Chapter

# Advances in Non-surgical Treatment Methods in Vision Rehabilitation of Keratoconus Patients

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## Abstract

Visual acuity decreases due to progressive irregular astigmatism in keratoconus (KC). Although glasses can be useful in the initial stages of vision rehabilitation, contact lenses (CL) are needed in many patients due to irregular astigmatism. Although rigid gas permeable (RGP) CLs provided the patient with a better visual acuity than glasses, their effects on corneal tissues and caused comfort problems. Although soft CL produced for KC have solved some of these problems, they could not increase visual acuity as much as RGPs in advanced stage KC. For this reason, new searches for vision rehabilitation and comfort in KC have continued. In this context, piggyback contact lenses (PBCL) have been used in vision rehabilitation. Hybrid CLs have gained popularity due to the fact that PBCLs cause corneal neovascularization and giant papillary conjunctivitis. Scleral CLs have been developed for limited benefit in some patients with advanced KC. Scleral CLs provided good vision rehabilitation. The biggest problem of scleral CLs is the application and removal difficulty. All these CL modalities try to improve the quality of life and delay surgical procedures by increasing the level of vision in patients with KC.

**Keywords:** spectacles, rigid gas permeable contact lens, soft contact lens, hybrid contact lens, scleral contact lens, piggyback contact lens

## 1. Introduction

Keratoconus (KC) is the most common ectatic disease of the cornea. It is characterized by progressive thinning and protrusion of the cornea [1, 2]. Consequently, irregular astigmatism, myopia and a decrease in visual acuity occur. Therefore, the disease has a negative effect on vision-related quality of life. The disease has become an important public health problem due to the economic burden of treatment and vision rehabilitation related processes [3]. KC in children may have negative effects on social and educational development. In this respect, it is necessary to improve the vision in children at an acceptable level [4].

This disease, which mostly starts in young adults, can also be seen in children. It stabilizes in the fourth-fifth decades of life. KC, which usually shows bilateral asymmetric involvement, can be asymptomatic at the beginning, and visual acuity decreases as the disease progresses [1, 2]. Although some systemic involvement of

KC is shown, it is generally known as a local corneal disease [5, 6]. Abnormalities in the corneal epithelium, Bowman's layer and especially the collagen structure of the stroma play a role in the pathogenesis of the disease. Although it is suggested that various biochemical and genetic factors play a role in the etiology, its exact cause is not known exactly. The main diagnostic method of KC is placido disc-based corneal topography [2, 5, 7].

While surgical options in KC management aim to change the natural course of the disease and increase vision, the main goal of non-surgical options is to improve vision without damaging the ocular surface. Classical non-surgical treatment of vision rehabilitation in KC is glasses in a small number of patients and CLs in the majority of patients. In addition, modern surgical options such as intraocular lens implantation, corneal cross-linking (CXL), intra-stromal rings and anterior lamellar keratoplasty are also used in treatment. The common feature of these surgical methods is that they increase visual rehabilitation to a certain level due to residual refraction after surgery and ongoing irregular astigmatism, even if they are performed very successfully. Therefore, CLs are needed for vision rehabilitation after surgical methods [2, 7, 8].

Today, there is a global consensus that CLs play the most important role in the visual rehabilitation of KC patients [8]. Later developments in CL design and materials expanded the application options for KC patients. Considering that CLs cause ocular surface changes even in non-KC individuals, the main purpose of CL application in KC should be to increase visual acuity without compromising the health of the cornea and ocular surface [9]. While the patient should have good vision and comfort with the lens, the practitioner must find a suitable lens fitting that does not compromise the anterior ocular surface health. Therefore, the process is often time-consuming and difficult for both the patient and the ophthalmologist. Due to the nature of long-term CL use in KC, a careful CL selection should be made considering the physiological needs of the cornea according to the level of ectasia. Since CL movements can cause mechanical effects on the cornea with CL movements during millions of blinking, it is necessary to ensure that CL applies minimal contact and pressure on the cone in KC patients. In addition, since there are stem cells in the limbus region, which are hallmarks of corneal physiology and regeneration, contact with the limbal region should be minimized in order to prevent CLs from damaging the limbal region [2]. Scheimpflug imaging and anterior segment optical coherence tomography, which are frequently used in ophthalmology practice in recent years, can be used to evaluate CL fit. These imaging technologies can be used to reduce the time we spend evaluating CL fitting and to improve guides for CL fitting [10].

In addition to the severity of the KC, it is decided which type of CL will be selected according to the visual demand and comfort of the patient and the CL tolerance. With the latest advances in CL features and design, many CL options have been developed for patients with corneal irregularities, such as large diameter RGP lenses, scleral lenses, hybrid lenses and KC specific soft lenses. New data reveal that special design CLs, new design scleral lenses and hybrid lenses provide better visual acuity as well as better comfort than traditional RGPs [2, 8, 11].

## 2. Advances in non-surgical treatment methods in vision rehabilitation of keratoconus patients

### 2.1 Spectacles

Since astigmatism is mild in the early stages of KC, vision can be corrected with glasses. However, as irregular astigmatism increases in the middle and advanced stages, vision decreases dramatically and glasses play a limited role in correcting vision. In addition, since the disease is usually asymmetrical, correction with glasses can lead to anisometropia and anzioconia. Therefore, it is necessary to evaluate CL options for a better vision [8, 11, 12]. Glasses can only be given to selected patients who are intolerant to CL and who are not willing to undergo any surgery. Glasses can be prescribed on soft CL in some KC patients. Depending on the developments in CL technologies, the decrease in side effects due to CL and the effect of increased comfort may cause patients in the initial KC stage who can benefit from glasses nowadays to turn to CL. Because we can observe that CLs are frequently preferred instead of glasses due to esthetic concerns [11–13]. However it has been suggested that wearing rigid gas permeable CL (RGP) will increase the irregularities in the cornea and cloud the central cornea due to low corneal stiffness in KC patients under the age of 20. In order to prevent these problems, it has been stated that when visual impairment is detected in KC patients under the age of 20, it should be corrected with glasses as much as possible [14].

### 2.2 Soft contact lenses

Conventional spherical or toric soft contact lenses (SCL) can provide benefit in improving vision by correcting myopia and regular astigmatism in early stage or form-frusted KC. Since they transfer the irregularities in the anterior surface of the cornea to their anterior surfaces, their ability to correct irregular astigmatism, high-order aberrations and vision level is very low in the KC, and therefore it limits the use of conventional SCLs in the KC. These conventional SCLs are generally ideal for those with a visual acuity of 1.0 with glasses [2]. They may be beneficial in some situations where high myopia is associated with KC disease [13]. After CXL treatment, they can assist in early vision rehabilitation. Hydrogel SCLs can be used in situations where comfort is more important [2]. The success of these lenses can be checked with a topography to be made over the lens. Depending on the needs of the patient, hydrogels with high water content and silicone hydrogel lenses with high oxygen permeability can be selected.

Developments in production technologies and specific basic curve designs have enabled the development of SCL specific to KC [15]. New design SCLs, customized hydrogel SCLs and pin-hole SCLs have expanded the usage spectrum of SCLs in KC [11]. It has also been found that they have similar quality of life between RGPs and SCLs [16]. Because of their good centralization, they can be used in decentralized cones and large diameter cones. In KC, it helps to increase visual acuity by making the anterior optic surface (front lens surface) more homogeneous topographically and by reducing high-order aberrations. In some sophisticated SCLs (customized SCL), asymmetric optical correction is performed, aberrations are further reduced and a better vision is achieved [17]. These special SCLs designed for KC have a greater central thickness than conventional SCLs (between 0.3 mm and 0.6 mm). This central thickness helps the CL to have a more stable structure and a regular anterior surface is tried to be created by preventing the direct adaptation of the lens on the irregular cornea. Increasing CL thickness contributes to the increase of visual performance, but also causes a decrease in oxygen permeability. This increases the risk of developing possible complications due to hypoxia. Therefore, they have a thinner peripheral thickness that can be adjusted independently of the silicone hydrogel central part and provides comfort with the movement of the lens. Since they are designed for use in KC, options with high spherical and toric values are available [12]. HydroCone® (Toris K) (SwissLens, Prilly, Switzerland) and KeraSoft® IC (Bausch & Lomb Inc., Rochester, NY) are silicone hydrogel SCLs specially designed for KC [18, 19]. It has been reported that with these lenses, visual acuity at a similar degree to RGPs is obtained in KC [15, 19]. It has been shown that SCLs increase vision in a significant portion of patients with corneal ring implantation. In cases where satisfactory vision cannot be achieved with SCLs, PBCL systems can be used in these patients [20].

It has been reported that visual performance decreases when the movement of the SCL exceeds 0.5 mm after blinking. Therefore, the movement of these lenses is requested not to exceed 0.5 mm, which may limit the tear change under the lens [12, 21]. These lenses, in which a sufficient visual level is obtained, have low infection rates due to a sufficient tear exchange. Although they provide more comfort, low oxygen permeability (excluding silicone hydrogels) compared to RGPs, failure to correct severe irregular astigmatism is the biggest disadvantage of SCLs [12]. As a result, with the developments in recent years, comfortable use and high visual performance have been achieved with SCLs specially produced for KC. However, it seems that the use of SCLs in KC will increase with future developments.

### 2.3 Rigid gas permeable contact lenses

RGPs are the most frequently used CLs in the world to increase the vision level in KC. In a study, it was found that RGPs delay surgical interventions in 98.9% of KC patients [8, 22]. Today, there are various RGPs developed for KC, including multicurve, asferic and quadrant-specific designs [23]. The lens has a steeper central curvature, a flatter peripheral curve, and they have a non-fused surface appearance. It is indicated in KC patients in whom glasses or SCLs fail to improve vision [24]. RGPs provide a better vision in KC patients compared to glasses [25]. It has also been reported that it controls the progression of the disease with its mild shaping effect [22, 26]. Providing a smooth spherical anterior optic surface, RGP helps maintain the shape of the cornea by applying light pressure to the cone area (**Figure 1**). In addition, optically low order astigmatism and high order aberrations are corrected with the tear fluid under the lens. Thus, contrast sensitivity and visual acuity increases. When the limbal region is desired to be protected, corneal RGPs are placed in most cases because they do not have any interaction with the limbal region [12, 27, 28].

The tear film under the lens is observed with fluorescent dye and the fitting can be evaluated and easily applied by an experienced practitioner. The disadvantage of these lenses is that the contrast sensitivity is low due to high-order aberrations, even if the visual acuity is good when the centralization is not good or when there is a tilt. To overcome this, RGPs with large optical zone (7.50–8.00) have been produced. Moreover, lenses with aspherical surfaces that correspond to the ectatic cornea have been produced with increased diameter up to 10.00–11.00 mm. Large diameter lenses are more complex to fit. Better fittings are obtained with small central or

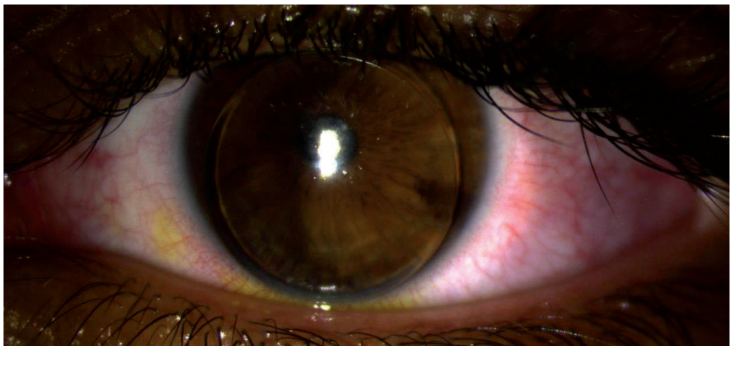

**Figure 1.**
*Rigid gas permeable contact lens on the cornea providing a smooth anterior optic surface.*

light cones [16, 29]. Dynamic and static fit should be evaluated 30 minutes after the CL is inserted. In dynamic fit, the centralization of the lens, its movement by blinking, and its stability in gaze positions are evaluated. The movement of the lens should not be more than 1 mm, it should not pass the limbus and its comfort should be maintained. In static fit, fluorescein is used to evaluate apical clearance, apical bearing, or three point touch [13]. Corneal astigmatism and higher order aberrations are reduced in all three methods. A larger diameter and flatter base curve is selected for apical bearing. The lens is directly supported by the corneal apex, and epithelial damage to the cornea secondary to the harsh between the lens and the corneal apex may develop an apical scar [30]. In this method, which provides a better visual quality, there is a risk of apical scarring. In apical clearance, a lens with a steeper base curve and smaller diameter is selected from the cornea, and the lens is supported by the cornea paracentral and there is a clear area between the central cornea and the lens. In this application where the risk of central corneal scar formation is reduced, tightening at periphery cornea may restrict tear exchange and may lead to hypoxic complications. In the three point touch method, which is the most popular method, the lens is supported mostly by the peripheral cornea and very little by the corneal apex [23, 31, 32]. In this method, attention should be paid to prevent contact of the lens with the corneal apex. Monocurve RGPs are used in mild to medium KC, and multicurve CLs are used in advanced KC. However, in some advanced KC, fitting of corneal RGPs may be more difficult and lens decentralization, dislocation, and disconfort may be encountered [33].

They can lead to a corneal warpage, especially in long-term use [34]. It can be a little difficult to get optimum comfort as it is made of rigid material only. There are studies showing that there is no relationship between KC severity and patient comfort, as well as studies showing that the opposite is valid [35–37]. Special cone-designed lenses such as Rose-K enabled RGPs to be very effective in visual acuity [38]. It has been reported that RGPs aggravate dry eye signs and symptoms in KC patients [39]. Since we may encounter a completely new eye after keratoplasty in liver patients, graft characteristics may make corneal RGPs contraindicated [40]. PBCL systems or scleral CLs can be used in these situations. RGPs allow for a good tear exchange. In advanced cases, a better vision can be obtained than SCLs, but discomfort, foreign body sensation and poor fitting in some advanced cases, especially in decentralized cones, are disadvantages of difficulty in centralization. Despite this, RGPs continue to be the first-line treatment in the visual rehabilitation of KC patients [8].

### 2.4 Piggyback contact lenses

Piggyback contact lenses (PBCL) contain two CLs in one eye, one soft CL on the cornea and RGP above the soft CL. Thus, the optical performance of RGP and the comfort of SCL are utilized. It is thought that the placement of an SCL under the RGP protects the cornea from the excessive pressure of the RGP, thus minimizing this possible complication of RGP use and increasing comfort. If the patient has residual astigmatism, residual astigmatism can be placed in the SCL (toric) in the PBCL system and thus a spherical RGP can be used. It has also been suggested that the use of SCL with high positive power will help improve the centralization of RGP on the keratoconic cornea especially in KC patients with inferior cone [13, 23]. PBCLs can be used as an alternative option in patients with intolerance to RGPs due to ocular surface disorders, and eyes that cannot be stabilized with RGP and staining at 3–9 o'clock. It is also indicated in keratoplasty and KC patients in whom rehabilitation cannot be achieved with RGP [13]. It has been detected that 2% of KC patients using CL used PBCL [13, 41]. They may also help increase vision in KC patients with a corneal ring [42]. First, a soft CL (preferably a silicone hydrogel with minus power) is inserted, in which optimum fitting is achieved. This SCL covers the entire cornea, providing a bandage effect that helps protect the KC apex and a better centralization. Therefore, PBCL systems provide better comfort and longer duration of use, although their visual acuity is similar compared to RGP alone [12]. The base curve of the RGP is selected according to the values in the topography and keratometry applied over this soft CL, and it is inserted over this soft CL. After the RGP is inserted, the compatibility of the lenses with each other is evaluated using fluorescein dye. By changing the power of the soft CL, the compatibility of the RGP can be changed. For example, a positive powered soft CL can be used to flatten the RGP, and a negative powered RGP can be used to steep the base curve of RGP [13, 43]. Most practitioners use a low positive power SCL as it is considered to facilitate the centralization of RGP. However, it has also been suggested that the use of negative powered SCLs in the PBCL system results in better oxygen transmission. Refraction is measured over the two lenses and subjective refraction providing the best visual acuity is added to the RGP power [44, 45]. For an optimal fitting, it needs to move independently but harmoniously with blinking at the slit lamp and have minimal touch in the pattern of fluorescence. This independent movement allows tear exchange between the lenses, allowing the use of dissolved oxygen in the tear [46, 47]. In order to reduce the risk of hypoxia, care should be taken to ensure that both lenses have a high Dk value. In addition, there are custom PBCLs produced by opening a groove where RGP will sit on the soft CL to increase the centralization of RGP. Since the edges of the RGP fit into the groove in these lenses, they can provide better comfort [13]. PBCL improves vision and comfort, but potential hypoxia-related problems are among its disadvantages due to the application of maintenance procedures for both lenses and the double barrier that prevents oxygen transmission to the cornea. Today, a combination of high DK silicone hydrogel SLC and high Dk RGP is often preferred to prevent hypoxia complications [47, 48]. Although the corneal epithelium and endothelium are not affected in this system, giant papillary conjunctivitis and corneal neovascularization may develop in some patients due to the presence of two lenses on the corneal surface [2].

### 2.5 Hybrid contact lenses

Hybrid contact lenses (HCL) consist of a combination of a rigid central zone and a soft peripheral skirt, manufactured using special technology. In these lenses, it tries to benefit from the best features of RGP (better vision) and soft materials (comfort). Therefore, HCLs can be an effective alternative to RGP and PBCLs. There are many special applications and designs that provide successful results in irregular corneas such as KC with these lenses [12, 49]. Modern HCLs are indicated when there is RGP intolerance or poor centralization, when an optimal RGP fit cannot be achieved, when there is reduced daily wearing time of RGP. They have also been shown to help improve vision after keratoplasty [33, 50]. Since these lenses with central RGP function and have soft peripheral skirt, they provide comfort as well as correcting vision. Therefore, they are preferred by many physicians and patients. Due to their design, HCLs distribute the contact equally between the cornea and conjunctiva or only touch the conjunctiva and peripheral cornea. Hybrid lenses generally consist of an 8.00 mm rigid part in the center and a soft hydrogel part with a total diameter of 14.50 mm. Correction principles are similar to those of RGPs. A good centralization is achieved in hybrid lenses owing to their soft skirt. However, they require special training and practice for successful application [2, 49, 50].

SynergEyes® Ultrahealth (SynergEyes Inc., Carlsbad, CA) HCLs are the next generation hybrid CLs that have been developed with a base curve design (KC), stronger RGP/silicone hydrogel coupling, and higher Dk of the central and peripheral region. Thus, hypoxia and fusion line tears are prevented. In the KC, the Vault of the rigid component and the skirt curvature of the soft component can be adjusted separately. In these lenses with a vault value ranging from 100 to 600 microns, optimum fitting is achieved with a full apical clearance with fluorescein dye and without air bubbles under the lens and a soft landing in the fusion area [12, 23]. There should be no air bubbles in the middle of the lens and a light touch on the rigid-soft junction. Unlike RGP lenses, the hybrid systems centralize the optics regardless of the cone position. Therefore it can be used in most central and decentralized cones. In this design, a steeper skirt enhances lens movement and prevents it from sticking. The data obtained from the corneal topography can be used to estimate the parameters when placing these lenses.

It has been shown in some studies that HCLs, which have the most superior features of comfort compared to RGPs, provide better visual acuity and contrast sensitivity than RGPs. For this reason, it has been stated that they have a higher vision-related quality of life score than RGPs. Disadvantages include giant papillary conjunctivitis and tearing of the soft skirt, corneal clouding [11, 51, 52]. In summary, HCLs serve the purpose of combining the superior features of rigid and soft CLs in a single lens. However, since studies in this area are limited, further research is needed.

### 2.6 Scleral contact lenses

The diameters of full scleral lenses range from 18.1–25.0 mm and have a scleral bed and maximum corneal clearance. Miniscleral lenses have scleral bed and minimal corneal clearance, with diameters between 15.0–18.0 mm. Semiscleral lenses have scleral and corneal beds and their diameters are between 13.6 and 14.9 mm. The corneoscleral lenses touch the corneal bed and sclera with a diameter between 12.9 and 13.5 mm [43]. Existing scleral lenses are produced from materials with high oxygen permeability such as fluorosilicon acrylate [53]. As the thickness of the lens increases, the oxygen permeability decreases, so nowadays it has become possible to make thin lens designs with new software. In addition, the lens surface is coated with plasma, increasing the surface wettability, thus increasing comfort and daily wearing time. Today, they can be produced with a very smoother surface and edge structure and less deficits during construction. Technological developments in lens materials, designs and lens production, lens placement techniques have led to an increase in interest in these lenses and increased acceptability of lenses in the treatment of KC [54, 55].

Scleral lenses rest on the sclera, do not touch the cornea and limbus, and leave a clear space between the cornea and the lens. Before the lens is placed in the eye, it is filled with a preservative-free saline. The lens consists of three parts: the optical part, the part extending over the sclera (haptic) and the Vault responsible for the corneal and limbal clearance of the lens. The optical part of the scleral contact lens (S-CL) is generally desired to be 0.2 mm larger than the horizontal visible iris diameter. However, it is also of great importance that the haptic part, which is more important in the fitting, and the corneal and limbal vault are appropriate for stabilization of vision [54, 55]. Today, the most commonly used S-CL fitting method is performed by the use of fitting trial sets. In addition, lens manufacturers can recommend a suitable guide. S-CLs mask irregular anterior corneal surface astigmatism with the fluid reservoir. The most important issue in applying these lenses is their alignment to the sclera. In some patients, edge lifts due to the toric structure of the sclera can be observed. Today, S-CLs with quadrant-specific peripheral designs can be produced for these KC patients with scleral asymmetry. This increases the comfort and lens wearing time of patients [56]. With the advances in CLs, S-CLs are also available today for elderly KC patients to rehabilitate near vision [8, 57]. However, studies on these are limited. Production of these specially designed lenses is still quite difficult, as they require special equipment and training and high cost [54].

Since the S-CL fits on the bulbar conjunctiva, minimal tear change occurs under the lens. The generally accepted minimum diameter for the cornea and limbal area to be unpressurized is 16 mm. Optical correction in these lenses is provided by the liquid under the well centralized lens. Therefore, anterior optical aberrations of the keratoconic cornea are neutralized. Front surface eccentricity in S-CLs aims to correct the optical quality and vision by compensating the back surface anomalies in the KC. Front surface eccentricity is zero in a spherical lens. Higher front surface eccentricity values indicate that the lens flattens rapidly from the center to the periphery [2, 27, 54, 58]. Providing continuous lubrication of the whole corneal surface ensures the stabilization of visual acuity [59]. S-CLs eliminate high grade aberrations and provide good centering and improve the visual quality. The complexity of the usage procedures and the poor comfort in long-term use limit their use [54]. S-CLs are generally not the first CLs to be applied in KC. They are preferred when tolerance problems are experienced with other CLs (SCL, RGP, PBCLs) or when acceptable vision cannot be obtained [49, 53, 54, 59]. S-CLs are indicated in RGP intolerance, very advanced and decentered cones, cornea staining at 3–9 o'clock, vascularization with PBCL, advanced KC. The fact that it is indicated in the presence of ocular surface disorder and in severe dry eye further expands the areas of use in the KC [60]. Corneal vaulting, centralization and perfect comfort have led to the preference of S-CLs in less severe cases, thus widening the indication for use of S-CLs in KC. S-CL designs are generally preferred after all corneal surgeries in the liver (CXL, intracorneal ring, keratoplasty). In such cases, higher Vault may be preferred if the ring or graft junction or sutures are to be protected [61–63]. If success is not achieved with these lenses, surgical methods are used. Contraindications are corneal edema due to decreased endothelial count, hydrops, and previous filtration surgery. Scleral lenses show success in extremely irregular and steep corneas because of their large diameters. Therefore, the role of treatment is increasing in advanced ectatic corneas where there is no option other than surgery. In addition, due to their large diameter and vaults, they are more comfortable than RGPs since they do not directly contact the cornea, which has much more innervation than the sclera. In recent years, new S-CL designs have expanded the scope of CL use in KC patients [11, 13].

Miniscleral lenses have less corneal opening than full scleral lenses. Small diameter lenses tend to adhere to the cornea due to the suction vacuum, which may cause difficulties for the practitioner [54, 64]. It has been shown that S-CLs reduce the need for keratoplasty and patients are successfully treated with S-CL instead of keratoplasty [65]. When the effect of CL on quality of life was evaluated in liver patients, it was seen that RGP, hybrid, soft CL had a similar effect. S-CLs are more comfortable than these lenses, but midday fogging continues to limit the quality of life in these lenses. In addition, unlike these lenses, S-CLs have been reported to reduce dry eye signs and symptoms [60, 66].

Haptic and vault are evaluated under biomicroscope in S-CLs. An acceptable fitting is defined by a corneal clearance, no air bubbles underneath, and no compression of the conjunctiva veins. After obtaining the appropriate fit, a trial use of 4–6 hours is required to evaluate the KC patient's comfort and visual quality. A 400–600 micron Vault is acceptable for scleral lenses. However, a slightly higher vault may be prescribed due to the detection of a decrease in the vault after four hours of use and also considering that KC may progress over time. A convenient central and peripheral vault ensures patient comfort and tolerability. Feeling suction while removing the lens after four hours of CL application and the presence of staining in the conjunctiva are indicators of choosing a flatter haptic. It is recommended that patients be examined again 3–4 weeks after removing the lens to make a final decision [13].

Disadvantages are maintenance procedures, frequent replacement of saline bottles, insertion regimes using plungers, which can be more cumbersome than other methods, reduced tear exchange, and high costs. S-CLs in KC can cause infectious keratitis or other adverse events. It has been suggested that this may be due to inadequate cleaning of the plunger used for inserting and removing the lens and improper use of saline solution [8, 67, 68].

## 3. The role of new imaging technologies in contact lens fitting in keratoconus

First of all, the data on the radii of curvature obtained in the corneal topography can be helpful in determining the initial base curve when placing the RGP. By evaluating the size and localization of the cone in the KC with the help of tangential maps in the topography, a more appropriate RGP diameter and base curve can be selected [69]. It has been reported that these data in the topography are also useful in hybrid lens fitting in KC [70]. These systems also include CL fitting simulation software to model the possible effects of lens designs and changes in parameters on the fitting. Rigid lens fluorescein simulations are based on corneal elevation data modeled on tangential maps. There are also studies showing that the video keratoscopic system gives successful results from standard methods in RGP fitting when compared to standard procedures. It was determined that the virtual sodium fluorescein staining pattern created based on the data from the CL simulator in the corneal topography and the actual staining pattern observed in the slit lamp were found to be highly matched. These findings show the importance of video keratoscopic virtual applications in CL management in KC patients and they have the potential to reduce the time we spend for CL [23, 71].

Previously, corneal clearance could roughly be estimated by comparing it with the thickness of the cornea. Today, with new technological devices such as anterior segment optical coherence tomography (AS-OCT), the amount of corneal clearance can be measured much more accurately (**Figure 2**). It is stated that the vault changed over time after the S-CL was inserted. It is important to follow this with

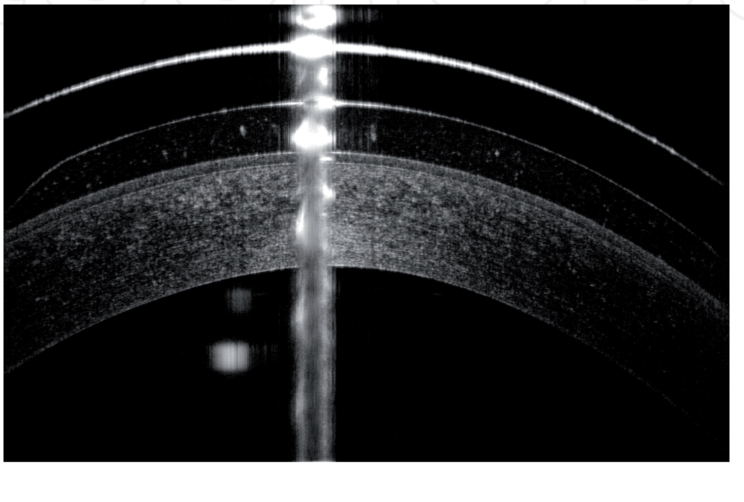

**Figure 2.**
*Anterior segment-optical coherence tomography image showing corneal clearance in a hybrid contact lens wearer.*

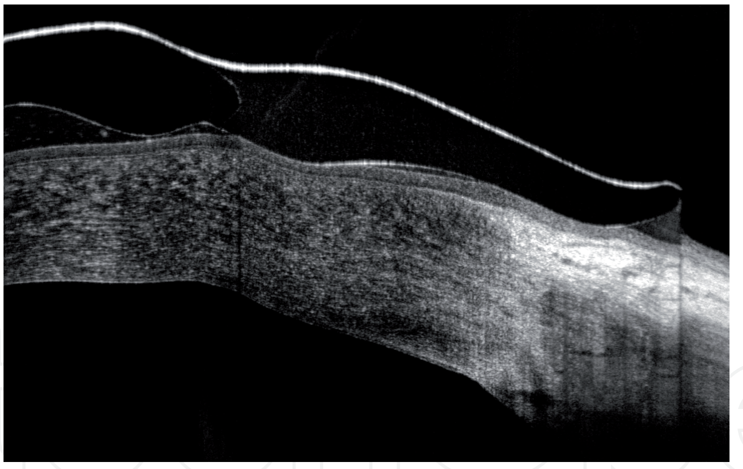

**Figure 3.**
*Anterior segment-optical coherence tomography image showing the interaction between the contact lens corneal and the conjunctival surface in a hybrid contact lens wearer.*

AS-OCT in progressive diseases such as KC. Because, in patients with KC, with the advancement of the cone and the decrease of the Vault, it may cause the touch between the cornea and the lens, corneal scarring and decreased vision. Therefore, the idea (owing to AS-OCT) that lenses can be used for a long time by increasing the vault has emerged in KC patients [54, 72]. The fact that the anterior segment AS-OCT provides in vivo information that cannot be obtained with videokeratoscopy and standard methods in CL applications of KC patients has led to an increasing interest in AS-OCT in CL practitioners. AS-OCT helps to examine the corneal midperiphery, the limbus region, the border structure of CL [73, 74]. Although OCT can also help evaluate scleral curvature, which will be useful in peripheral designs of S-CLs, it is not yet possible to measure scleral shape. OCT also helps to accurately evaluate the interaction between the anterior corneal and conjuctival surface and CL (**Figure 3**). It can measure the central and peripheral tear film clearance under the CL and thus provides information about the fitting [75, 76]. Central and peripheral vaults of hybrid, scleral and miniscleral lenses can also be measured with OCT. This helps us to examine in detail the relationship between asymmetric cornea and CL in KC. With using AS-OCT in CL practice, the maximum central cone vault values required to prevent edema due to hypoxia in the cornea under the scleral lens have been suggested. OCT also plays a major role in defining the relationship between CL and tears [8, 77].

## 4. Conclusions

Despite current surgical advances in KC treatment, CLs continue to be important for visual rehabilitation (even after surgery) in KC. Advances in CL design and materials have significantly expanded the application area of CL in the KC and ensured that the majority of patients have a satisfactory visual acuity. Thus, the rate of patients undergoing keratoplasty has decreased or the need for keratoplasty has been delayed. Although it takes a lot of time to choose the appropriate lens in KC, most of the patients with KC can benefit from CL use with the new designs and materials developed. CLs offer non-surgical options generally preferred for vision rehabilitation in the KC. SCLs, RGPs, PBCLs, HCLs, S-CLs constitute the contemporary range of lens types available for the vision rehabilitation of KC patients. This wide CL range meets the optometric needs of most of the patients with KC disease today and eliminates the need for major surgical procedures such as keratoplasty for vision rehabilitation for most of the patients.

Today, while SCL and HCL are the most commonly used in mild KC, the most frequently used CL in advanced KC is still RGPs and S-CLs. Since KC is a progressive disease, CL compliance should be controlled dynamically in certain periods of the patient's vision and comfort. If discomfort or intolerance develops in RGP, soft toric, PBCL or hybrid lenses may be considered. In the initial stages of the disease, SCLs are usually applied before other CLs are tried. Thus, the patient attains a good visual acuity and quality of life. When SCLs cannot provide this, secondly, RGPs are preferred because they provide a significant improvement in vision quality. When unsuccessful results are obtained with these CLs, PBCL or HCLs are used. If problems are encountered with these CLs, S-CLs are usually tried before surgery as a last option.

Imaging technologies such as corneal topography and OCT have enabled us to examine in vivo the relationship between asymmetric cornea and lens in the KC. Even with different modern CL treatments, it was found that both the quality of vision and life were lower in KC patients compared with the control group (healthy individuals without KC disease). This shows that CL treatment options and alternatives in KC treatment still need to be advanced.

## Conflict of interest

The authors declare no conflict of interest.

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