Chapter

How to Improve Visual Acuity in Keratoconic Cornea?

Josefina A. Mejías S, Marta G. Hadid, Luis Izquierdo and Maria Henriquez

Abstract

Keratoconus is one of the most important corneal diseases that causes preventable blindness, so we decided to review the main techniques for improving visual acuity in patients with progressive and nonprogressive keratoconus, in order to expand knowledge in relation to the range of therapeutic possibilities that exist today and the benefits and risks of each of these alternatives.

Keywords: keratoconus, visual acuity, corneal blindness, intrastromal corneal rings, scleral lenses, phakic toric lenses, ICL, artisan, Artiflex, corneal transplant, DALK, penetrating keratoplasty

1. Introduction

Keratoconus is an asymmetric bilateral corneal disease, defined as noninflammatory in which the cornea changes its usual morphology and begins to cause a corneal thinning with protrusion of the thinnest area. It usually begins between the first and second decade of life, without predilection for sex, and progresses gradually until the third decade with deterioration of visual acuity in the form of irregular myopic astigmatism that does not improve with the usual existing correction measures (frame lenses or soft contact lenses) [1, 2].

Histopathological changes include disruption of Bowman's layer, stromal and epithelial thinning, folding or rupture of Descemet's membrane in severe cases, and a variable amount of scarring, especially in the anterior stroma, always with normal endothelium [2].

Some of the risk factors described are eye rubbing, asthma, a history of allergic rhinitis, or allergic conjunctivitis, as well as a family history of keratoconus, although there is no inheritance or genetic pattern involved so far [3, 4].

In relation to the clinic, it is presented as a decrease in progressive visual acuity without improvement with correctors.

About the treatment, there are different approaches according to the objective planned. For correction of visual acuity in mild cases, it can be achieved for rigid gas-permeable lenses; in moderate to severe degrees, contact lenses are also used, but surgical techniques are added such as intrastromal rings, toric intraocular lenses, refractive phakic toric lens surgery, and lamellar and penetrating corneal transplants.

About progressive keratoconus there are two lines of treatment, as a first line to stop the progression of the disease and in the second instance to improve the visual

acuity and quality of life of the patient. Currently the only FDA-approved treatment to stop the progression of the disease since April 18, 2016 is corneal collagen cross-linking (CXL) [4].

2. Visual acuity improvement techniques in patients with keratoconus

Intrastromal corneal rings
Toric intraocular lenses of anterior and posterior chamber
Corneoscleral contact lens
Lamellar and penetrating corneal transplant

2.1 Corneoscleral contact lens (CScL)

Keratoconus patients tend to be complicated to treat because they are forced to leave their glasses frequently due to oscillations in their refraction because their measurements are unstable and must continually adapt to new glasses or other types of devices to achieve an optimal visual acuity [5]. The visual correction of the keratoconus will depend on the stage in which it is found; in the early stages astigmatism can be corrected with glasses; however, when it is moderate to severe, contact lenses become the most appropriate option before placement of intrastromal rings or corneal transplantation [6].

Contact lenses for the treatment of keratoconus were induced by Adolf Fick in 1888 [6]. The corneoscleral contact lens (CScL) are rigid oxygen-permeable gas lenses and are composed of fluorosilicone acrylate; these rest partially on the cornea and conjunctival tissue and are used to improve vision in patients with high or irregular astigmatism either secondary to keratoconus, marginal pellucid degeneration, keratoglobus, or posttransplant astigmatism, as well as other pathologies such as Steven-Johnson syndrome, scar pemphigoid, or graft versus host disease may require its use, and also for patients who do not tolerate conventional gas-permeable rigid lenses [7, 8].

There are several types of contact lenses that can be used for the correction of visual acuity, astigmatism, and high-order aberrations in patients with keratoconus such as the corneoscleral contact lenses mentioned above, the mini-scleral contact lens (MSCL), the piggyback contact lens, and the rigid gas-permeable contact lens (RGPCL), being the hybrid contact lens (HCLs), soft toric lenses (STCLs), and corneoscleral contact lens (CScL) the most used for the correction of refractive error reporting excellent comfort and better vision with the corneoscleral contact lenses since the latter tends to be more accessible to use than conventional [5, 6, 9].

There are two types of scleral lenses: those ventilated by air or fenestrated or those ventilated by fluid or not fenestrated; according to Rathi et al. [7], fenestrated lenses tend to compromise visual acuity because air bubbles can enter the visual axis altering vision, while this does not happen with non-fenestrated ones. There is a difference between mini-scleral lenses that have less corneal clearance but are likely to get stuck in the cornea due to the suction vacuum and its smaller diameter [7].

Corneoscleral contact lenses have factors that can affect your refractive performance such as the scleral or haptic portion that rests on the sclera and should be between 12.60 and 13.5 mm, the vault that is involved in the corneal and limbal clearance, the base curvature which should vary between 5.8 and 9.2 mm, the peripheral or scleral curves ranging from 5 to 6 to 11.4 mm, and the central optical portion that should be 0.20–0.27 mm more than the horizontal diameter of the iris, and its powers range from +20.00 to −25.00 D so that when making the calculation of the lens and its adjustment, these three factors must be taken into account [7, 8].

The advantages of these lenses are that they are less mobile, focus better on the cornea, and have no contact with it so it does not cause irritation discomfort since they settle on the conjunctiva and the sclera; the ideal measures are between 15 and 17 mm of diameter or more. One of the advantages of this type of contact lenses is that they create a new ocular surface to compensate for the optical system so they must be filled with liquid before being placed and can be used for a longer time than conventional ones as long as the height of the vault is larger, so it is usually comfortable for some patients given the extended hours of use without complications [5–7, 10].

The disadvantage of soft, silicone hydrogel and permeable gas lenses concerning scleral lenses is that they cannot neutralize irregular astigmatism, so they do not provide visual acuity as suitable as corneoscleral contact lenses [5, 6].

Soft toric lenses (STCLs) are limited for the correction of astigmatism in an irregular cornea but are comfortable and are only indicated in patients with early keratoconus [6]. The corneoscleral contact lenses correct astigmatism through the fluid reservoir, and the haptic should be aligned with the sclera to position it properly and avoid high-order aberrations and correct them [8, 10].

On the other hand, RGPCL improves corneal irregularities through the tear layer between the lens and the anterior corneal surface and decreases higher-order aberrations because they provide a regular refractive surface but tend to be intolerable and are indicated in mild to moderate keratoconus. HCLs have a rigid central part and a soft peripheral part to reduce discomfort and improve visual acuity but still develop many complications. MSCL and CScL improve visual acuity, are comfortable, and delay the need for keratoplasty in the eyes with advanced keratoconus; these lenses rest in the sclera without touching the cornea or limbus but should be used with appropriate ophthalmic solutions to reduce turbidity [6, 8, 10].

In the study of Saraç et al. [6], it was determined that the uncorrected visual acuity (UCVA) of users with MSCL, CScL, and RGPCL was greater than the users of STCL; topographic astigmatism in MSCL and CScL was greater than those of the STCL, but the cones that were in the center had a spectacle-corrected visual acuity (SCVA) lower. In conclusion, MSCL and CScL are good alternatives to RGPCL and HCL for the correction of visual acuity since it achieves more efficient levels of visual acuity than other types. The study it was also determined that patients undergoing corneal collagen crosslinking (CXL) had a better visual acuity than those who had not undergone this treatment, so that a condition to achieve adequate visual acuity can also be submitted to patients to this type of treatment and then adjust the contact lenses.

According to Montalt et al. [10], residual high-order aberrations remained high compared to normal eyes after the use of CScL; this study highlights that although spherical and high-order aberrations were improved after the use of CScL for 1 year, it is not clinically significant since they are only corrected at the time of use without anatomically modifying the cornea after use.

The CScL has decreased the incidence of performing corneal transplants either PK or DALK; these contact lenses are used in mild to moderate keratoconus and constitute a conservative route for treatment, and their advantage is that they are reversible; however, its high cost and perhaps its difficulty in placement may limit its use in some patients. Patients should be informed about the total reversibility of CScL unless adequate visual acuity is not achieved, and the patient must be informed of the complications of transplantation, such as glaucoma, high post-keratoplasty astigmatism, ametropia, or anisometropia, that tend to be difficult to correct to provide a more appropriate visual correction [11].

There are patients who, although they have implanted intracorneal lens segment (ICRS), will require a certain degree of visual correction, and in some cases

corneoscleral contact lens, conventional or customized soft lenses, and rigid gas permeable, hybrid or piggyback contact lens can be complemented [8].

It should be noted that after the insertion of the ICRS, the anterior and posterior cornea may undergo certain variations in its surface so that the visual quality, the increase in corneal aberrations, and the alteration of the contrast sensitivity can be affected by the irregularity that this ICRS tends to produce; one option is to place corneoscleral contact lens since acceptable visual acuities and decreased high-order aberrations or vertical coma have been achieved; therefore, despite the fact that the placement of ICRS can contribute to the treatment of keratoconus, they induce aberrations that the ICRS cannot control and can be complemented with CScL [8].

The use of CScL showed no adverse effects such as corneal edema, compromised areas of the cornea, or corneal physiological deterioration. The visual quality was maintained; the number of hours of use of the lens and the comfort was adequate so it is a good option for additional correction in patients who require it [8].

2.2 Intrastromal corneal rings

The intrastromal rings correspond to small circular segments of biocompatible material (polymethylmethacrylate (PMMA)), which are inserted into the corneal thickness, specifically in the stromal layer in order to regularize the surface and improve the main refractive defect. Several studies show successful results in relation to corneal remodeling, but the evidence is scarce to show effect on its progression [1].

It is thought that the insertion of corneal implants results in a flattening of the corneal center with the consequent reduction of myopia and astigmatism that patients with keratoconus usually suffer, also generating a biomechanical support of the thin ectatic cornea. A tunnel is performed in the corneal stroma manually or assisted by femtosecond, and the intrastromal implant is inserted. This implant can be removed at any time, but usually they are removed only in case of complications or displacements of their original position [2].

Changes in the corneal structure can be explained by Barraquer's law, in which when a material is added to the corneal periphery or the same amount of material is removed from the area of the central cornea, a flattening effect is achieved. On the other hand, when a material is added to the center or removed from the corneal periphery, the curvature of the surface protrudes. It is postulated that the corrective results vary according to the thickness and diameter of the segment [12].

Each segment has a double effect: one of flattening, through the virtual line that connects the two terms of the segments, and another of protrusion perpendicular to the line reached by the action of the ring established by the difference between the plane of the segment and the plane of the cornea in the insertion area. With this, each segment flattens the axis parallel to the line and protrudes the perpendicular axis, which is why the segments are implanted in the most protruding axis [12]. In addition, it has been seen that the most flattening action is greater when the arc is longer and, on the contrary, the protrusion action is greater when the arc is smaller. The general flattening is greater with thicker segments [13].

Most publications suggest that the indications for intrastromal segments are patients with moderate keratoconus with a clear optic zone and those who are intolerant of contact lenses. The upper limit of K max should not be greater than 60 D, the patient should not have any scar on the visual axis, and the cornea should be at least 350 mm thick by ultrasonic pachymetry in the optical zone or over the area in which the segments will be installed and the refractive error less than −6 D [14].

The corneal segments can be implanted using manual techniques or assisted by femtosecond laser. It is believed that the creation of the mechanical tunnel is more

complex and dependent on the skill of the surgeon; however, the technique with the femtosecond laser is faster and more precise, and with this a better reproducibility is achieved [15].

There are few studies that describe visual and refractive results in relation to implant depth to date, which have delivered results without significant differences [16].

On the other hand, several studies have evaluated with very good results the combination of cross-linking treatments and implants of intrastromal rings, because it is postulated that the first is the only effective treatment to stop the progression of the disease and the second for visual and refractive improvement without having a great implication in its progression [17–21]. ICRs combined with CXL showed that UDVA improved 0.12 logMAR at 12 months of follow-up, CDVA worsened 0.03 logMAR at 12 months of follow-up, but the mean sphere and cylinder component improved 3.03 ± 1.99 and 1.99 ± 0.96 D, respectively, at 12 months of follow-up. Keratometry improved 4.31 ± 2.62 D at 12 months of follow-up. Thus, UDVA, refraction, and keratometry improved to a greater degree than if only the ICR procedure was used [22].

Regarding the complications of the implant of rings, the systematic review by Izquierdo et al. [22] carried out in 1325 eyes showed that complications are rare but do occur. Intraoperative complications are mainly linked to the construction of the tunnel in manual techniques. Decentration of the segments, inadequate depth of the tunnel, and asymmetry of the segments are the most frequent. Postoperative complications include ring segment extrusion, corneal neovascularization, corneal haze, segment migration, corneal melting, and infectious keratitis, among others. Related to the combined procedure, the primary complications in the ICR group were white deposits (57 [5.75%]), epithelial defects (56 [5.65%]), extrusion (21 [2.11%]), decentration (14 [1.41%]), segment migration (6 [0.6%]), and halos and glare (6 [0.6%]). In the ICR and CXL group, the main complications were edema (17 [5.08%]), extrusion (2 [0.59%]), perforation (2 [0.59%]), and corneal melting (1 [0.29%]) [22].

2.3 Phakic anterior IOLS for keratoconus

Several surgical options have been reported for patients undergoing corneal transplants secondary to keratoconus with refractive errors that are difficult to correct or patients with keratoconus and virgin corneas that do not tolerate contact lenses or who want the independence of the glasses. The variety of treatment is wide, such as photorefractive keratectomy, corneal wavefront-guided customized ablation, corneal relaxing incisions, small incision lenticule extraction, or intrastromal corneal rings. However, the previous chamber iris-fixated phakic intraocular lens (ACIF-PIOL) has taken advantage of other correction techniques that can be provided to the patient for their safety and effectiveness [23].

The toric Artisan (Ophtec BV) is a one-piece polymethylmethacrylate intraocular lens with a 5 mm optical zone, and a concave-convex shape is fixed to the iris and corrects a sphere from −23.00 D to +14.00 D and a cylinder of −1.00 D to −7.50 D. While the Artiflex toric intraocular lens (Ophtec BV) has a 6 mm optical zone and a concave-convex shape, it has a flexible polysiloxane optics and two rigid polymethyl methacrylate haptics and corrects spheres from −1.00 D to −13.50 D and cylinders −1.00 D to −5.00 D [24, 25].

This technique has the advantage to preserve the integrity of the post-transplant graft, prevent tissue ablation, having no risk of postoperative turbidity, and correcting high degrees of spherical and astigmatic refraction, and they are stable, safe, and effective and can correct elevated refractive errors [24–27].

It should be noted that the treatment with anterior chamber phakic intraocular lens must be complemented with the corneal collagen cross-linking before implantation to maintain the keratometry and a stable refraction; these phakic lenses are indicated in patients with mild to moderate progressive keratoconus with regular myopic astigmatism. The implementation of pIOL 6 months after the corneal collagen cross-linking is recommended to consider changes in refractive errors and keratometry values that could alter the lens calculation [23–25, 28].

Before placing the ACIF-PIOL, all sutures should be removed in the case of posttransplant patients, and the candidate patients must have a stable keratoconus; these are not recommended in patients with newly diagnosed keratoconus or young patients with progressive keratoconus [24, 25, 27]. The implementation of anterior chamber phakic intraocular lens can improve a UDVA from 20/40 to 20/20 according to the Snellen scale with a nonsignificant loss of endothelial cells; in the same way, an annual request is recommended for studies such as specular microscopy and anterior segment optical coherence tomography to monitor corneal changes [24, 28].

Some complications that may result from the implantation of this type of lens are endothelial cell damage, cataract formation, glare, haptic disintegration, pigmentary dispersion that can cause pigmentary glaucoma, and the corneal incision that can modify residual astigmatism, but they are very rare [26, 27].

In general, visual rehabilitation in patients, after the insertion of the anterior chamber phakic intraocular lens, is quite rapid, with maximization of vision and an optimal focus within the eye, without serious complications, and can be considered as an alternative treatment before transplantation because it is less invasive [25–27].

2.4 Implantable collamer toric lenses

The implantable collamer lens (ICL; Visian; STAAR Surgical, Nidau, Switzerland), which is used as a posterior chamber pIOL, is made from collamer, a biocompatible hydrophilic copolymer of collagen and hydroxyethyl methacrylate with an ultraviolet light. The lens is implanted in phakic patients in the posterior chamber, between the iris and the anterior lens capsule, without making contact with it so as not to cause cataracts or any other complication. There are toric devices, and with spherical correction, the toric models (Visian TICL) were developed in 1998, but only in 2006 it gets approved by the FDA and marketed for use.

A toric ICL is typically indicated for the correction of myopia in adults aged 21–40y with myopia up to −18.0 diopters (D) with up to 6.0 D of astigmatism. Toric ICL cannot correct irregular corneal astigmatism; therefore, it is an alternative method to correct myopia and myopic astigmatism in the eyes with stable KC for partial visual rehabilitation.

Toric models are identical in material, chromophore, haptic design, size, and thickness to spherical models. It has a central convex-concave optical zone with a cylindrical component intended to correct astigmatism. Usually with the identification by extended alignment marks that orient the surgeon with respect to the degrees and direction of rotation that he has to do in relation to the horizontal axis to achieve a correct alignment.

Regarding the calculation of the power of the ICL, it is performed with nomograms provided by the manufacturer according to the patient's refraction, axial length, curvature and corneal thickness, distance to the vertex, depth of the anterior chamber, and the dimensions of white to white and of sulcus to sulcus, so as to determine the most appropriate ICL size for each patient.

A toric ICL corrects only spherical and cylindrical errors of refraction; it cannot correct HOAs caused by an irregular corneal shape. Patients who have a good spectacle-corrected visual acuity would benefit from toric ICL implantation. A toric

ICL does not induce HOAs. The aberrations associated with an irregular cornea in KC that are uncorrected by the pIOL have an effect on the final visual quality. A phakic toric ICL can correct a high degree of myopic astigmatism without inducing new HOA. High corneal irregularity limits the potential visual acuity and may need another surgery to make the cornea more regular [29, 30].

2.5 Penetrating keratoplasty

As we know, the cornea is a transparent dome-shaped surface that, from a microscopic point of view, is composed of six layers that from the outside inward correspond to the stratified epithelium that helps keep the ocular surface smooth and provides a barrier against the external injury; the Bowman layer, an acellular structure that does not regenerate after damage; the stroma, which has anatomical and biochemical properties that maintain the physical stability of the corneal shape and transparency; the Dua layer, which would measure only 15 μm thick and would be located between the stroma and Descemet's membrane; the Descemet's membrane, which is 10 μm thick and can be easily separated from the stroma regenerating rapidly after trauma; and finally the endothelium, a thin layer of cells that maintain the hydration of the corneal stroma in a gradual manner and contribute to maintaining corneal transparency [31].

Due to the layered or lamellar characteristic of the cornea and the partial or complete commitment of the disease or condition that leads to the decision to perform a corneal transplant, two types of management can be distinguished: those that involve all the corneal thickness and which are lamellar, depending on the layer of the cornea affected.

Penetrating corneal transplantation is a surgical procedure in which the entire corneal is replaced by healthy donated tissue [32]. In DALK, the epithelium, the Bowman membrane, and a small part of the stroma are replaced, leaving the Descemet's membrane and the endothelium undamaged.

Penetrating keratoplasty (QPP) has been the technique traditionally used during the twentieth century, independent of the cause of the transplant requirement. The first technically successful cornea transplant with human graft was performed by Power et al. [33]; however, a loss of corneal transparency was recorded at approximately 20 days [34].

Penetrating technique has been associated with multiple surgical complications such as the risk of tissue rejection, infections, and high astigmatism related to the need to ensure a tight seal for the donor graft [35–37].

The aforementioned complications, mainly graft rejection, have led to the development of new surgical techniques in which only the damaged cornea layer is replaced [32]. Lamellar techniques have been gaining popularity in recent decades and have involved preserving the healthy tissue of the recipient cornea by replacing only the compromised portion [38].

If we consider that the visual loss that affects the person with visual disability and that requires a corneal transplant has repercussions in the psychological, social, and labor, severely affecting their quality of life, there is no doubt that vision is one of the most important aspects of the functional activity of people. Our society attaches great importance to visual communication, to the point that those people who cannot make full use of this sense begin to be marginalized from the world around them, directly or indirectly.

2.6 Deep anterior lamellar keratoplasty (DALK)

The objective of the corneal transplant is to achieve an acceptable visual acuity with a minimum of retraction error and with a long duration. DALK was introduced

by Eduardo Archila in 1984 [39]; it is a very innovative technique indicated for patients who have no compromise of the corneal endothelium or Descemet's membrane and for mild cases of keratoconus [40–45].

This type of transplant consists of removing the diseased stroma from the cornea and separating it from the Descemet's membrane and the Dua layer and replacing it with donor tissue [39, 43, 45, 46]. In the United States, according to the Eye Bank Association of America, DALK is the main indication of lamellar transplantation, accounting for 43.4% of cases, and in countries such as the United Kingdom, Singapore, and Australia, this technique has taken up the last 10 years [43].

There have been several techniques that have been developed, such as manual dissection/delamination of the corneal stroma or separation of the DM from the stroma using intrastromal injection of fluid, viscoelastic, hydro-delamination, or a big-bubble [40, 43]. Hydro-dissection is better than the others because it allows an easier dissection of the deep stroma and is more controlled than the rest [41], while Romano et al. [43] concluded that there was no significant difference between manual dissection and the big-bubble technique. In the same way, it has been decided that the best technique is with which each surgeon has more experience [41].

Few of the advantages of this technique over penetrating keratoplasty (PKP) are the preservation of the host's endothelium; a low rate of graft rejection; minimal loss of endothelial cells; lower postsurgical risk; a short term of steroid use during the postoperative period, reducing complications such as cataract, glaucoma, and late wound healing; and lower risk of intraocular infections; adding to this, Romano et al. [45] refer that it produces a stronger cornea, being less prone to spontaneous or posttraumatic wounds, as well as a longer graft survival than PKP [39, 43, 44, 47].

However, a fairly long learning curve is required, since the technique can be complicated for some surgeons, and the surgery time is longer than PKP; it also has unpredictable visual results compared to PKP since it takes between 6 and 12 months to reach an acceptable visual acuity and generate high degrees of spherical and astigmatic refractive errors, and this depends on the thickness of the stromal bed or the presence of folds in the Descemet's membrane; there may also be graft tears that require conversion to PKP [42–46].

The stromal bed is one of the factors that determine a good visual acuity after performing a DALK; several studies suggest that for better visual results, you should have a stromal bed less than 20 mm and not more than 65 mm, and these results are comparable to PKP [39, 45–47].

Moreover to the stromal bed and the folds in the Descemet's membrane, other factors that can influence the variation of visual acuity and refractive errors have been determined, such as vitreous length, suture tension, the time at which sutures are removed, previous keratometric values, donor graft size, and donor-recipient disparity, which can modify the radius of corneal curvature [39–45, 48].

Corneal sutures are one of the most common morbidities in terms of poor visual acuity due to myopia and residual astigmatism that remain secondary to their withdrawal; in some studies it is said that residual myopia may become greater than in PK [40]. Therefore, it is recommended that suture removal be initiated in the 1st month of operation and maximum between 18 and 24 months postoperatively [42–44]. This will depend on postoperative topographic astigmatism, which generally varies from >4 D to 6 D, as well as the loosening of sutures or their degradation or vascularization, taking into account that in PKP, the sutures remain longer than

in DALK [44, 45]; in any case, each patient should be assessed as graft dehiscence may occur that requires an early adjustment if they are not removed at the appropriate time [40, 42, 43].

Refractive errors are the first causes of patient dissatisfaction. The most common refractive error is myopia due to lengthening of the posterior segment of the eye [40, 44] and can vary from −3.00 to −13.00 D [46]. Javadi et al. [42] determined that the spherical refraction remained stable after 6 months of suture extraction and refer that the refractive instability of DALK may be secondary to the avascular vertical wound between the donor and the recipient causing changes in the wound architecture during healing and in some cases due to the recurrence of keratoconus.

As for the spherical equivalent, Javadi et al. [42] indicate that the changes in it continued until 6 months after suture removal and remained stable afterward, in an average of 5 years, without changes in refractive astigmatism, and in some cases they recommend refractive surgery 6 months after the spherical equivalent is stabilized in patients who require it. Henein C et al. [48] conclude that the spherical equivalent did not vary between PK and DALK.

A preoperative UCVA of 20/100 and a preoperative BCVA of 20/40 are recommended for DALK since this could result in a postoperative UCVA of 20/50 and a BCVA of 20/25 to 20/20 preoperative in a period of 36 months [43]. Javadi et al. [42] said that the patients evaluated obtained a postoperative visual acuity from 20/30 to 20/40 at the end of the 60-month follow-up. And according to Huang et al. [44], there is no difference in refractive errors between DALK and PK and that a graft diameter size of 8.75–10.0 mm can achieve BCVA between 20/40 and 20/25 and less apparent astigmatism than grafts of 8 mm and less spherical aberrations [39]. According to Romano et al. [43], the DALK is comparable with PK in terms of BCVA and refractive results as is Henein et al. [48].

According to a systematic review by Henein et al. [48], it was shown that BCVA and UCVA at 12 months of follow-up favored PK more than DALK, while better postoperative refractive astigmatism, lower episodes of graft rejection, and greater graft survival supported DALK more than PKP. However, the spherical equivalent and the density of endothelial cells did not vary between these two transplant techniques. They also report that the potential factors for postoperative keratometric and refractive astigmatism are the disparity of the donor graft, the bed of the host, and the degree of preoperative ametropia as some authors conclude [42–44, 46, 48].

It has been determined that factors such as central and peripheral corneal thickness, recipient trepanation size, surgical technique, duration of steroid administration and elevated intraocular pressure do not contribute to postoperative refractive outcomes [40, 42, 45].

In a comparative study about visual results between DALK and PKP, it was determined that there were no significant differences in the best-corrected visual acuity between DALK and PKP at 12 and 24 months; however, patients who underwent DALK were more recorded nearsighted without changes in the cylinder, with greater spherical equivalent than PKP [43, 47].

Some complications that can result from DALK are perforations of the recipient bed, double anterior chamber, corneal opacities, stromal rejection, high astigmatism, vascularization and/or loosening of the sutures, and elevation of intraocular pressure, which are usually controlled, have a very low incidence, and tend to be less frequent than the PKP [45–47].

In conclusion, according to several studies, DALK has many advantages over PKP for the treatment of mild or moderate keratoconus, with visual results that

tend to be unpredictable but similar to PKP, with a lower incidence of graft rejections and postoperative complications.

3. Conclusions

Up to date, there are several treatments that improve visual acuity in patients with keratoconus. The best method should be selected according to the characteristics of each patient.

Conflict of interest

The authors declare no conflict of interest.

Author details

Josefina A. Mejías S*, Marta G. Hadid, Luis Izquierdo and Maria Henriquez
Research Department, Instituto de Ojos Oftalmosalud, Lima, Peru

*Address all correspondence to: josefina.mejias.smith@gmail.com

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