoplasty may be suggested in keratoglobus because of the poor vision and the thinning of the corneal stroma [78].

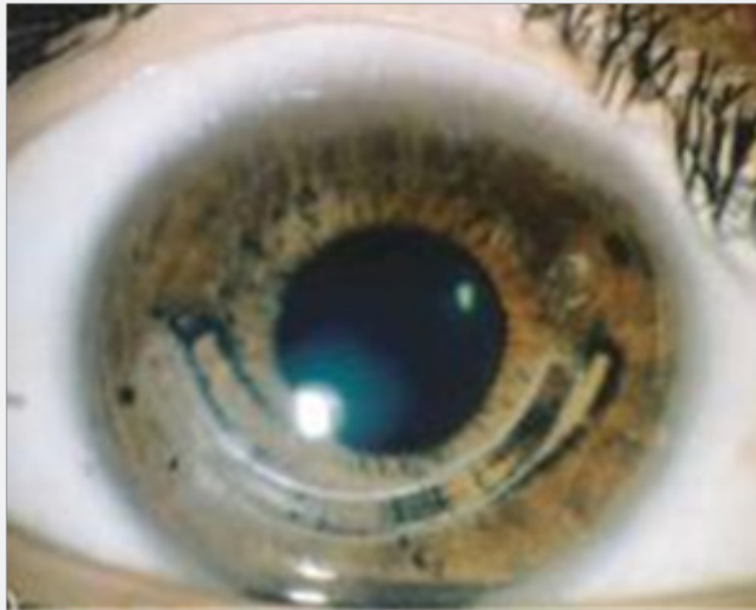
#### **c) Keratoconus**

Keratoconus (KC) is a disorder characterized by an asymmetric, non-inflammatory corneal ectasia that leads to progressive corneal thinning and ectasia of conical shape [79]. This disease results in central or paracentral cornea thinning and steepening causing myopia and irregular astigmatism [80]. These corneal abnormalities, usually affect both eyes and can lead to blurry vision, double vision, nearsightedness, astigmatism, dryness, corneal scars, foggy vision and light sensitivity. Keratoconus most commonly occurs in males than in females and this disease usually manifests in the late teens or twenties and may progress for 10-20 years before it slows down or gets stabilized [81].

There are many theories about what causes keratoconus based on a range of studies. Conditions that might induce keratoconus include are environmental factors, allergies, eye rubbing, stress, and genetic causes [82]. Moreover, keratoconus could appear in patients as a secondary keratectasia after refractive operations [80]. In such cases, it is called iatrogenic post-refractive ectasia. Thakrar [83] indicates that slit lamp signs of keratoconus include "Fisher's ring in the corneal epithelium, Vogt's striae in the posterior stroma and anterior stroma scars".

Keratoconus management in the early stages can be done with the use of eyeglasses or soft contact lenses in order to correct the resulting refractive error. As the disorder progresses and the cornea continues to thin and change shape, rigid gas permeable (RGP) contact lenses are generally prescribed to correct vision more adequately. It is necessary to point out that frequent follow up sessions are

required, and lens changes may be needed to achieve and maintain good visual acuity. Intacs Corneal Inserts or Implants can also be used in the management of keratoconus [84]. The goal of this surgical treatment is to improve vision either directly by correcting part of the irregular astigmatism or indirectly by allowing for better contact lens fitting [85]. Intrastromal Corneal Ring Segments are flexible and crescent-shaped rings made of polymethylmethacrylate (PMMA) that are placed in the periphery of the cornea and, as a result, they flatten the shape of the cornea and correct some of the irregular astigmatism [86] (Figure 7).



**Figure 7:** An Intacs segment inserted in a patient with keratoconus [87].

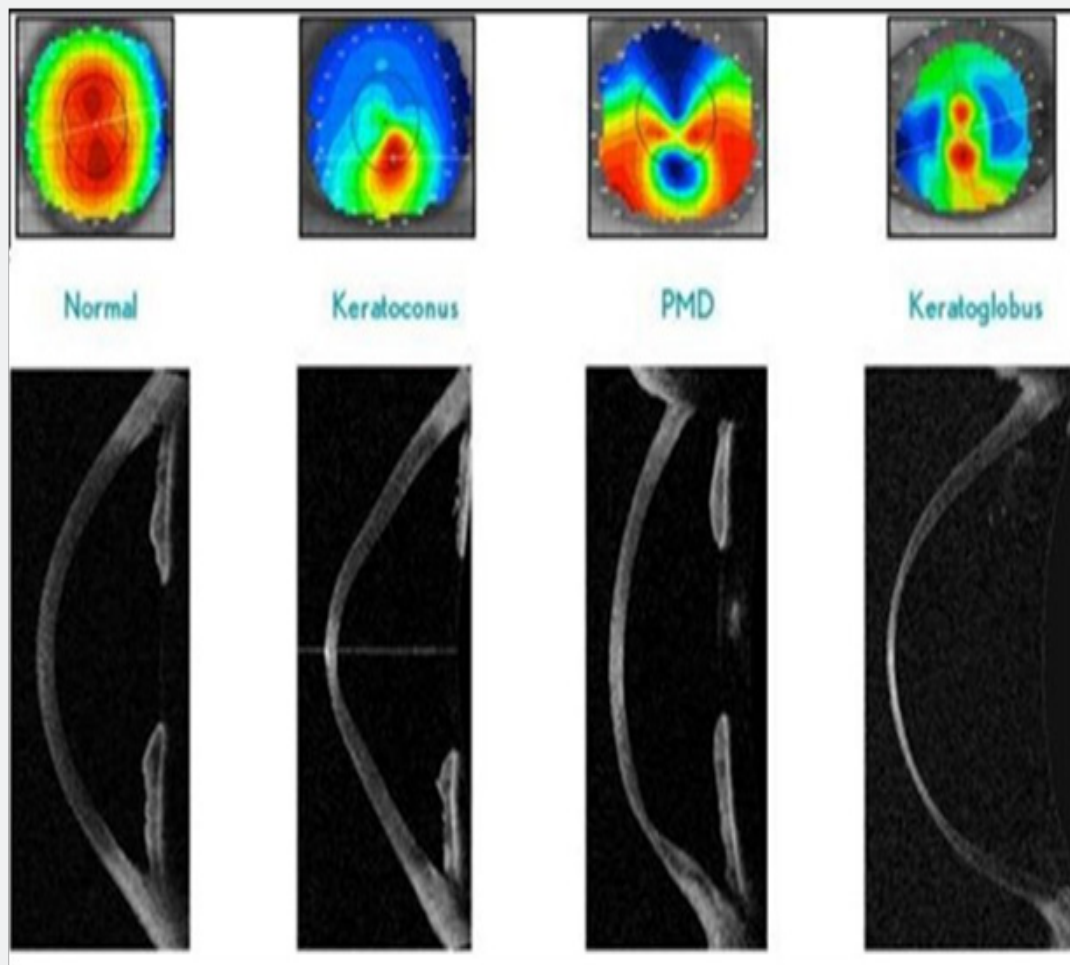
Another treatment that is indicated in progressive keratoconus, is corneal crosslinking therapy that aims to stabilize corneal thinning progression using riboflavin and ultraviolet A (UVA) light. In some cases, a surgical combination is recommended in the management of keratoconus with CLX and photorefractive keratectomy (PRK) [88].

Phakic intraocular lenses, including toric lenses, either alone or after implantations of ICRS are an additional option to correct refractive errors. Keratoplasty may be indicated in cases of scarring, extreme thinning or contact lens intolerance. This is a surgical procedure that replaces the keratoconus cornea with a healthy donor cornea graft [89].

Ophthalmic examinations include measurements that should be followed over time selecting data and determining changes in patients with keratoconus.

- i. Visual acuity
- ii. Slit lamp examination
- iii. Corneal power
- iv. Pachymetry and OCT pachymetry
- v. Tonometry
- vi. Topography
- vii. Subjective refraction
- viii. Retinoscopy
- ix. Cycloplegic retinoscopy
- x. Axial length with IOL Master
- xi. Anterior chamber depth
- xii. Tear film evaluation
- xiii. Corneal wavefront

Topography helps to assess the differences between keratoconus and normal astigmatic cornea. Also, topography detects the progress of keratoconus through the different stages and avoids misdiagnosis, in cases, for example, of pellucid marginal degeneration [15] (Figure 8).



**Figure 8:** Corneal topography and anterior segment OCT of a normal eye (a), keratoconus (b), PMD (c) and keratoglobus (d) [90].

#### D. Vital Keratoconus Classification

Vital keratoconus classification is a new generation coding system with 10 clinical parameters for the next generation treatment options for keratoconus developed by the Athens Vision Eye Institute and the Hellenic Eye Bank Demokritos Gregorios Georgariou in Athens, Greece. This research design incorporates 10 important clinical parameters that are necessary in choosing the two novel treatments: Sub Epithelial Collagen Refractive Treatment or Wavefront Phakic IOL-Gregory lens. This classification system gives a clear conclusion for the best surgical treatment option. The Vital classification or rather coding system provides clinical and anatomical keratoconus parameters that calculate an individual surgical treatment. These measurements are the age of the patient, visual acuity, best corrected visual acuity, visual acuity with glasses or contact lenses, minimal pachymetric thickness (using OCT pachymetry), the presence or not of scarring, Axial Length (AL) and Anterior Chamber Depth (ACD) with the IOL Master, topography of axial, curvature and wavefront maps as well as ablation maps (unknown/progressing/stable-topography). The coded system is Vi T A L, Vi for best corrected visual acuity, T for minimum thickness, A for Ablation map, L for anterior chamber depth and axial length. For example, for a 28-year-old patient with ViTAL: 28' Vi 1x, T 3s, A4, L13 with best corrected visual acuity 20/25, 434 $\mu$ m thickness and stable topography, ablation volume of 3500 nl, Anterior Chamber Depth >3,4mm and axial length more than 28 mm the best surgical treatment is Artiflex Toric Lens implantation [91].

Contact lenses are used to correct myopia and irregular astigmatism in keratoconus and to provide the best vision possible and comfort to the patient. Chang & DeNaeyer [17] report that the "increased higher order aberrations in patients with keratoconus lead to impaired vision function, making the need for the best possible contact lens fit even more important". A lens is selected based on the manifest refraction and the degree of corneal ectasia. It is important to mention that subjective over refraction is mandatory after contact lens fitting depending on the type of contact lens that the physician will choose in different situations. This refraction is usually calculated over the trial lens with the spherical equivalent of the prescription. There are a variety of lenses that can improve quality of vision in patients with keratoconus: soft contact lenses and soft toric contact lenses, rigid gas-permeable contact lenses, piggyback contact lens system, hybrid contact lenses, scleral and corneoscleral contact lenses [92]. The correct type of the contact lens that Optometrists choose is based on the stage of keratoconus. Clinicians select a soft contact lens in mid cone, a rigid gas permeable contact lens in cases of an advanced cone and a hybrid or scleral contact lens in severe cones for a better result of visual acuity and comfort [17].

The Table 1 that follows describes in detail each contact lens and the indications for use.



# Contact Lens Fitting: A Guide and Methodology of Contact Lens Fitting

**Table 1:** Contact lens and their indications for use.

<p>Soft contact lenses are spherical or spherical and toric contact lenses and are recommended at the early stage of keratoconus. These lenses are appropriate in patients with high myopia associated with keratoconus. Spectacles could be prescribed over soft contact lenses to provide better visual acuity. Soft toric contact lenses have a laser mark at the 6 o'clock position for physicians to evaluate proper contact lens fitting for astigmatism. Suitable contact lens movement is 1-2 mm and while movement up to 3 mm with good visual acuity is acceptable as well [93]. Soft keratoconus design contact lenses, especially soft hydrogel lenses, are about three to six times thicker in the center than in the periphery.</p>
<p>Rigid gas permeable contact lenses are lenses that are commonly used in vision rehabilitation of irregular astigmatism [94]. Moreover, RGP lenses reduce high order aberrations due to their movement and the small diameter of the lens. The GP lenses are placed at the center or near the apex of the cone. This is the most suitable choice of GP lenses in cases of central nipple cones and mild paracentral oval cones [93]. There are many materials and designs of modern RGP lenses with high oxygen permeability. These lenses have a small diameter, the lens adjusts to the cornea and the movement does not pass 1 mm from the limbus. Chang &amp; DeNaeyer [17] report that rigid gas permeable lenses categories depend on iris size:</p> <ol style="list-style-type: none"><li>Small diameter (8-9 mm)</li><li>Medium diameter (9-10 mm)</li><li>Large diameter (10-11.50 mm)</li></ol> <p>Due to the aspheric design technology of the front and back surface, RGP contact lenses produce clear vision because of the varying curvatures across the surface, thus correcting irregular corneal astigmatism. Frequently, wearers of RGP lenses experience corneal edema or neovascularization secondary to hypoxia [36]. According to Andy Franklin and Ngaire Franklin [20] in cases of an RGP lens both dynamic and static fitting can be used in which "dynamic fit refers to how the lens moves and centers on the eye and the static fit refers to how the back surface of the lens relates to the cornea".</p>
<p>Piggyback is a moderate fitting procedure that is used to describe a GP lens that is worn above a soft silicone hydrogel contact lens. A minus spherical power lens of -0.25 D or -0.50 D could be used to steepen the RGP lens and a plus spherical power of +0.25 D or +0.50 D could be used to flatten the RGP lens. Also, in the piggyback system, the refractive power of the soft lens accounts for about 20%. Both dynamic and static fit can be used to determine proper contact lens fitting. This method avoids apical bearing and protects the cornea from trauma and contact lens wearers from long-term discomfort. Daily disposable contact lenses are often preferable to avoid having two lens cleaning systems. Silicone hydrogel soft contact lens material ensures high oxygen transmissibility (Dk/t) that ensures tear exchange under the lens. Sherman &amp; Wilson [36] report that "the GP lens should be well centered over the soft contact lens, with minimal edge lift and good movement upon blink". The piggyback system's disadvantage is the insertion and removal of two different contact lenses, the increased cost and the fact that patients easily lose the RGP lens. Because of the two lenses the piggyback system poses a greater risk for the development of hypoxia and its complications. This method is not suggested in progressive keratoconus of an inferior cone [83]. Rathi, Mandathara and Dumpati [93] indicate, that piggyback lenses are required in patients with "RGP discomfort or intolerance, unstable RGP on the eye, popping out of the lens, 3 and 9 o'clock staining with RGP fit and presence of scar". When contact lenses are adjusted Optometrists can check the base curve on a flat k value with keratometry or topography measurements over the lens and a diameter of 9 mm to 9.50 mm.</p>
<p>Hybrid contact lenses have a new design with a central gas permeable lens surrounded by a soft material in the periphery. The GP center offers good vision quality while the soft skirt material provides comfort to the patients. The hybrid lens is a good choice for highly myopic patients, soft toric lens wearers and GP intolerant patients. Chang &amp; DeNaeyer [17] state that a lot of hybrid contact lenses have a reverse geometry design and "offer increased mid-peripheral sagittal height to better accommodate a decentered corneal apex" providing more comfort. These lenses have a small apical touch with poor centration and patients are at risks of hypoxia, edema and central cornea blur [93].</p>
<p>Scleral lenses achieve good visual acuity in advanced keratoconus. In this category there are mini-scleral, semi-scleral and scleral contact lenses [95]. Modern technology of scleral lenses are gas permeable contact lenses that have a unique design to correct irregular astigmatism created by keratoconus [96]. The diameter of a scleral lens is larger or equal with a small soft contact lens. The smallest diameter of a scleral lens is about 14.55 mm and the largest diameter can reach up to 24 mm. Due to their large size they fit under the eyelids and rest on the sclera providing a stable lens with less contact lens movement and more comfort. In addition, they protect and prevent irritation. Slit lamp examination helps Optometrists obtain proper corneal and limbal clearance with sodium fluorescein color patterns. Also, optical Coherence Tomography (OCT) measurements can be used in order to achieve a proper fit with scleral lenses. Scleral lenses are proposed in cases where contact lens fit does not improve vision because of discomfort and in cases of failed RGP fit [93].</p>

## E. Optical Coherence Tomography (OCT)

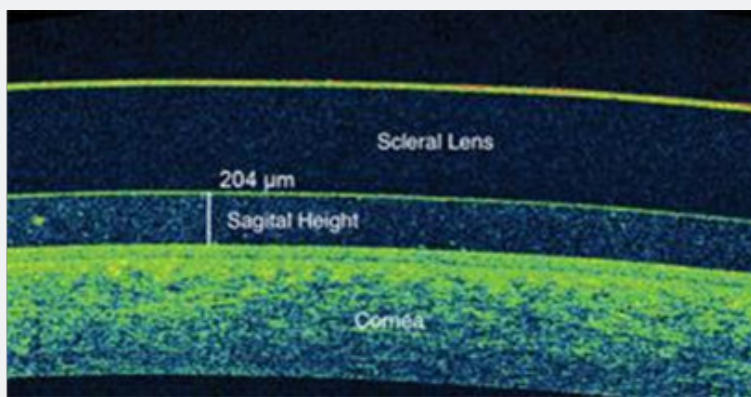
An optical coherence tomography device (OCT) improves scleral contact lens fitting with efficiency and accuracy. The software has the capability to assess both the posterior and anterior segment. OCT has the ability to measure the distance between the posterior part of the scleral lens to the anterior part of the cornea to determine the amount of central clearance in microns. Scleral contact lenses have to settle for at least 20 to 30 minutes before evaluation. Optometrists have to check central, limbal and edge clearance of the contact lens fitting when the patient looks right or left to see if there is any compression [97].

According to the article written by Pa [98] using optical coherence topography (OCT) for a "15 mm diameter scleral lens, the desired sagittal height is calculated by measuring the sagittal height of the cornea at the 10 mm chord and adding 2,350  $\mu\text{m}$  (2,000  $\mu\text{m}$  for the average height of cornea from the 10 mm to 15 mm chord and 350  $\mu\text{m}$  of desired tear film vault above the cornea). For each 1mm increase in size of the scleral lens, practitioners should add 150  $\mu\text{m}$ ".

OCT evaluation is useful when fitting hybrid lenses as it can measure the amount of clearance both for soft skirt and for gas permeable (GP) (Figure 9).





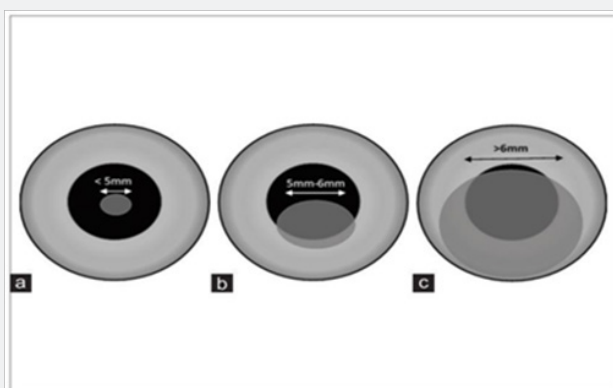


**Figure 9:** The OCT measurement of central lens clearance after the lens has settled (Pa, 2017a).

## F. Size and Position of the Cornea Ectasia

Selecting the type of contact lens depends on the shape, size and position of the cornea ectasia. There are three types of cone morphology:

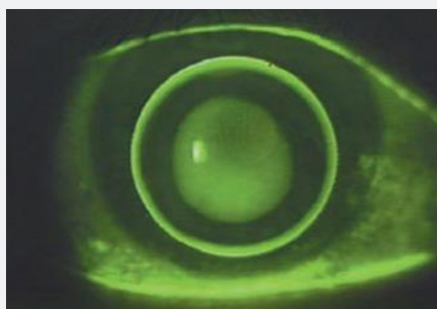
1. Nipple cone has a small size of 5 mm and steep curvature. The apical center is either central or paracentral and it is commonly displaced inferonasally [99].
2. Oval cone (or sagging cone) is a larger ellipsoid shape of 5-6mm size and it is usually displaced inferotemporally [99].
3. Globus cone is a very large and globe shape of > 6 mm size and may involve more than 75% of the cornea. The best map in the evaluation of corneal topography in order to determine the morphology of the cone is the tangential map [100] (Figure 10).



**Figure 10:** The three types of cones a) Nipple, b) Oval, c) Globus [100].

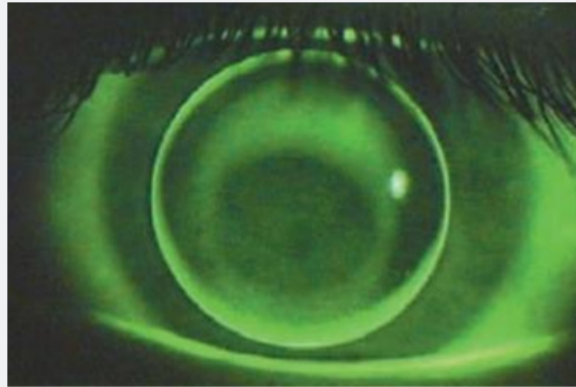
There are three different fitting techniques after placing fluorescein and observing contact lens fitting with cobalt blue filter using a slit lamp.

**A. Apical clearance:** Apical clearance refers to a steep clear central fit with lots of tears in the center and a tightening in the periphery. These lenses tend to be small in diameter and have a small optical zone. The benefits of this contact lens fitting method is that it reduces central corneal scarring [93]. On the other hand, the drawbacks of this technique are more. Some disadvantages are poor tear film because of the tightening of the peripheral area, corneal edema and poor visual acuity because of the bubbles that are usually trapped under the lens [102] (Figure 11).



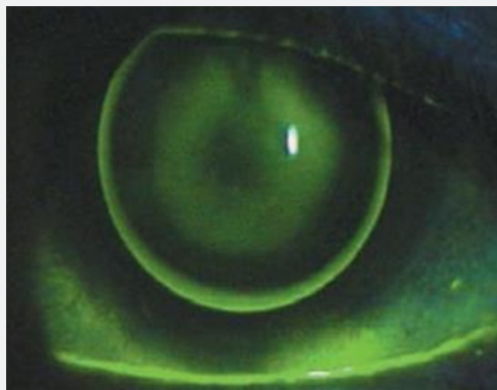
**Figure 11:** This figure shows use of the apical clearance technique with fluorescein patterns and line diagrams [101].

**B. Apical bearing:** The apical bearing technique, refers to the situation where the contact lens touches directly the cornea center. The advantages of this contact lens fitting method is that this method slows down the progression of keratoconus and provides good visual acuity. However, there are disadvantages in adopting this technique. This contact lens fitting technique creates excessive central pressure on the apex of the cone causing distortion, intolerance over time, scarring and swirl staining (quick circular staining). This method is rarely used today [102] (Figure 12).



**Figure 12:** This figure shows use of the apical bearing technique with fluorescein patterns and line diagrams [101].

**C. Three-point touch:** The McGuire fitting philosophy is based on three-point touch and it is the most advanced fitting technique in clinical practice providing long term comfort, stable fitting and vision to the patients [104]. The lens lightly touches the apex of the cone with a very low value of the edge of the cone touching the near edge of the lens of 0.5 mm-0.7 mm [93]. This fitting philosophy works very well for small central cones and it can be easily achieved and decreases the risk of apical scarring [102] (Figure 13 & 14).



**Figure 13:** This figure shows use of the three-point touch technique with fluorescein patterns and line diagrams [101].



**Figure 14:** This figure shows use the three-point-touch technique [103].

Contact lenses that are ordinarily used for keratoconus treatment are Menicon contact lenses:

- 1) Rose K2 are for early pellucid marginal degeneration, oval and nipple keratoconus.
- 2) Rose K2 NC are indicated for moderate and steep nipple cones.
- 3) Rose K2 IC are indicated for pellucid marginal degeneration, keratoglobus, oval keratoconus, Lasik, large or oval cones and in post grafted patients. These are large diameter lenses that improve lens centration and reduce movement of the lens [93].

- 4) Rose K2 Post Graft (PG) is for patients after keratoplasty, oval keratoconus, nipple keratoconus and Lasik induced ectasia.

## Theme 15. Contact Lenses after Keratoplasty

Contact lenses are used for rehabilitation of vision after keratoplasty.

Keratoplasty types are:

- a) Penetrating keratoplasty (PK)
- b) Deep anterior lamellar keratoplasty (DALK) (Reinhart et al., 2011).
- c) Descemet Stripping Endothelial Keratoplasty (DSEK)
- d) Descemet stripping automated endothelial keratoplasty (DSAEK)
- e) Descemet Membrane Endothelial Keratoplasty (DMEK) [105].

Keratoplasty is a technique to restore vision in patients with keratoconus, keratoglobus, post refractive ectasia, pellucid marginal degeneration, Fuchs' dystrophy, Bullous keratopathy, iridocorneal endothelial syndrome and other eye diseases [106]. Moore [107] mentions that a lot of contact lenses can correct astigmatism after keratoplasty and these are "scleral, rigid gas permeable and reverse geometry hydrogel lenses and silicone hydrogel soft contact lenses". With small amounts of astigmatism (about 1 D) physicians could start with soft contact lenses and in bigger amounts of astigmatism (about 4 D) hard gas permeable or large diameter rigid gas permeable lenses are suggested [107].

## Theme 16. Contact Lens Fitting after Refractive Laser Procedures

As mentioned in the beginning of the guide laser refractive surgery procedures correct myopia, hyperopia and astigmatism such as Laser in-situ keratomileusis (LASIK) and photorefractive keratectomy (PRK). In the LASIK procedure a flap is created with a microkeratome or femtosecond laser and it is placed back after application of the excimer laser. In the PRK procedure the epithelium is removed manually and then the excimer laser is applied. In LASEK the epithelium layer is replaced again and then the excimer laser is done to correct refractive errors [108].

Firstly, therapeutic contact lenses are used after refractive surgeries to protect the cornea. The bandage contact lens helps the regeneration of the epithelium from the abrasion of the eyelids. In other cases, contact lenses are worn because of complications after refractive surgery. In over correction of hyperopia contact lenses are worn to correct the cornea shape and to avoid another surgery. Also, contact lenses are used for over correction or under correction of refractive errors.

Refractive surgery may have the unpleasant result of corneal ectasia. Frogozo [109], mentions that a "typical cornea has a prolate shape, it is steeper centrally with flattening towards the periphery". Hyperopic LASIK or PRK surgery works by "ablating the peripheral cornea in order to steepen the central cornea". Moreover, Frogozo [109] states that in myopia surgery "the central cornea is ablated in order to make it flatter, which causes the peripheral cornea to steepen".

On the other hand, Rigid Gas Permeable contact lenses are a safe choice because they correct a big range of refractive errors of regular and irregular astigmatism and result in very good visual acuity. After refractive surgery there are changes in corneal shape, keratometry, cornea power, spherical equivalent and visual acuity. Scleral lenses in regular or in reverse design are used in high irregular astigmatism after refractive surgery, especially after LASIK.

The progression of myopia, astigmatism and of cornea steepening after laser refractive surgery is called iatrogenic keratectasia. Treatment with contact lenses is the same as the methods used in keratoconus. For better visual acuity and to protect the flap in cases of LASIK, scleral contact lenses of large diameter are recommended. If there is intolerance of contact lenses or poor visual acuity, keratoplasty is the other solution to regain vision.

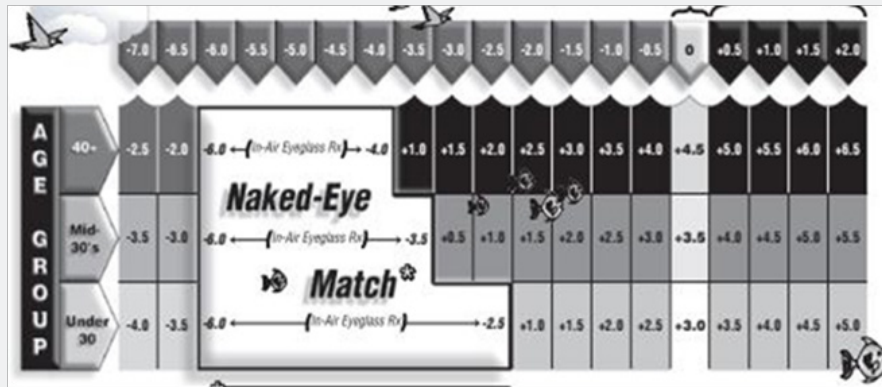
## Theme 17. PROSE Contact Lenses

PROSE or Prosthetic Replacement of Ocular Surface Ecosystem contact lenses are large diameter scleral or semi-scleral gas permeable lenses. PROSE lenses work well in patients with: corneal ectasia, ocular surface disease, graft-versus host disease, corneal dystrophies and complications after surgery. PROSE contact lenses restore quality of vision by correcting refractive errors such as high myopia, high hyperopia, regular and irregular astigmatism. These lenses protect the cornea and supports cornea healing, reduce pain and decrease light sensitivity. BostonSight PROSE contact lenses were approved by the United States Food and Drug Administration (FDA) in 1994 as devices that replace or support corneal diseases and ectasia [110].

## Theme 18. Contact Lenses and Scuba Driving

Under-water correction of refractive errors is achieved with corrective glasses or contact lenses. Contact lenses provide better peripheral vision underwater than prescription masks. Soft contact lenses are recommended over hard and gas permeable contact lenses. These lenses are larger in size and are difficult to lose, thus, providing a stable solution to the diver. Soft lenses also allow gas to pass through offering clear vision and comfort. According to Charles [111] "the cornea is a fast tissue meaning it will absorb nitrogen under

pressure rapidly". The contact lenses are prescribed by Optometrists because they can correct far vision or both far and near vision, with multifocal and monovision contact lenses. The disadvantages of using contact lenses underwater are that there is a possibility that bubbles might appear under the contact lenses and displacement of contact lenses might occur (Figure 15).



**Figure 15:** Contact lens power depending on age group and refractive errors or emmetropia for far distance [112].

Additionally, flat masks block 75% of the scuba diver's view. The HydroOptix MEGA 4.5DD is a new technology mask that provides 100% natural panoramic vision with a NASA technology. Only near-sighted divers can use this mask with their naked eyes; otherwise the users have to wear contact lenses in order to create temporary myopia. This is achieved with contact lenses in both eyes or by using the monovision method of correcting far distance with contact lens in the dominant eye. For example, a young diver under 30 years old, with emmetropia, can induce myopia on purpose with +3.00 D contact lenses in both eyes [113].

## Theme 19. Complications of Contact Lens Wear

Complications related to contact lens wear are caused due to inappropriate maintenance and extended wear. Many patients do not follow Optometrists' recommendations regarding proper contact lens hygiene. The most important risks and complications are: sensation of discomfort, cornea ulcer, dry eye and keratitis.

Feeling discomfort is related to environmental reasons such as high or cold temperatures. Also, computer vision syndrome and eye staining result from using a monitor for a long period of time daily. Peripheral ulcers due to contact lens wear cause significant conjunctival injections. Palioura [114] mentions that bacterial keratitis can "lead to severe visual impairment from corneal ulceration, subsequent scarring, and perforation". Treatment involves intensive use of toric antibiotics [115-117].

### III. Conclusions

This is a contact lens guide and it has a specific purpose. Its purpose is to make the reader understand the importance of contact lens fitting. Learning about the variety of contact lens materials, new technology, lens types and fitting techniques is crucial for the patients' well-being.

As time progresses a lot of research has been conducted and still is being conducted to assist patients and improve their eye-sight. Having good eye-sight not only enhances one's appearance for aesthetic reasons, but also boosts their self-confidence. Being healthy, in general, plays a significant role in a person's life and this must be acknowledged. The eye must be protected, as eye-sight is essential in a person's everyday life.

Contact lenses are used for many reasons; to mention a few: to correct refractive errors, to provide comfort and to give better visual acuity to the patient. These tips, for a proper contact lens fitting, prevent unpleasant situations, dissatisfaction and eye infections. This information enables Optometrists to have the proper knowledge in clinical practice for contact lens fitting at hand.

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