Scleral contact lenses for visual rehabilitation after penetrating keratoplasty: Long term outcomes

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Abstract

Purpose: To evaluate the success rate of highly gas permeable scleral contact lenses (SCL) for visual rehabilitation after penetrating keratoplasty (PK), over a period of up to 9 years.

Methods: A total database of 31 consecutive patient fitted with SCL between January 2004 and December 2009 was retrospectively reviewed. Demographic data, etiology prior to lens fitting, visual outcomes, follow up time and complications were analyzed.

Results: All eyes were fitted due to inadequate spectacle-corrected vision after successful penetrating keratoplasty or failure of other contact lens modalities. Out of 31 patients fitted, 28 (33 eyes) continue to wear SCL for periods between 0.5 and 8.8 years. The mean duration of follow-up after contact lens fitting was 5.2 ± 2.2 years. The mean age of corneal graft was 17.6 ± 11.4 years (range 4.3–42), and the mean interval between PK and initial contact lens fitting was 12.2 ± 10.7 years (range 0.7–36.0). The average steepest keratometry of our cohort was 55.0 ± 7.5 diopter (D) and the refractive astigmatism was 8.0 ± 4.4 D. The mean contact lens corrected visual acuity (BCVAcl) was 0.78 ± 0.25 (range 0.3–1.2). Twenty-three (82%) patients achieved a functional vision of 0.5 or more.

During the studied period, ten (30.0%) eyes presented at least one graft rejection episode and two eyes (6%) had an episode of microbial keratitis. Corneal transplants of 20 years or more show a higher rate of refits due to ectasia recurrence.

Conclusions: Scleral lenses should be considered as lens of choice in eyes with complex corneal geometry, as besides visual rehabilitation, their use may delay or prevent further surgical involvement.

1. Introduction

Penetrating keratoplasty (PK) or corneal graft is a surgical procedure which has been used for more than a hundred years. It provides vision restoration for a variety of corneal dystrophies and deformities. Indications for PK may include corneal ectasia, especially keratoconus (KC), corneal scarring, secondary to trauma or infection, various forms of keratopathy (pseudophakic bullous keratopathy and herpes simplex keratitis) and congenital corneal opacities (Peter’s anomaly, aniridia).

The main goal of penetrating keratoplasty is visual rehabilitation. However the procedure itself frequently causes abnormality of refraction, such as high degrees of astigmatism, irregularity or anisometropia which prevent the achievement of satisfactory vision and create a primary optical challenge [1]. New developments have taken place with the introduction of the deep anterior lamellar keratoplasty (DALK) procedure. As an extracocular procedure, DALK has important theoretic safety advantages in terms of the corneal endothelium survival [2]. Numerous studies indicate that the visual rehabilitation and refractive outcomes of DALK technique are similar to PK [3,4], however improved graft survival in DALK has yet to be demonstrated [2].

Spectacles are often impractical to rehabilitate the visual acuity (VA) of the grafted eye. In those cases, contact lenses may be required in order to improve vision and achieve binocularity. However, not all contact lens modalities can be fitted successfully after PK. The complex shape of the post-graft cornea, frequently featured by the centrally flat and peripherally steep pattern and/or over all asymmetry (i.e. irregular astigmatism) is a challenge to fit. Rigid gas permeable (RGP) contact lenses are commonly used after PK procedure [5,6]. Despite being considered as “gold standard of irregular cornea visual rehabilitation” [7] RGP contact lenses may not always be appropriate. Variable curvatures both centrally and at the donor–host junction [8] are often the reason for rigid lens decentration or even complete ejection from the cornea. Rigid
lens mechanical interaction with irregular or highly toroid corneal surface [9,10], leads to corneal micro-trauma, epithelial and ante-
rior stroma disruptions, and consecutive ocular inflammation [11].
The use of hydrogel contact lenses after PK is quite limited due to
inability of such lens to neutralize irregular or highly astigmatic
corneal surface. Increased lens thickness required for optical neu-
tralization of irregular cornea or when high astigmatic correction is
incorporated into the lens, leads to reduced gas transmission. Insuf-
ficient oxygen supply may cause corneal ischemia and, therefore,
increase the risk of graft rejection [12].

In recent years scleral contact lenses (SCL) have gained pop-
ularity among contact lens practitioners worldwide. These lenses are used to improve visual functions in patients with keratoconus
or other forms of corneal irregularity and to provide relief and an
improvement of corneal integrity in eyes with refractory ocular
surface disease [13–15,25,26]. Indications for scleral lens fitting
vary among authors, but the consensus amongst all is correction
of high or irregular corneal astigmatism after penetrating kerato-
plasty [13–15,25]. The first description of fitting scleral contact
lenses after PK procedure goes back to the early sixties [16], how-
ever, since then, new techniques in the manufacture of rigid gas
permeable scleral lenses have been developed [21–24].

Until the last decade of the past century, the advantages of scl-
eral contact lenses could not be fully realized, because of chronic corneal hypoxia attributed to low gas permeability of polymethyl
methacrylate (PMMA) and other materials from which the lenses
were made [17–19]. The development of rigid gas-permeable plas-
tics greatly reduced the hypoxic complications associated with
daily wear corneal lenses and added a new dimension to the poten-
tial of scleral lenses for the visual rehabilitation of patients with
markedly irregular corneas. Ezekiel [20] was the first to describe
the use of preformed fenestrated, silicone/acrylate gas permeable
scleral contact lenses in fitting patients with keratoconus, severe
myopia, aphakia, and corneal scarring. More recent reports based
on a large groups of patients describe an expanding role for scleral
lenses with respect to corneal ectasia and post keratoplasty visual
rehabilitation [14,15,25], together with high patient satisfaction
[26].

A variety of scleral lens designs have sprung up recently. In
addition to existing full size scleral lenses, corneo-scleral
(12.5–15.0 mm in diameter), and mini–scleral (15.0–18.0 mm) [27],
designs were developed. Mini scleral lenses, as a rule, exhibit min-
imal corneal clearance with moderate areas of scleral bearing. The
narrow haptics on mini-SCL provides a smaller area of landing
over the sclera, a fact that frequently leads to excessive compres-
sion near the limbus. Advantages of full scleral design, 18.1 mm to
24+ mm, are complete corneal clearance and broader area of scleral
alignment, the second in turn lessens a limbal compression.

In this article we describe our experience with 18.50 mm, pre-
formed gas permeable scleral contact lenses after PK procedure,
visual outcomes, and safety associated with their use. To the best
of our knowledge, this study has the longest follow up of patients
with corneal transplant fitted with scleral contact lenses.

2. Methods

Clinical data from the records of 31 patients (36 eyes), fitted with
SCL for visual rehabilitation after PK, in the 6-year period between
January 2004 and December 2009, were retrospectively analyzed
to determine the visual outcomes and safety of its use. The data
collection was made from December 2012 to January 2013.

All patients were referred to the contact lens clinic in the
Department of Ophthalmology, Hadassah University Hospital, due
to failure of spectacles, RGP or soft contact lenses to correct vision
adequately, or when fitting of such lenses was contraindicated and
other surgical options were undesirable. Only eyes fitted with SCL
three or more years prior to data collection were included in the
study. Collected demographic data includes patient’s age, sex, ini-
tial diagnosis, corneal graft age, follow-up period, and indications
for fitting. Best manifest refraction, at consultation, and contact
lens, at dispensing, visual acuities (BCVAref and BCVAcl respec-
tively) were recorded in the decimal equivalent of the Snellen ratio.
Patients manifest refraction in form of spherical component (Sph),
and refractive astigmatism (Cyl), steepest keratometry (Kmax) from
corneal topography measurements (Eye Sys Topography System
3000, EyeSys Vision, Inc., Houston, TX) obtained at the time of
the initial visit were recorded. Contact lens induced complications,
episodes of rejection and the number of refits during contact lens
use were evaluated. A statistical analysis was conducted by using
SPSS software (SPSS Inc., Chicago, IL), with the significance level set
at \( p < 0.01 \).

2.1. SCL features

The lenses fitted were lathe-cut preformed, non-fenestrated,
scleral contact lenses with an overall diameter between 18.50
and 19.00 mm (Microlens Ltd., Tel Aviv, Israel). The average cen-
ter thickness of the lenses was 0.30 mm. All lenses were prepared
from highly gas permeable polymer: Optimum Extreme (Con-
tamac Ltd., Saffron Walden, UK) having a permeability Dk value of
125 × 10–11 cm 2 mL/O2/s mL mm Hg (International Organization
for Standardization [ISO]/Fatt). Use of hyper-Dk/t RGP lens materi-
als (>100 Dk/t) have been shown to supply enough oxygen to the
cornea in all day lens wearers, which does not compromise corneal
health in terms of increased corneal swelling [28].

Each lens was designed to barely clear the steepest point of the
cornea and to provide the most uniform thickness profile of the
fluid accumulated between the lens and the cornea. The desired
clearance after lens settling (settling was minimal and inconsis-
tent) was 30–50% of a thickness of a healthy average cornea, i.e.
200–300 \( \mu \)m. By maintaining the minimal thickness of this reser-
voir, we optimized the oxygen transmissibility of the lens–cornea
system [29] and minimized the degradation of vision that occurs
if excessive tear debris accumulates inside. Liquid reservoir under-
neath the lens bathes the ocular surface with unpreserved saline or
artificial tears, therefore masking any irregular corneal astigmatism
(Fig. 1).

2.2. Fitting procedure

A single examiner (B.S.) fit the lenses for all patients. An indi-
vidual lens design was determined by an on–eye evaluation of
diagnostic scleral lenses with known parameters, after the lens had
been placed on the eye and had been in the position for at least
2 h. Corneal clearance was evaluated by slit lamp examination to
establish the optimal sagittal height of each lens.

In average lens, the internal optic zone of 12.5 mm was a
single curve surrounded by a 1.5–2.0 mm wide multi-curve tran-
sitional zone vaulting the limbus and merging seamlessly into the
posterior haptic surface. The haptic parameters of individual lenses
were determined by observing the vascular compression patterns
of the bulbar conjunctiva, using a series of diagnostic lenses of
different haptic designs aimed at minimizing lens induced com-
pression of conjunctival blood vessels and enabling unobstructed
blood circulation.

The patients were advised to wear the lenses on a daily basis.
The patients were also instructed to take short breaks every 6 h for
cleaning and refilling the lens with fresh, unpreserved saline. Lens
care consisted of cleaning, wetting, and disinfecting with standard
rigid gas–permeable lens solution systems. If there were excessive
CL deposits a peroxide based cleaning was added on a weekly base.
After dispensing, the patients were monitored periodically at the cornea and contact lens clinics for the status of the corneal graft, contact lens fit and complications associated with the CL wearing.

### 2.3. Indications for success/failure

We considered the fitting of SCL to be successful when wearing time of 10 h a day or more was achieved. Partial success was defined as ability to wear the lenses between 6 and 10 h a day. Wearing time less than 6 h a day was considered to be a failure.

### 3. Results

36 eyes of 31 patients were fitted with SCL. 26 patients were fitted in one eye and five patients in both. The male/female ratio was 26:5. The mean age ± standard deviation (SD) at time of fitting was 43.0 ± 14.2 years (range 19–74 years). The mean age of corneal graft was 17.6 ± 11.4, and ranged from 4.3 to 42 years.

Keratoconus, other forms of primary keratoectasia, and failed corneal grafts for KC were the most common indications for PK. Together, these groups accounted for 31 (86%) of the 36 eyes in the study. The remaining indications occurred relatively infrequently (Table 1).

The most common reason for contact lens fitting was irregular astigmatism 24 (67%) eyes, followed by significant graft toricity, defined as refractive cylinder of 5 or more diopters (D), 16 (44%) eyes. Seven eyes (19%) were found to have significant spherical anisometropia with a difference of 3 or more diopters of the spherical equivalent between the eyes. Two eyes with irregular astigmatism also had therapeutic indications for SCL fitting, one eye received corneal graft due to corneal descemetocoele secondary to alkaline burn and the other developed an ingrowth of irregular epithelium cells. Listed above categories are not absolute, as many patients were found to have multiple indications.

Three patients (3 eyes) failed to wear SCL for the first few weeks after dispensing, due to an inability to increase wearing time or to follow wearing schedule and therefore were excluded from further statistical analysis. Regarding the other 28 patients (33 eyes) continued with SCL, the duration of contact lens wearing period ranged from 0.5 to 8.8 years, with the mean follow-up time of 5.2 ± 2.2 years. The mean interval between PK and initial contact lens fitting was 12.2 ± 10.7 years (range 0.7–36.0 years).

The majority of our patients underwent corneal graft procedure due to keratoconus. Penetrating corneal grafts for keratoconus, counting for their third decade of life, have a tendency to reveal a decline in graft survival rates [30], and develop late-phase complications like progressive astigmatism [31] or recurrent ectasia [32,33]. We performed a separate analysis for a subgroup of our cohort, 12 patients (15 eyes) consisted of patients with corneal grafts older than 20 years of age (Group II). Eyes with corneal transplants aged less than 20 years were listed as group I. There was no statistically significant difference in manifest refraction sphere and astigmatism values between the groups. However eyes in group II demonstrated a trend to higher K max values, 57.0 ± 7.6 vs. 53.2 ± 6.8 D, but this was not statistically significant (Table 2).

#### 3.1. Efficacy

All treated eyes were fitted due to inadequate spectacle-corrected vision after successful penetrating keratoplasty. Some of those eyes had undergone multiple unsuccessful surgical procedures for reducing the iatrogenic astigmatism. In most of these cases, the scleral lens provided useful corrected vision, regardless of the amount or type of corneal astigmatism present.

The mean overall BCVAcl was 0.78 ± 0.25 (range 0.3–1.2). There was no clinically significant difference in BCVAcl between treated groups, 0.8 ± 0.3 in group I vs. 0.75 ± 0.2 in group II. The mean BCVAref was 0.30 ± 0.18 (range 0.05–0.7). There was a significant increase in visual acuity with scleral lenses (Fig. 2) compared to the spectacle corrected VA in all fitted eyes (p < 0.0001, paired t test). Improvement in BCVA, defined as a gain of two or more decimal acuity lines, was observed in 31 eyes (94%). In terms of functional vision 23 patients (82%) achieved a Snellen visual acuity of 0.5 or better.

Out of 28 patients who continued with SCL, 21 (75%) were successfully fitted as defined by success criteria, i.e. able to wear the lenses for more than 10 h a day, and 5 patients (18%) achieved partial success with SCL. Mean wearing time of successful wearers group was 13.0 ± 2.0 h a day (range 10–16). The mean wearing time among all fitted patients was 11.9 ± 3.5 h a day.

Four patients (4 eyes) discontinued the use of SCL after different periods of successful wear (average follow up of 1.8 years). The reasons for discontinuation were development of corneal decompensation (2 eyes), graft rejection secondary to lens abuse (one eye),

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**Table 1**

<table>
<thead>
<tr>
<th>Indications for PK</th>
<th>Eyes (%)</th>
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<tbody>
<tr>
<td>Keratoconus</td>
<td>27 (75%)</td>
</tr>
<tr>
<td>Failed PK for KC</td>
<td>4 (11%)</td>
</tr>
<tr>
<td>Cohan’s syn.</td>
<td>2 (6%)</td>
</tr>
<tr>
<td>Post LASIK ectasia</td>
<td>1 (3%)</td>
</tr>
<tr>
<td>HSK scar</td>
<td>1 (3%)</td>
</tr>
<tr>
<td>Alkaline burn</td>
<td>1 (3%)</td>
</tr>
<tr>
<td>Total</td>
<td>36 (100%)</td>
</tr>
</tbody>
</table>

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Fig. 1. Optical section is used to define pre-corneal tear reservoir thickness profile.
Table 2

$K_{\text{max}}$, refractive cylinder and daily wearing time values for post keratoplasty groups (Group I – corneal transplants <20 years of age; Group II – corneal transplants >20 years; SPH, spherical component of manifest refraction; CYL, refractive astigmatism; $K_{\text{max}}$, steepest keratometry; D, diopter; F/U, follow-up time).

<table>
<thead>
<tr>
<th>Groups</th>
<th>Eyes (%)</th>
<th>SPH ± SD (D)</th>
<th>CYL ± SD (D)</th>
<th>$K_{\text{max}}$ ± SD (D)</th>
<th>F/U ± SD (years)</th>
<th>Daily wearing time ± SD (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>18 (54.5%)</td>
<td>−2.2 ± 5.6</td>
<td>8.4 ± 5.3</td>
<td>53.2 ± 6.8</td>
<td>4.5 ± 2.0</td>
<td>11.8 ± 2.4</td>
</tr>
<tr>
<td>Group II</td>
<td>12 (45.5%)</td>
<td>−2.3 ± 5.4</td>
<td>7.6 ± 3.2</td>
<td>57.0 ± 7.6</td>
<td>6.0 ± 2.2</td>
<td>11.9 ± 4.0</td>
</tr>
<tr>
<td>Total</td>
<td>30 (100%)</td>
<td>−2.2 ± 5.4</td>
<td>8.0 ± 4.4</td>
<td>55.0 ± 7.5</td>
<td>5.2 ± 2.2</td>
<td>11.8 ± 3.5</td>
</tr>
</tbody>
</table>

and end stage glaucoma (one eye). There was no statistically significant difference between the mean of refractive cylinder, $K_{\text{max}}$ or wearing times of patients who dropped-out lens wear to those who continued.

An average of 1.7 lenses per eye was fitted during the study period. There was a trend to more frequent lens refits in the group II, 1.95 lenses vs. 1.4 in the group I. The primary reason for refit, in this group, was the gradual decrease of corneal clearance, observed over time in 6 (40%) of 15 eyes. Thinning of the pre-corneal liquid reservoir was contributed to progressive steepening of host cornea, as a part of the natural course of the disease or recurrent ectasia.

3.2. Complications

During the study period, serious graft complications occurred in 12 (36.4%) out of 31 fitted eyes (Table 3). Out of ten (30.0%) eyes that demonstrated at least one graft rejection episode, eight eyes were successfully treated and controlled by topical corticosteroids. Two other eyes exhibited signs of corneal decompensation and were advised to discontinue the lens wear. The incidence of rejection episodes was higher in group I, 7 (21%) eyes. Two eyes (6%) in group I had an episode of microbial keratitis (MK) that was probably related to patient non-compliance. The other noticeable complications were contact lens induced corneal graft edema (Fig. 3), corneal erosions and compression due to ectasia recurrence (Fig. 4).

One of the benign complications associated with scleral lens wear is conjunctival folds (Fig. 5), but clinically it does not seem to have any effect on either corneal transplant or scleral lens performance.

4. Discussion

Contact lenses are used by more than 50% of patients after successful penetrating keratoplasty to achieve better visual functions [34]. In our series, vision improvement was the primary indication for SCL fitting, and was achieved in most instances by the establishment of an optimal anterior optical surface, with an appropriate refractive correction. Our patients tolerated contact lenses well with significant improvement of VA, as compared to the best-corrected vision without a SCL. Visual outcomes varied according to the pre-existing ocular status and the clarity of the corneal transplant, and ranged from 0.3 to 1.2. All of our patients demonstrated high degrees of astigmatism or/and corneal irregularity. Studies have shown that the rates of postoperative astigmatism, higher than 5.0 D, may vary from 18% to 23% [35]. Irregular astigmatism induced by a corneal graft misalignment is one of the main reasons why contact lenses provide better visual results than spectacles [36]. However, the irregular corneal surface after PK often prevents achieving an optimal fit with corneal lenses [37]. Scleral lenses that are characterized by excellent centration do not touch any part of the cornea and provide good optical correction without the danger of corneal damage.

A number of surgical procedures were developed to decrease post-keratoplasty astigmatism or anisometropia [38]. When the graft astigmatism is of moderate amount and regular, laser refractive surgery has been shown to be effective. LASIK (laser in situ keratomileusis) might be superior to PRK (photorefractive keratectomy) for the treatment of myopia and astigmatism of low degree [39,40]. Correction of high refractive errors requires high energy levels and, therefore, may be associated with corneal haze, scarring or graft rejection. Furthermore, the application of microkeratome itself may provoke wound dehiscence [40]. Incisal techniques [41,42] have been shown to be effective in correcting post keratoplasty astigmatism, but the results are frequently unpredictable, since the depth or location of the incisions cannot be calculated preoperatively. Additionally, the risk of perforation always exists. Contrary to surgical options, the safety and efficacy of scleral contact lenses was previously reported by a number of investigators [13–15,25,43]. Studies performed on a large cohort of patients described the successful use of SCL for visual rehabilitation of

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**Fig. 2.** Graph showing the distribution of manifest refraction vs. contact lens BCVA in eyes dispensed with SCL ($n = 33$).

**Fig. 3.** SCL induced corneal graft edema. Note: contact lens full-thickness crack corresponded to edematous area.
Table 3
Corneal graft complications among groups fitted with SCL (percentage given out of the total number of eyes wearing SCL). Group I – corneal transplants <20 years of age; Group II – corneal transplants >20 years.

<table>
<thead>
<tr>
<th>Complication</th>
<th>Mean graft age (years)</th>
<th>Graft rejection</th>
<th>Graft–host ectasia</th>
<th>Microbial keratitis</th>
<th>Corneal edema</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I, eyes</td>
<td>8.8 ± 3.8</td>
<td>7 (21%)</td>
<td>3 (9%)</td>
<td>2 (6%)</td>
<td>1 (3%)</td>
</tr>
<tr>
<td>Group II, eyes</td>
<td>28.1 ± 8</td>
<td>3 (9%)</td>
<td>6 (18%)</td>
<td>0</td>
<td>1 (3%)</td>
</tr>
<tr>
<td>Total, eyes</td>
<td>17.6 ± 11.4</td>
<td>10 (30%)</td>
<td>9 (27%)</td>
<td>2 (6%)</td>
<td>2 (6%)</td>
</tr>
</tbody>
</table>

Fig. 4. Subepithelial fibrosis of donor tissue located near to the host–donor junction (left). The fibrosis is related to the contact lens corneal bearing (right), as a sequence of corneal profile elevation (recurrent ectasia).

irregular corneas, when keratoplasty was listed as one of the primary indications.

Various studies on scleral lenses used different methods to assess wearing time. The mean wearing time in the current study was 11.8 h a day, that similar to reported by Severinsky and Milledot [15] (11.9 h daily wearing time) in the retrospective study conducted on 97 patients, when nearly all had either ectatic corneas or corneal irregularities following penetrating keratoplasty. In the study performed on a larger amount of patients, Pullum et al. [43], found an average of 10 h or more wearing time in 59% (n = 538) patients.

The performance of scleral lenses is also reflected in the necessity to take a break during the day. Scleral lenses are designed to rest on bulbar conjunctiva, which is a pliable tissue. In some eyes, the lens may depress it and cause compression. In this case the paralimbal area will become swollen and injected. Also tears exchange underneath the lens will decrease significantly [44]. When the lens is not fluid-vented or the exchange of liquid reservoir has damped due to a lens seal-off, the cornea will be exposed to a toxic swamp that has accumulated beneath the lens. Stagnation of the fluid in pre-corneal chamber may lead to severe punctate epithelial keratophaty (Fig. 6), corneal ischemia and edema. Aspiration of the fresh tears under the lens edge provides additional oxygen supply to the cornea, and was shown to be associated with successful fit and increased wearing time [15]. Thus graft patients should be advised to have breaks during contact lens wear as often as possible in order to minimize toxicity damage. Tan et al. [45] reported that patients with gas-permeable lenses scleral lenses need a break in 45.5% of the eyes. In the study by Visser et al. [26], nearly half (48.9%) of the patients removed and reinserted their lenses during daily wearing.

Fig. 5. Superiorly located conjunctival fold (arrow) under well fitted SCL.

Fig. 6. Epitheliopathy of corneal transplant.
The failure rate of our study was 19.4%. Four patients had stopped the use of SCL after different periods of successful wear, and three individuals failed to wear SCL in the first weeks after dispensing. This number concurs well with the results of other investigators. In a retrospective study, Tan et al. [45] found that 71% of the eyes could continue wearing the scleral lens, Pullum and Buckley [13] described that 22% of their cases failed a scleral trial or stopped wearing their scleral lenses completely.

Most complications associated with SCL wear responded well to appropriate management. Ten (30%) eyes demonstrated at least a single episode of graft rejection. Whereas eight eyes were successfully treated by conservative treatment (topical corticosteroids), two eyes had demonstrated corneal decompensation, which was attributed to the reduction in endothelial cells density, and the patients were advised to stop SCL use. While it cannot be directly proven that contact lenses by themselves play a significant role in graft decline, we do believe that factors associated with contact lens wear, such as corneal hypoxia, microtrauma, epithelial erosions and the toxic effects of preservatives in rigid gas-permeable contact lens solution systems, may all compromise corneal graft health and cause chronic ocular surface inflammation. This chronic inflammation may in turn provoke episodes of graft rejection and graft decline.

Corneal graft rejection rate in our cohort coincides with the results of other researchers. In a longitudinal study Jonaschiet [46] and colleagues found that of 43 penetrating grafts for keratoconus, 15 experienced at least one episode of rejection. Another retrospective study [32] reports rejection rate of 30% in clear corneal transplants 20 or more years old.

Two of our patients had an episode of microbial keratitis. The exact etiology of MK remains unknown, but we suggest it was probably related to patient non-compliance to remove and reinsert the lenses during the day, contact lens over wear or bacteria aggregates in precipitates covering contact lens surface as a sequence of poor cleaning (Fig. 7).

Most irregular cornea patients are fully dependent on their contact lenses and therefore wear them all day long. This may lead to corneal hypoxia. In our study two eyes (6%) had demonstrated recurrent episodes of transient corneal edema. Edema has a tendency to appear when oxygen level is below minimal requirements for normal corneal oxygenation. Mild edema resolves spontaneously with discontinuation of contact lens wearing. The use of hypertonic saline (5% NaCl) has been shown to accelerate corneal recovery from hypoxic events [47]. When the episodes of corneal edema persist, we tend to advise topical instillation of 5% NaCl solution during the removal/reinsertion procedure. Additional to positive fluid-venting properties of SCL, a combination of hyper gas permeable lens materials and minimization of contact lens and pre-corneal fluid layer thicknesses will increase oxygen permeability of the lens–cornea system [29].

 Conjunctivochalasis is frequent in eyes of contact lens wearers especially when the ocular surface is compromised [48]. Since conjunctiva is pliable, it may get underneath the space designated for “limbal clearance” and create a “conjunctival fold”. The “folds” may block fluid exchange beneath the lens and lead to stagnation. In such cases decreasing limbal vault, i.e. minimizing the space between the lens and the limbus may be helpful.

In our study the major indication for PK was keratoconus. It is known that penetrating grafts performed for keratoconus exhibit better visual outcome and graft survival than grafts performed for other indications. The 20-year graft survival for a penetrating graft for keratoconus in recipients of all ages stands at 49% [35].

The average initial graft to fit interval in our study was more than 12 years. This value is relatively high when compared to the data presented by other researchers [5,6] and may be explained by good spectacle corrected visual acuity, which is often a rule after a successful PK. In an Australian corneal graft registry study in 44% of 4834 total penetrating grafts for keratoconus, spectacles were used as primary visual correction, while 39% did not use any type of visual correction at all [35]. As corneal astigmatism progressively worsens and the cornea becomes more irregular, spectacles became impractical and the need for contact lens correction rises.

Practitioners should be aware of ectasia recurrence when fitting corneal transplants, counting for second or third decades of their lives. Among our cohort, the average $K_{\text{max}}$ value was higher in group II, 57.0 ± 7.6 D. Six (40%) of 15 eyes in this group, required one or more lens changes due to over time developed SCL bearing on donor cornea or graft–host wound. Elevation of corneal profile may be explained by progressive misalignment of the graft–host interface or steepening of the host cornea (i.e. recurrent ectasia).

The rate of graft–host ectasia varies from 11% to 39.6% [32,33] with 20-year keratoconus recurrence probability of 10% [49]. However, despite graft ectasia, most of these corneal transplants remain clear and may provide excellent vision. Additionally, as each subsequent corneal transplant has a higher risk of early failure, delaying surgery in such cases would be beneficial.

This retrospective study describes prolonged and successful use of scleral contact lenses after penetrating keratoplasty. Our patients demonstrated good visual outcomes and sufficient daily wearing times. The major complication of concern remains graft rejection. However, its rates were consistent with data provided by other, non-contact lens related, reports. Contact lens mechanical complications such as compression and corneal erosions, which thought to be related to the protrusion of corneal profile, were successfully resolved by changing lens design.

We believe that scleral lenses are the best contact lens option available for eyes with complex corneal graft geometry. In addition to successful visual rehabilitation, SCL may delay or prevent further surgical involvement.

**Conflict of interest and source of funding**

Boris Severinsky, Joseph Fruct-Pery and Abraham Solomon have no financial or proprietary interest in any material or method mentioned.

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