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ORIGINAL PAPER

Indications and techniques of corneal transplantation in a referral center in Colombia, South America (2012–2016)

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Abstract

Purpose To describe the indications and techniques of corneal grafting in a tertiary institution in a middle-sized city in Colombia.

Methods A retrospective review of surgical reports and medical records of patients undergoing keratoplasty from January 2012 to December of 2016.

Results A total of 346 eyes from 316 patients were included. The first three indications for keratoplasty were: bullous keratopathy (BK) with 46.2% of the cases, active infectious keratitis (22.3%) and the group of corneal dystrophies and degenerations, including Fuchs' endothelial dystrophy (9%). Keratoconus was in the sixth place (4.9%). 73.3% of the procedures were penetrating keratoplasties ($n = 255$), 21.7% posterior lamellar ($n = 75$) and 3.5% anterior lamellar ($n = 12$). While in 2012, 25 cases of endothelial grafts were performed, only 13 were done in 2016.

Conclusions BK was the first cause of keratoplasty with almost half of the cases, and keratoconus was relegated to sixth place with less than 5%. In comparison, in a study from eye banks from the US, BK was the second and keratoconus was the third indication for corneal grafts. The frequency of endothelial lamellar techniques in our institution decreased from 2012 to 2016. This could have been related to both the long time that the patients had to be on a waiting list, which made them unsuitable candidates for this technique, due to stromal fibrosis, and to the fact that surgeons of our institution had less experience with posterior endothelial grafting than with penetrating keratoplasties.

Keywords Corneal transplantation · Keratoconus · Keratoplasty technique · Penetrating keratoplasty · Lamellar keratoplasty · Pseudophakic bullous keratopathy

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Introduction

The first successful corneal transplant was performed by Eduard Konrad Zirm in 1906 using an enucleated eye from a living donor [1–3]. Vladimir Filatov became the first physician ever to complete a successful corneal transplant using a cadaver cornea

in 1931. With this achievement, Filatov opened the way for eye banking [2, 3].

Currently, more than 180,000 corneal transplants are performed every year in the world, around twice the number of kidney transplants [4, 5]. Indications for corneal grafting are multiple and vary when comparing different countries [5–22]. In the last two decades, changing trends have been reported in the indications as well as in the techniques used for corneal transplants, which we have also seen in our country [5–22].

This article describes the indications of corneal transplants and the techniques used at Fundación Oftalmológica de Santander FOSCAL (Floridablanca, Colombia) from January 2012 to December 2016 and compares them with those found in our previous study conducted in an immediately previous period of time (2004–2011) to identify changes that have occurred in recent years [7].

Materials and methods

Using surgical reports, a retrospective study was performed. The data collected span from January 2012 to December of 2016 and contain information regarding the technique of the surgery performed: penetrating keratoplasty (PK), posterior lamellar keratoplasty (PLK) [including Descemet stripping automated endothelial keratoplasty (DSAEK) and Descemet membrane endothelial keratoplasty (DMEK)], anterior lamellar keratoplasty (ALK) [including Deep Anterior Lamellar Keratoplasty (DALK) and pachymetry-assisted lamellar keratoplasty (PALK)], and sclerokeratoplasty. We analyzed the patient's age, gender, eye and the indication for corneal transplant. The indications were divided into eight categories: keratoconus; stromal opacities (sequelae resulting from already resolved and inactive inflammatory conditions, infectious keratitis or trauma); infectious keratitis (active fungal, bacterial, parasitic and polymicrobial infections); bullous keratopathy (BK), defined as irreversible corneal edema that occurred after an intraocular surgery (usually cataract with implantation of an intraocular lens) and that in the present study was pseudophakic in all the cases; regraft (due to primary or secondary failure or rejection); corneal dystrophies (including Fuchs' endothelial dystrophy) or corneal degenerations (excluding keratoconus); and the final category that included other indications. In the group classified as corneal dystrophies or corneal degenerations, the eyes underwent corneal graft either before or simultaneously with cataract surgery. If the keratoplasty was performed after the cataract extraction, the case was classified as BK. Seven ophthalmologists with extensive experience in corneal surgery performed 282 cases and 19 young ophthalmologists performed 64 cases during their year of cornea and anterior segment fellowship. Lamellar procedures were performed only by four surgeons with experience in penetrating keratoplasty, but on the other hand they were in the learning curve of lamellar techniques during the period of study (DSAEK, DMEK, DALK and PALK).

Table 1 Demographics of cases included in the study

Eyes (*n*)	346
Laterality	
Right[a]	170 (49.1%)
Left[a]	176 (50.9%)
Patients (*n*)	316
Sex	
Female[a]	160 (50.6%)
Male[a]	156 (49.4%)
Age	
Total[b]	60.8 ± 20 (range 1–92)
Female[b]	63.5 ± 18.8 (range 1–90)
Male[b]	58.1 ± 20.8 (range 8–92)

[a]*n* (%)

[b]Mean +/− SD

Upon reviewing the surgical reports, we found 327 records of patients who underwent corneal transplantations during the period of study. We had access to the medical records of 316 patients who were included in the study (Table 1).

Surgical techniques

Below we make a brief description of the surgical techniques used:

- *Penetrating keratoplasty* After performing a paracentesis and injection of ophthalmic viscosurgical device in the anterior chamber, the cornea of the host (with a diameter between 7.5 and 9.0 mm) was trephined with a Hessburg–Barron trephine

until penetration to the anterior chamber was evident, and then the circular cutting was finished with scissors. Afterward, the cutting edge was remodeled with Vannas scissors, to make it as regular as possible. The donor's cornea was usually trephined with a diameter 0.5 mm larger than that of the host. It was sutured in the vast majority of cases with 16 separate nylon sutures. Only one surgeon used combined sutures: eight separate sutures and one running suture.

- *Deep anterior lamellar keratoplasty (DALK)* The "big bubble" technique was used by injecting air using a disposable needle, deeply and bevel down, in the paracentral corneal stroma to separate the central Descemet membrane. Initially, a partial thickness trephination was performed (approximately two-thirds of the stroma), followed by the insertion of the needle deeply through the incision of the trephination until reaching the appropriate paracentral depth (ideally just before the Descemet membrane) and the air was injected to form a bubble between the Descemet membrane and the corneal stroma. After performing the anterior lamellar keratectomy, without compromising the bubble, a small opening was made in the bubble and the remaining stromal layers were lifted with an iris spatula, and resected with scissors, leaving the Descemet membrane exposed. The donor tissue was placed without endothelium and sutured with separate nylon stitches.
- *Pachymetry-assisted lamellar keratoplasty (PALK)* For this technique, a pachymetry-guided ablation was performed in the host corneas [based on a pachymetry map generated with the Sirius® (CSO, Firenze, Italy)] using a transepithelial approach with an excimer laser (Amaris®, Schwind, Kleinostheim, Germany). A residual stromal bed thickness of 100 µm was planned. Donor cornea endothelium and Descemet membrane were removed mechanically, and then the donor tissue was fixed with 16 interrupted nylon sutures.
- *Descemet stripping automated endothelial keratoplasty (DSAEK)* First, a lamellar cut using a microkeratome was performed in the donor cornea, while it was kept in an artificial anterior chamber, to remove 300–350 µm of the anterior cornea. The descemetorhexis in the host's cornea was performed using an anterior chamber maintainer. The donor DSAEK disk (8–8.5 mm in diameter) was folded ("taco technique" with 60/40 overfold) and inserted into the anterior chamber. The graft was unfolded with balanced salt solution and the anterior chamber inflate with an air bubble to push the donor tissue up. Ten minutes later, the air was partially evacuated to left around 80% of the anterior chamber full or air.
- *Descemet membrane endothelial keratoplasty (DMEK)* Donor corneal endothelium and Descemet membrane were harvested by the surgeons. A clear corneal incision was created, descemetorhexis was performed in the host's cornea, and the graft was introduced using a specially designed cartridge. After injecting the tissue into the anterior chamber, it was unrolled and oriented with a mixed technique, i.e., with a bubble of air on top of the graft, light taps on the corneal surface (van Dijk taps) as well as manipulations of the small air bubble (Dapena maneuver). An inferior iridectomy was performed. A full bubble of air was injected into the anterior chamber and left for 10 min. Finally, the bubble was partially aspirated.
- *Sclerokeratoplasty* After creating a groove in 360°, around 1.5 mm behind the limbus, a lamellar scleral dissection was performed until entering around 1 mm in the cornea. The anterior chamber was entered. The peripheral keratotomy was done and the host tissue removed. The donor tissue, including 1.5 mm scleral rim, was placed on top on the defect and fixed with interrupted nylon sutures.

Statistical analysis

The data were initially entered into an Excel sheet (Microsoft Corp., Redmond, Washington, USA), and the Chi-squared test in the STATA program (StataCorp LLC, College Station, Texas, USA) was used to compare proportions. A value of $p < 0.05$ was considered statistically significant.

Results

A total of 346 eyes from 316 patients who underwent corneal transplantation were included in the study. Demographic characteristics of the patients are shown in Table 1, and changes of the number of corneal transplants over the 5 years period are shown in Fig. 1.

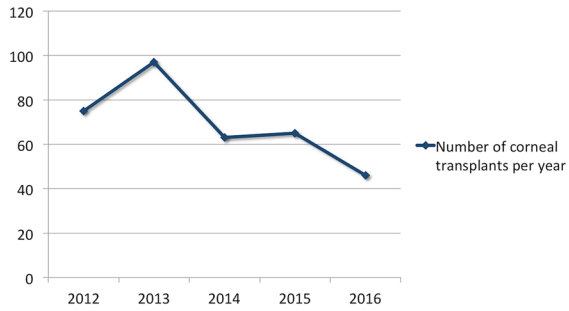

Fig. 1 Number of annual corneal transplants during the study period (2012–2016)

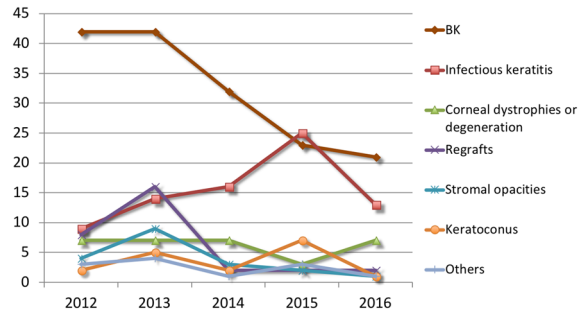

Fig. 2 Changes over time from 2012 to 2016 in the indications of keratoplasties

- Indications
  The complete data on indications are shown in Table 2 and Fig. 2. Taking into account the whole period from 2012 to 2016, BK, defined as irreversible corneal edema after intraocular surgery, was the first indication for the surgery, counting for almost half of the cases (46.2%), with some fluctuation from one year to another (Fig. 2). A total of 154 (96.3%) of BK cases undergoing corneal transplantation presented following phacoemulsification (or manual extracapsular extraction) and intraocular lens implantation, and six (3.7%) presented following combined trabeculectomy and phacoemulsification. BK was the first cause of corneal transplants in every yearly period, with the exception of the year 2015, when "infectious keratitis" took the first place (Fig. 2). The second indication in the whole period was "infectious keratitis," and the third was "corneal dystrophies" (mainly Fuchs' endothelial dystrophy, 61.2% of this group). Keratoconus occupied sixth place analyzing data for the complete 5-year period, fluctuating between third place in 2015 and seventh place in 2012 (Fig. 2).
  With respect to the optical indications of the corneal grafts, these included those performed due to keratoconus, stromal opacities, BK, regraft, corneal dystrophies or degenerations, and others (269 cases, 77.7%) while those due to active infectious keratitis (77 cases, 22.3%) always had tectonic purposes, due to the presence of perforation or imminence of corneal perforation.
- Used surgical techniques
  The surgical techniques of the procedures for each yearly period are shown in Table 3 and Fig. 3.
  Among anterior lamellar keratoplasties, seven procedures were performed using the DALK technique and five with the PALK approach. The

Table 2 Indications for keratoplasty period 2012–2016

Indications	Number of cases	%	Place according to frequency
BK[a]	160	46.2	1
Infectious keratitis	77	22.3	2
Corneal dystrophies or corneal degeneration[b]	31	9.0	3
Regraft	30	8.7	4
Stromal opacities	19	5.5	5
Keratoconus	17	4.9	6
Others	12	3.5	7
Total	346	100	

[a]Bullous keratopathy was defined as irreversible corneal edema following intraocular surgery (in the present study all the cases were pseudophakic)

[b]Including Fuchs' endothelial dystrophy (61.2% of cases in this group) but excluding keratoconus, which was classified in a separate group

Table 3 Surgical techniques for corneal transplants (2012–2016)

Technique	*n*	%
Penetrating keratoplasty	255	73.7
Posterior lamellar keratoplasty: DSAEK/DMEK	75	21.7
Anterior lamellar keratoplasty: PALK/DALK	12	3.5
Sclerokeratoplasty	4	1.2
Total (eyes)	346	100

DSAEK Descemet stripping automated endothelial keratoplasty, *DMEK* Descemet membrane endothelial keratoplasty, *PALK* pachymetry-assisted lamellar keratoplasty, performed using the Amaris® excimer laser (Schwind, Kleinostheim, Germany), *DALK* deep anterior lamellar keratoplasty (manual technique)

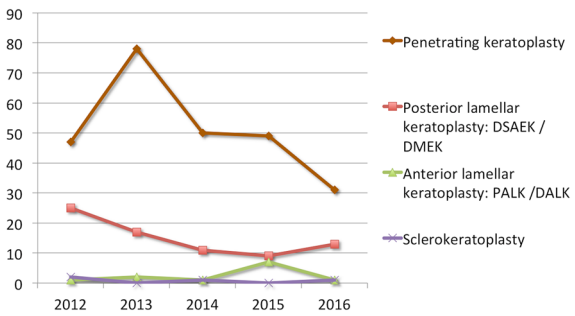

Fig. 3 Changes over time from 2012 to 2016 in the number of procedures performed for each keratoplasty technique

latter procedure was introduced in 2015 in our institution, and since that moment all the anterior lamellar corneal grafts were done using this option. In the posterior lamellar corneal grafts group, DMEK technique was introduced in our institution in 2015 and eight procedures were performed until 2016. The proportion of endothelial transplants using DMEK increased from 22.2% in 2015 (2 out of 9) to 46.2% in 2016 (6 out of 13), while in exactly the opposite way, the frequency of DSAEK decreased (from 77.8 to 53.8%).

Four cases with severe corneal compromise due to infectious keratitis (three fungal and one bacterial) and secondary diffuse corneal melting required sclerokeratoplasty.

Discussion

This is the second study that was performed at our institution (Fundación Oftalmológica de Santander—FOSCAL, Floridablanca, Colombia) where the indication and techniques of keratoplasty were analyzed. In our previous study, BK, defined as irreversible corneal edema following intraocular surgery, was the primary indication for corneal transplant with 139 surgeries (34.6% of the cases from 2004 to 2011) [7]. A significant increase in the frequency of this condition as an indication for corneal transplantation was evident ($p = 0.001$), reaching 160 procedures (46.2% of the grafts) from 2012 to 2016 (Table 4). We do not have an accurate explanation of the rise in cases of BK, but it might be related to the increase in the number of cataract surgeries performed in our geographical area. We carried out corneal grafts in patients who underwent prior cataract extraction in our institution, but also received many cases from other surgical centers in our region. (Unfortunately, we did not collect that information and we could not analyze how many of the patients had cataract surgery in our clinic and how many came from other surgical facilities.)

Other studies in Ireland, USA and Canada have also identified BK as the first indication of corneal transplantation [12, 19] (Table 5). Upon analyzing the numbers from 2011 to 2014 in the study on keratoplasty with tissue provided by eye banks from the USA, BK was found to be the second most common reason for surgery but only with 12.8% of the corneal grafts [9].

No doubt that one factor for the high frequency of this indication is that nowadays a very large number of patients undergo cataract surgery (globally, approximately 23 million cases in 2014) [23]. The necessity of a corneal transplant following phacoemulsification has been reported in a range between 0 and 0.6% [23–28]. On the other hand, in high-risk groups (like patients with Fuchs' endothelial dystrophy) the rate of corneal decompensation after phacoemulsification has been found to be much higher (30.8%) [29]. In one study in patients requiring corneal transplant due to BK, including only those with available information of the corneal status prior to cataract surgery, 65% of the eyes had endothelial disease. Thus, a significant percentage of cases classified as BK in the studies (including the present one) in fact were patients with previous Fuchs' dystrophy [30]. According to our

Table 4 Changes in indications for corneal transplantation compared with a previous study in our institution

	2004–2011[a]		2012–2016[b]		*p* value[c]
	n (%)	Ranking	*n* (%)	Ranking	
BK	139 (34.6)	**1**	160 (46.2)	**1**	0.001*
Infectious keratitis	58 (14.4)	**3**	77 (22.3)	**2**	0.005*
Corneal dystrophies or corneal degenerations	30 (7.5)	6	31 (9.0)	**3**	0.456
Regraft	31 (7.7)	5	30 (8.7)	4	0.618
Stromal opacities	63 (15.7)	**2**	19 (5.5)	5	< 0.0001*
Keratoconus	51 (12.7)	4	17 (4.9)	6	0.0002*
Others	30 (7.5)	6	12 (3.5)	7	0.018*
Total	402		346		

The first three indications of each period of time are highlighted in bold type

BK Bullous keratopathy (in the present study all cases in this group were pseudophakic)

*Statistically significant difference between the two proportions

[a]A 7-year period (August 2004–August 2011)

[b]A 5-year period (January 2012–December 2016)

[c]Calculated using Chi-squared test

knowledge, none of the researches performed on keratoplasty indications (including ours) has separately analyzed the eyes with preexistent endothelial disease that presented postoperative corneal decompensation following cataract surgery, and therefore it is a generalized weakness of virtually all published works (Table 5). However, on the other hand, no doubt that the surgical trauma is the key factor in the triggering of corneal edema in most of the cases, which is why it is very complex, and practically impossible, to analyze independently the effect of the previous disease and the trauma caused by the surgery. The standard of care in cataract surgery in our geographical area is removal of the cataract using either phacoemulsification or manual extracapsular extraction, depending on the hardness of the nucleus, and intraocular lens implantation using ophthalmic viscosurgical devices (viscoelastic solutions) to protect the corneal endothelium.

Unfortunately, we do not have data on the prevalence of Fuchs' dystrophy or on the frequency of corneal complications after cataract surgery, which would help us to analyze more accurately the high frequency of BK as an indication for transplantation in our institution.

The second most common indication in the present study was active infectious keratitis (22.3%), which significantly increased from 14.4% in our previous study, $p = 0.005$ (Table 5). As mentioned, we reserved corneal graft in these cases with active infection for when there was perforation or an imminent risk of it. Keratitis was the leading indication of PK in Asia and the second in Africa in the period from 1980 to 2014 [12]. We do not have a clear explanation of the reason of the increase in this indication in our institution, and this topic will be the subject of a future study.

The third most frequent reason for corneal grafting in our institution during the years of 2012–2016 was corneal dystrophies (9.0%). Most of the cases in this group in the present study were due to Fuchs' endothelial dystrophy (61.2%). In other series, corneal dystrophies also were ranked in third place as an indication for corneal grafting [6, 8, 15]. Park et al. [9] taking into account both PK and endothelial procedures and considering the record of corneas distributed by eye banks of the USA for both domestic and international use found that Fuchs' dystrophy was ranked first place during the period from 2011 to 2014 (21% of the cases).

Keratoconus, which has been identified as the primary indication of corneal transplant in several studies, only was in the sixth place in the present one [5, 8, 10–15]. In a study including indications of PK, between 1980 and 2014, keratoconus was the number one reason for surgery in Europe, Australia and Africa

Table 5 Selected studies on indications and techniques of corneal transplants published in the period 2012–2016

Author	Year of publication	Period studied	Number of corneas	Country	First indication (percentage of cases)	Second indication (percentage of cases)	Third indication (percentage of cases)
Zare et al. [13]	2012	2004–2009	1859	Iran	KC (38.4%)	BK (11.7%)	Regrafts (10.6%)
Kanavi et al. [11]	2016	2006–2013	47,129	Iran	KC (45.3%)	BK (18.2%)	Opacity and scars (15.2%)
Altay et al. [8]	2016	2005–2014[d]	1330	Turkey	KC (33.8%)[d]	Corneal scar (27%)[d]	Corneal dystrophy (17.1%)[d]
Dong et al. [6]	2016	2002–2014	1390	Vietnam	Infectious Keratitis (48.2%)	Corneal scar 24.0%	Corneal dystrophy (9.9%)[c]
Bozkurt et al. [14]	2016	2004–2014	815	Turkey	KC (27.7%)	BK (23%)	Corneal Scar (13.5%)
Tan et al. [10]	2014	2002–2011	4843	Canada	FED (18.9%)	BK (17.4%)	Regrafts (17.1%)
Kim et al. [15]	2016	2011–2015[f]	1469	New Zealand	KC (34.5%)[f]	Regrafts (23.1%)[f]	Corneal dystrophy (17.6%)[f]
Galvis et al. [7]	2013	2004–2011	450	Colombia	BK (34.6%)	Corneal scar (15.7%)	Infectious keratitis (14.4%)
Park et al. [9]	2015	2011–2014[a]	260,773[a]	USA and International	FED (21%)[a]	BK (12.8%)[a]	Keratoconus (1.3%)[a]
Eye Bank Association of America [21]	2016	2014–2015[b]	142,298[b]	USA and International	Unknown (29.3%)	FED (21.6%)	
Le et al. [22]	2017	2012–2013	229	Canada	FED (25%)	BK (21%)	Regrafts (17%)
Matthaei et al. [12]	2016	1980–2014	72,972[e]	Europe (51 studies)	KC (24.2%)	BK (20.6%)	Keratitis (13.2%)
			20,427[e]	Australia and New Zealand (8 studies)	KC (33.2%)	BK (21.1%)	Regrafts (18.8%)
			27,728[e]	Middle East (9)	Corneal scars and others (36.4%)	KC (32.8%)	BK (13.6%)
			608[e]	Africa (7 studies)	KC (32.4%)	Keratitis (28.9%)	BK (9.4%)
			6599[e]	South America (16 studies)	Corneal scars and others (28.7%)	KC (22.8%)	BK (18.6%)
			37,622[e]	Canada and USA (29 studies)	BK (28%)	Regrafts (16.3%)	KC (14.2%)
			14,909[e]	Asia (21 studies)	Keratitis (32.3%)	BK (15.5%)	Regrafts (11.1%)

Table 5 continued

Author	Year of publication	Period studied	Number of corneas	Country	First indication (percentage of cases)	Second indication (percentage of cases)	Third indication (percentage of cases)
Gain et al. [5]	2016	2012	184,576	97 Countries (Survey to surgeons and eye banks)	According to global number of procedures: Fuchs' endothelial dystrophy (39%). According to first place in countries: keratoconus (40 countries)	According to global number of procedures: keratoconus (27%). According to second place in countries: PBK (29 countries)	According to global number of procedures: sequelae of infectious keratitis (20%). According to third place in countries: sequelae of infectious keratitis (24 countries)
Present study	2017	2012–2016	346	Colombia	BK (46.2%)	Infectious keratitis (22.3%)	Corneal dystrophy (9%)[g]

Studies including at least 200 corneal transplants were incorporated in this table

FED Fuchs' endothelial dystrophy, *BK* bullous Keratopathy, *KC* keratoconus

[a]The study included data from 2005 to 2014, but only the information from 2011 to 2014 was incorporated in this table

[b]The document included data from 2011 to 2015, but only the information from 2014 to 2015 was incorporated in this table

[c]Corneal dystrophy indication apparently included both stromal and endothelial dystrophies

[d]The study included data from 1999 to 2014, but only the information from 2005 to 2014 was incorporated in this table. Corneal scar indication included the diagnosis of non-herpetic, herpetic and traumatic corneal scars. Corneal dystrophy indication included both stromal and endothelial dystrophies

[e]The study included only penetrating keratoplasties

[f]The study included information from 1991, but data on indications showed in the table correspond to the period 2011–2015. Corneal dystrophy indication included both stromal and endothelial dystrophies

[g]Corneal dystrophy indication included both stromal and endothelial dystrophies

[12]. In a recent global survey, the first reported indication was keratoconus in 40 countries (41%) [5]. Undoubtedly, differences in local prevalence of keratoconus could be associated with the frequency of corneal transplants in those patients [11, 31, 32]. In addition, the effect of corneal crosslinking (introduced in our institution in 2007) could be related to the smaller number of corneal transplants in keratoconus in our clinic in the recent years (Table 4) [33].

Taking into account the number of corneal transplantations performed, in a recently published global survey Fuchs' dystrophy was the leading indication worldwide, followed by keratoconus, sequelae of infectious keratitis and bullous keratopathy [5].

The number of corneal grafts in our institution did not increase during the period from 2012 to 2016, and in fact it decreased the last year. This could be related to serious difficulties with tissue availability in Colombia. Due to cultural reasons, the inhabitants of our country are not prepared to donate, and the families are very often opposed to the recovery of the tissues. Because of this, waiting lists are very long, and we think this is one of the reasons the number of keratoplasties has not significantly grown in the last 10 years [7]. We are hopeful that a new law promulgated in the country that establishes that all citizens are donors unless they have signed a denial document in life, and the mass awareness campaigns of the population that have been carried out make donation rates increase in the near future.

When comparing the data from the present study with the previous one performed in our institution, an

important limitation is that the periods of time were different: 5 years in the present study versus 7 years in the previous one (Table 4). Nevertheless, there seemed to be, on average, an increased number of yearly procedures in the last 5-year period (64.3 vs 69.2 cases/year). We found that the use of posterior lamellar techniques, i.e., DSAEK and DMEK, increased only slightly in our institution from 18.7% in the period between 2008 and 2011 [7] to 21.7% in the present study ($p = 0.36$). However, when making this parallel, the differences in the intervals of time (3 vs 5 years) did not allow us to make balanced comparisons and also affected the proportion of cases seen and therefore surgical techniques applied. When the year 2012 is compared with the following 4-yearly period, the frequency of posterior lamellar procedures in fact showed a tendency to decrease (Fig. 3). PK continues to be the preferred technique used in our institution (corresponding to 73.7% of the procedures), similar to other countries like Vietnam [6], Iran [8, 11], Turkey [13], as well as in the global survey performed by Gain et al. [5]. Several factors could be related to this lack of growth of the frequency of posterior lamellar procedures in our institution. One could have been the mentioned scarcity of available donor corneal tissue in our country during the period of study (and even nowadays), situation that made patients who were good candidates for DSAEK/DMEK had to wait too long on the list (even up to 2 years), and when the donor tissue became available, the surgeon found contraindications for a lamellar posterior procedure (usually stromal fibrosis and opacity). Another factor could have been that the endothelial techniques were relatively new during the period of the study and the surgeons at our center were on their learning curve; therefore, it could have been less likely that they decided to perform a posterior lamellar transplant instead of a penetrating one, with which they had more experience.

The shortage of corneal tissue is not restricted to only our country, but affects many parts of the world, and it may have slowed the growth of the frequency of use of posterior lamellar techniques in corneal transplants due to the appearance of the mentioned stromal opacities in patients waiting too long for the surgery [5, 34]. In a recently published survey including data from 95 countries, only 29.7% of the corneal grafts were lamellar (either anterior or posterior), which is in close accordance with the present study in our institution, but much lower than in countries like New Zealand, Canada, Turkey, Ireland, the USA, and in the countries where the American eye banks distribute corneal tissue, where a trend to significantly reduce the percentage of PK and increase the rate of DSAEK/DMEK techniques has been observed, especially in the last 5 years (Table 5) [5, 9, 10, 14, 15, 19–22].

In the USA, the total number of corneal grafts has steadily increased over the last decade and at the same time the percentage of PK has noticeably decreased (from 95 to 42%), while posterior lamellar techniques increased from 5 to 58%. [9]. On the contrary, in our institution in Colombia the volume of corneal transplants decreased between 2012 (75 cases) and 2016 (46 cases). As previously mentioned, we also observed a reduction in the absolute number of endothelial transplants (from 25 to 13) and a downward trend in the percentage of these posterior lamellar techniques with respect to the total number of grafts (from 33.3 to 28.3%) although the latter shift did not reach statistical significance ($p = 0.56$). Thus, we can affirm that the expected increase in endothelial transplants in the span of these 5 years was not observed.

As mentioned, a weakness or the present study was that we did not have information on the endothelial condition before surgery of the eyes which underwent corneal transplant due to BK, and undoubtedly a number of those cases had previously Fuchs' dystrophy. In addition, we did not gather information on the institution where the cataract surgery was performed. In future studies, we will collect data on these topics.

In conclusion, in our third-level referral institution located in a middle-sized city in northeastern Colombia, with a population close to one million inhabitants, the first indication for keratoplasty from 2012 to 2016 was BK. Infectious keratitis and corneal dystrophies (including Fuchs' endothelial dystrophy) were ranked second and third, respectively. In comparison with our previous study (including cases from 2004 to 2011) BK maintained its first place, infectious keratitis moved from third to second place, and corneal dystrophies rose from sixth place to third place. Frequency of keratoconus as an indication of transplant dropped from fourth to sixth place (Table 5) [7].

The frequency of DSAEK/DMEK was not significantly higher compared to the years 2008–2011, nor increased between 2012 and 2016, but we expect that it will grow in the future in our country, especially as the availability of donor tissue improves [7].

Compliance with ethical standards

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership or other equity interest; and expert testimony or patent-licensing arrangements) or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (place name of institute/committee) and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. For this type of study, formal consent is not required. This article does not contain any studies with animals performed by any of the authors.

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