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ARTICLE

Eye bank and theatre factors for positive microbiological culture of corneoscleral rim and cornea storage medium in the real-world

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Abstract

Objectives To evaluate microbiological culture rate and positivity of corneoscleral rim and cornea storage media as well as possible risk factors for contamination with real-world data.

Methods Data of consecutive cornea donors implanted in the reference centre from January 2013 to January 2018 were reviewed. Information about cornea characteristics (donor demographic data, endothelial cell density, type of cornea conservation, days of storage, and precut vs full-thickness tissue), and microbiological culture information (corneoscleral rim *vs* storage sample, positive result) were statistically analysed.

Results During the study period, 1369 corneas (737 donors) were implanted. Cultures were performed in 76.8% ($n = 1052$) of them and were positive in 3.2% of cases, mainly bacteria (84.4%). Corneas preserved in hypothermia represented 61.8% of all positive microbiology results ($p < 0.001$). Other analysed risk factors did not reach statistically significant association with microbiological positivity. None of the 34 cases with positive microbiological cultures reported ocular infection for the recipients in at least 6 months' follow-up.

Conclusions Microbiological tests rate in real-world practice are high despite not being compulsory. Organotypic cultured corneas showed a statistically less positivity in corneoscleral and storage medium than hypothermic ones, resulting in another advantage of this kind of cornea storage. Although precut corneas are thought to present less microbiological positivity, a statistically significant association was not found in the present study.

Introduction

Donated organs and tissue presenting microbiological positivity are usually considered not suitable for transplant, discarded for clinical purposes and never reaching a potential recipient. In Europe, about 2.5% of donated corneas are not suitable for clinical use due to contamination [1]. This may represent a crucial problem for the national healthcare system, since there are countries worldwide which do not achieve sufficient corneal donation to meet the annual demand [2].

Several studies have evaluated donor causes for corneal microbiological contamination [3, 4]. Routinely, samples of corneoscleral rim and/or storage medium of the cornea implanted are sent for microbiological study. Positivity rate of microbiological cultures of corneoscleral rims described in the literature can reach 16.8% [5–8]; however, infectious complications are uncommon after keratoplasty, with reported rates between 0.08% and 0.77% [5–7, 9–12]. Quality control, diagnosis, and, especially, prevention of endophthalmitis and keratitis in the receptor are outstanding advantages and therefore microbiological cultures are strongly motivated [13, 14].

Many reports have tried to determine whether there is a relationship between positive microbiological cultures of donor corneas and postoperative infection in recipients [5, 7, 15, 16] Others recognize donor-to-host transmission

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of bacteria and fungi as serious adverse reaction that can lead to endophthalmitis, keratitis and poor visual outcome [5, 10, 13, 17]. Some authors have claimed that donor-to-host microbial transmission may be as much as 12- to 22-fold times greater in the presence of a positive rim culture [11, 12].

This study aimed to investigate in first place the rate of microbiological positivity tests performed in a real-life setting, in order to then search potential causes for such finding.

Materials and methods

Study design

This was a retrospective study carried out at a single eye bank in Barcelona, Spain (*Barcelona Tissue Bank*; BST). Data was included for donors that had at least one cornea implanted in a high-volume implanting centre in Barcelona (Instituto de Microcirugía Ocular*;* IMO) over a 5-year period (from January 2013 to January 2018). Institutional Ethics Committee Board approval was obtained for clinical history revision (approval number HCB/2015/0879, Hospital Clinic de Barcelona, amended on 14th November of 2018). Research methods and analysis plan adhered to the tenets of the Declaration of Helsinki.

Patient data were encoded for management in accordance with the Spanish legislation on personal data protection (RD05/2018). Informed consent for surgical procedures was obtained in the implanting centres. Authorization, and informed consent for biological sample analysis were treated in accordance with local law. Data related to ocular tissue, and its traceability were treated in accordance with the appropriate European Union directives (2004/23/EC, 2006/17/EC, and 2006/86/EC).

Procedures

Corneoscleral buttons were obtained by retrieval teams at the donor procurement units' hospital. By routinely standard operating protocol, 5% povidone-iodine solution was applied for 5 min, abundantly washed with 0.9% physiological solution, and then the corneoscleral discs were retrieved under sterile surgical conditions and placed in Optisol GS medium (Bausch & Lomb Surgical Inc., San Dimas, California) for storage at 4 °C. The mean time between death and preservation was 12 ± 8 h (range, 8–24 h). Donated corneoscleral discs were later processed, evaluated, and preserved at 4 °C (cornea in hypothermia) or 31 °C into organotypic culture conditions (cultured cornea) in CorneaMax® (Eurobio, Les Ulis, France) at eye bank facilities. At surgeon's request, corneoscleral material was either sent without further manipulation (surgeon-cut button) or sent as precut tissue for Descemet Membrane Endothelial Keratoplasty (DMEK) or Descemet Stripping Automated Endothelial Keratoplasty (DSAEK).

After transplantation, the trephined remnant of donated corneoscleral rims and/or the original corneal storage medium—Optisol GS for hypothermic cornea; deswelling medium CorneaJet® (Eurobio, Les Ulis, France) for cultured cornea—were sent for conventional microbiological testing. The remnant corneoscleral rims, storage medium or both were cultured depending on surgeon/implanting centre preferences.

Data collection

The following information was collected: donor demographic data (age, sex, cause of death), endothelial cell density, date of cornea retrieval and eye bank entry, type of corneal conservation, date of cornea delivery to the implanting centre, date of surgery, surgical technique and microbiological culture information (type of sample cultured, microbiological result). In those cases, in which the second cornea of the same donor had been implanted in a different centre than the reference centre of this study, tracing was applied to collect information about mate corneas. Surgeons from other implanting centres were interviewed to provide information about the mate cornea in those cases.

Statistical analysis

Descriptive results are presented as median and their 95%CI or absolute frequencies and percentages for quantitative and qualitative variables respectively. All results were tabulated for presence of culture (yes or no), outcome of this culture and type of cornea implanted. Mann–Whitney U Test or Fisher's Exact test were used for statistical analyses for quantitative or qualitative variables respectively. All statistical tests were performed with a two-sided type I error of 5%, with the statistical software SPSS v.25.0 (IBM, Armonk, New York, USA).

Results

From 1st January 2013 to 31st January 2018, 737 consecutive donors had at least one cornea implanted in the reference centre: In some cases, both corneas were implanted in the reference centre, in others the mate cornea was implanted in another centre or was discarded by the eye bank due to quality criteria. Then, a total of 1369 corneas (737 donors) were implanted in the period of study. Destination of donor corneas is summarized in Table 1.

Table 1 Destination of 737 consecutive donor corneas with at least one of them implanted in the reference centre.

Donors	*n*
One cornea implanted in the reference centre	737
Mate cornea	
Implanted in the same centre	145
Implanted in another centre[a]	487
Did not accomplished quality criteria and discarded by the eye bank	105
Total of corneas implanted	1369

[a]Corneas were implanted in 78 different centres elsewhere in Spain by 97 surgeons.

Details about donor characteristics (demographics and cause of death), donor corneal characteristics and criteria quality (endothelial cell density, laterality, days in the eye bank, time from delivery to surgery, type of corneal conservation—hypothermia *vs* organotypic), and technical approach used for tissue delivered are resumed in Table 2.

Microbiological analysis was performed in 76.8% ($n = 1052$) corneal remaining material. Samples sent for microbiological study were corneoscleral rim (89.8%, $n = 945$), cornea storage medium (2.6%, $n = 27$) or both (7.6%, $n = 80$). Test results were available in 97.4% ($n = 1025$) of cases. The real-world flow chart is represented in Fig. 1.

Microbiological culture was positive in 3.2% ($n = 34$), in which 85.3% ($n = 29$) of microorganisms found corresponded to bacteria and the remaining 14.7% ($n = 5$) corresponded to fungal or mixed flora (*Enterococcus faecalis* plus *Candida albicans*). The most prevalent microorganism found was *Staphylococcus epidermidis* ($n = 17$), followed by *Enterococcus faecalis* ($n = 3$), and *Escherichia coli* ($n = 3$). In the reference centre, 78.9% ($n = 830$) of all microbiological cultures were performed compared to an 18% in all other centres ($p = 0.001$), and 85.3% ($n = 29$) of positive microbiological cultures corresponded to corneas implanted in the reference centre ($p = 0.279$). Microorganisms isolated and its corresponding cornea characteristics are detailed in Table 3.

The 34 cases of positivity corresponded to 31 donors, in other words, only 3 donors had both corneas with positive cultures: both corneas of them were positive for the same microorganism (*Staphylococcus epidermidis* in two donors, and mixed *Enterococcus faecalis* plus *Candida albicans* in the other one). Among the other 28 positive microbiological cultured donor corneas, microbiology was indeed negative in mate corneas for 13 cases. In 15 out of the 28 remaining donors we have not information about culture of the mate cornea because in 5 cases mate cornea did not reach quality standards for clinical application and were discarded by the eye bank, and, on the other hand, due to microbiological tests not being performed in 10 cases. None of the 34 cases

Table 2 Demographics and characteristics of donors and donated corneas.

Donor cause of death: *N* (%) ($n = 737$)	
Brain damage	196 (26.6)
Cancer	155 (21)
Respiratory	146 (19.8)
Trauma	42 (5.7)
Non-septic shock	32 (4.4)
Septic shock/Active infection	20 (2.7)
Cardiovascular	9 (1.2)
Other	137 (18.6)
Donor age: mean and range (years)	62 (range 0–89)
Donor sex: *N* (%) female	366 (35.8%)
Cornea laterality: *N* (%) right	540 (52.7%)
Mean ECD: mean and range	2568.5 (range 2000–5102)
Method of corneal preservation: *N* (%)	
Hypothermia	240 (23.4%)
Organotypic (cultured)	785 (76.6%)
Days of storage: Median (95% CI)	
All corneas	26.0 (26.0; 27.0)
Corneas in hypothermia	5.0 (5.0; 6.0)
Corneas in culture	28.0 (28.0; 29.0)
Time from delivery to surgery: *N* (%)	
Same day	599 (58.4%)
One or more days before	426 (41.6%)
Technique of preparation by the eye bank: *N* (%)	
Full-thickness tissue[a]	941 (92.3%)
DSAEK	27 (2.7%)
DMEK	51 (5.0%)

ECD endothelial cell density, *DSAEK* Descemet Stripping Automated Endothelial Keratoplasty precut tissue, *DMEK* Descemet Membrane Endothelial Keratoplasty precut tissue.

[a]Full-thickness tissue was used for either penetrating keratoplasty, anterior or posterior lamellar techniques prepared in theatre.

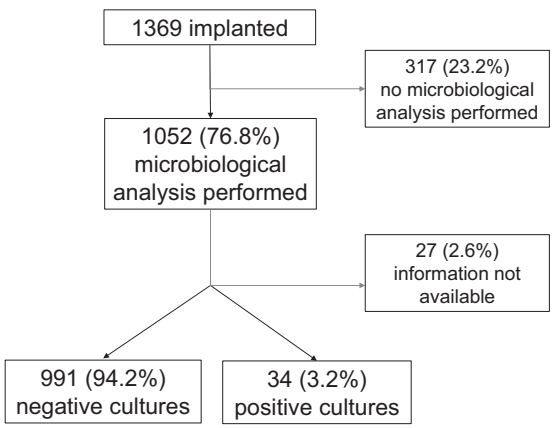

Fig. 1 Flowchart of the study design (real-world data). Microbiological tests performed over the total of corneas implanted and their results.

Table 3 Microbiological results of positive cultures and cornea tissue characteristics.

Cornea n°	preservation	Precut tissue	days delivery to implantation	sample	microorganism	Mate cornea
1	C	No	1	CSR	*Staphylococcus epidermidis*	CSR cultured: negative
2	H	No	0	CSR	*Staphylococcus epidermidis*	No microbiology
3	H	No	0	CSR	*Staphylococcus epidermidis*	CSR cultured: negative
4	C	No	0	CSR	*Escherichia coli*	CSR cultured: negative
5	H	DSAEK	1	CSR	*Staphylococcus aureus*	No microbiology
6	H	No	0	CSR	*Staphylococcus epidermidis*	No microbiology
7	H	DSAEK	1	CSR	*Corynebacterium sp*	CSR cultured: negative
8	H	No	1	CSR	*Candida glabrata*	discarded
9	C	No	1	CSR	*Candida parapsilosis*	discarded
10	C	No	0	CSR	*Burkholderia cepacia*	No microbiology
11	H	No	1	CSR	*Staphylococcus epidermidis*	mate cornea: number 12
12	H	No	1	CSR	*Staphylococcus epidermidis*	mate cornea: number 11
13	H	No	1	CSR	*Staphylococcus epidermidis*	No microbiology
14	H	No	0	CSR	*Staphylococcus epidermidis*	No microbiology
15	H	No	1	CSR	*Candida albicans, Enterococcus faecalis*	mate cornea: number 16
16	H	No	1	CSR	*Candida albicans, Enterococcus faecalis*	mate cornea: number 15
17	C	No	0	CSR	*Escherichia coli*	CSR cultured: negative
18	H	No	1	CSR	*Staphylococcus epidermidis*	No microbiology
19	H	No	1	CSR	*Staphylococcus epidermidis*	Discarded
20	C	No	0	CSR	*Staphylococcus epidermidis*	No microbiology
21	H	No	0	SM+CSR	*Corynebacterium sp*	CSR cultured: negative
22	C	No	0	CSR	*Staphylococcus epidermidis*	CSR cultured: negative
23	C	No	0	CSR	*Bacillus spp*	No microbiology
24	C	No	0	CSR	*Enterococcus faecalis*	SM cultured and negative
25	H	No	0	CSR	*Enterococcus faecalis*	discarded
26	C	No	0	CSR	*Staphylococcus epidermidis*	CSR cultured: negative
27	H	No	0	CSR	*Enterococcus faecalis*	CSR cultured: negative
28	C	No	0	CSR	*Haemophilus influenzae*	CSR cultured: negative
29	H	No	0	CSR	*Staphylococcus epidermidis*	discarded
30	C	No	1	CSR	*Staphylococcus epidermidis*	No microbiology
31	C	No	0	SM+CSR	*Escherichia coli*	SM+CSR cultured: negative
32	H	No	1	CSR	*Aspergillus niger*	CSR cultured: negative
33	H	No	0	SM+CSR	*Staphylococcus epidermidis*	mate cornea: number 34
34	H	No	0	SM+CSR	*Staphylococcus epidermidis*	mate cornea: number 33

H: hypothermia; C: cultured cornea; 0: same day; 1: one or more days before.

CSR corneoscleral rim, *SM* storage medium, *DSAEK* Descemet Stripping Automated Endothelial Keratoplasty precut tissue.

with positive microbiological cultures reported ocular infection for the recipients in at least 6 months' follow-up.

Regarding hypothermic corneas, 8.8% ($n = 21$) had positive microbiological culture whereas only 1.6% ($n = 13$) of organotypic cultured corneas. In other words, corneas preserved in hypothermia represented 61.8% of all positive microbiology results ($p < 0.001$). *Staphylococcus epidermidis* and *Enterococcus faecalis*—alone or isolated with *Candida albicans*—were also more prevalent in hypothermic corneas, corresponding to 57.1 and 19% of all specimens isolated respectively. Corneas in hypothermia ($n = 346$) remained on average 5 days in the eye bank (CI 95% 5; 6) and cultured corneas ($n = 1023$) remained on average 28 days (CI 95% 28.0; 29.0). Median time of corneas with negative microbiological culture ($n = 991$) were 26 days (CI 95% 26; 27) (range 0; 150 days) and with positive

microbiological culture ($n = 34$) were 7 days (CI 95% 7; 26) (range 0; 37 days) ($p = 0.001$).

Septicaemia showed more microbiological positivity than other causes of death ($p = 0.044$). Other factors that could eventually be related to positive microbiological cultures were also studied: precut vs surgeon-cut tissue ($p = 1.000$), one vs both corneas implanted ($p = 0.203$), both corneas sent at the same time vs one after the other ($p = 0.856$), days from eye bank shipment to surgery ($p = 0.748$), endothelial cell density ($p = 0.939$), or sample sent for microbiology (corneoscleral rim, cornea storage medium or both) ($p = 0.251$). Overall, none was found significant for a statistical association with microbiological positivity.

Discussion

Microbiological culture of corneoscleral rim and/or cornea storage medium is widely used as quality control of donors when the cornea is implanted. This study provides real-world information on actual day data about microbiological culture results of corneoscleral rims and storage medium of corneas provided by a single public official eye bank. As a whole, it reports less microbiological culture positivity in organotypic cultured corneas than those conserved in hypothermia. In our study, 78.9% of all donor microbiological control cultures carried out corresponded to corneas implanted in the reference centre ($p = 0.001$). That could suggest that high volume implanting centres could be more prone to perform microbiological cultures.

Causes for positivity related to donor cornea characteristics were searched for, showing more microbiological positive results of those corneas stored in hypothermia than those cultured ($p < 0.001$). Several groups have studied risk factors for donor cornea contamination detected in the eye bank [3, 4, 18, 19]. It seems than cultured corneas have lower risk to have a positive culture because of the eye bank protocol that imply more accurate microbiological controls during the period of culture. For example, in our ocular tissue bank cultured cornea is released after three sequentially negative microbiological analysis by standard protocol [20].

Most of the provided corneas were full thickness tissue (92.4%). Among precut tissue ($n = 78$; 7.6%)—for DMEK or DSAEK—only 2 cases of positivity were found, in this case, in precut tissue for DSAEK. Only a fraction (65.2%) of delivered full-thickness corneas was used for penetrating keratoplasty as some of them (34.8%) were indeed prepared by the surgeon to perform a selective endothelial procedure. This additional manipulation in the theatre to prepare a whole cornea for lamellar surgery could eventually contaminate it although no statistical differences in microbiological testing results between precut corneas and whole corneas than could be cut in theatre were found ($p = 1.000$). Since in 2013 our eye bank started to deliver precut corneas for DSAEK and in 2017 for DMEK, some surgeons and implanting centres opted for purchasing precut tissue while others continued to prepare the corneas for posterior keratoplasties in site. These last corneas were cut with a microkeratome or peeled in theatre without laminar flow in most of the cases, having an extra chance for contamination. Taking into account that the most prevalent microorganism found in our study is *Staphylococcus epidermidis*, which is considered a microorganism of normal mucous membrane flora, we could not discard an eventual theatre contamination. On the other hand, precut tissue has shown less positive bacterial donor rim cultures than surgeon-cut, as previously reported [21, 22]. It is not possible to know the trends in keratoplasty techniques from this study data, as only in some cases (surgeon preferences or implanting centre protocol, for example) DMEK and DSAEK were undertaken using precut tissue [23], while in the reference centre, most of the full-thickness corneas purchased (34.8%) were used for posterior lamellar techniques (data not shown).

Other causes that could be related to microbiological positivity were also studied. For example, the material for sample cultured (corneoscleral rim, cornea storage medium or both) could be associated to the positivity rate. In this study both corneoscleral rim and storage medium were simultaneously cultured in only 80 cases (7.6%), an insufficient number to perform statistical associations. Corneoscleral rim cultures and storage media have been previously compared in literature, observing that corneoscleral remaining tissue showed more positivity [24]. In addition, different methods of microbiological culture or incubation time, can lead to different positivity results due its different sensibility [8, 25]. We could not stablish and compare types of microbiological culture methods due to the heterogeneity of protocols and approaches of the centres involved. Sharma et al. demonstrated that different microbiology protocols directly influence the rates of positive rim cultures [8]. The donor cause of death has also proven to be a major factor for corneal suitability because death related to infections are more prone to cause positive cultures in the eye bank and being discarded consequently [26]. Despite our study showed than septicaemia had a statistically significant microbiological positivity ($p = 0.044$), only one major death cause was reported by donor. Other causes of death—as cancer, respiratory—could cause sepsis as well and be ignored for being a secondary death cause.

Some limitations of this study are related to the real-world origin of the data, sample size, and its related biases. In addition, we observed that 23.2% of the keratoplasties

carried out had no microbiological perioperatively control of the donated tissue. Since this is not required by protocol, it could still be considered a high microbiological control rate compared with other areas [22]. Despite some authors question the prognostic role of corneoscleral rims [15], recent studies are more prone to perform them, based on an efficient rationale [14, 24].

Being able to know the exact moment of donor corneal contamination would be of crucial interest. However, the microbiological control rate, number of corneas with its mate cornea discarded in this study, and the study design itself, leave this question unanswered. For any not clearly defined reason, cultured corneas tend to have less positivity rate than hypothermic ones. Eye banks current trends are to supply organ-cultured corneas instead of hypothermic tissue —BST started to supply organotypic corneas in January 2010 and stands for the 65% of the overall storage method for the last 3 years. It seems they have less risk of have a positive microbiological result: hypothermic storage ranged from 4 to 37% [6, 27]. By contrast, organ culture literature reports values up to only 16% [2, 28, 29]. However, some authors have found major positivity in organotypic corneas compared to hypothermic ones [27]. Our data showed that only 40.6% of all positive microbiological results have been on cultured corneas, corresponding to 76.7% of all supplied tissue. Moreover, cultured corneas have other added advantages over the hypothermic ones, as for example the longer storage time that has improved the logistics of the supply procedure as well as decreased the waiting list in some regions [27].

In summary, this study reports rates of positive microbiological culture of corneoscleral rims and cornea storage medium in real-world practice. It shows a statistically significant more positivity in those corneas conserved in hypothermia compared to those in organotypic cultures. In addition to other commented advantages of cultured cornea method, as greater tissue availability despite improved costs, the future of cornea tissue conservation in eye banks could be expected to consolidate higher rates of organ-cultured corneas.

Summary

What was known before

- several factors are related to keratoplasty postoperative infection ·microbiological cultures are used as predictors for keratoplasty infectious complications ·the relationship between positive microbiological cultures and keratoplasty infection is weak.

What this study adds

- microbiological culture rates in real-world are studied ·causes for microbiological culture positivity are studied ·organotypic cultured corneas are less prone to have positive corneoscleral rims or cornea storage media

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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References

1. European Eye Bank Association. Annual Directory. 28th Edition. Venice, Italy; 2020.
2. Builles N, Perraud M, Reverdy M, Burillon C, Crova P, Brun F, et al. Reducing contamination when removing and storing corneas: a multidisciplinary, transversal, and environmental approach. Cornea. 2006;25:185–92.
3. Gruenert AK, Rosenbaum K, Geerlling G, Fuchsluger TA. The influence of donor factors on corneal organ culture contamination. Acta Ophthalmol. 2017;95:733–40.
4. Röck D, Wude J, Bartz-Schmidt KU, Yoeruek E, Thaler S, Röck T. Factors influencing the contamination rate of human organ-cultured corneas. Acta Ophthalmol. 2017;95:e706–12.
5. Rehany U, Balut G, Lefler E, Rumelt S. The Prevalence and Risk Factors for Donor Corneal Button. Cornea. 2004;23:649–54.
6. Kloess PM, Stulting RD, Waring GO, Wilson LA. Bacterial and fungal endophthalmitis after penetrating keratoplasty. Am J Ophthalmol. 1993;115:309–16.
7. Keyhani K, Seedor JA, Shah MK, Terraciano AJ, Ritterband DC. The incidence of fungal keratitis and endophthalmitis following penetrating keratoplasty. Cornea. 2005;24:288–91.
8. Sharma RA, Park JSY, Wang Y, Zhang T, Sharpen L, Dixon W, et al. Association between positive corneal rim cultures and microbiology screening protocols in Ontario. Can J Ophthalmol. 2018;53:272–7.
9. Chen JY, Jones MN, Srinivasan S, Neal TJ, Armitage WJ, Kaye SB. Endophthalmitis After Penetrating Keratoplasty. Ophthalmology. 2015;122:25–30.
10. Hassan SS, Wilhelmus KR. Eye-banking risk factors for fungal endophthalmitis compared with bacterial endophthalmitis after corneal transplantation. Am J Ophthalmol. 2005;139:685–90.
11. Leveille AS, McMullan FD, Cavanagh HD. Endophthalmitis following penetrating keratoplasty. Ophthalmology. 1983;90:38–9.
12. Antonios S, Cameron J, Badr I, Habash N, Cotter J. Contamination of donor cornea: postpenetrating keratoplasty endophthalmitis. Cornea. 1991;10:217–20.
13. Matsumoto M, Suzuma K, Miyamura N, Imamura N, Kitaoka T. Conjunctival swabs and corneoscleral rim cultures from corneal

transplantation donors as possible early indicators for post-transplant endopthalmitis. Jpn J Ophthalmol. 2011;55:321–6.
14. Kiatos E, Armstrong JJ, Hutnik CML, Tsioros SM, Malvankar-Mehta MS, Hodge WG. The value of corneoscleral rim cultures in keratoplasty: a systematic review and cost-effectiveness analysis. Clin Outcomes Res. 2017;9:459–74.
15. Wilhelmus KR, Hassan SS. The prognostic role of donor corneoscleral rim cultures in corneal transplantation. Ophthalmology. 2007;114:440–5.
16. Everts RJ, Fowler WC, Chang DH, Reller LB. Corneoscleral rim cultures: lack of utility and implications for clinical decision-making and infection prevention in the care of patients undergoing corneal transplantation. Cornea. 2001;20:586–9.
17. Hajjar Sesé A, Lindegaard J, Julian HO, Højgaard-olsen K, Møller NF, Heegaard S. A presentation of culture-positive corneal donors and the effect on clinical outcomes. Graefe's Arch Clin Exp Ophthalmol. 2019;257:135–41.
18. Linke SJ, Fricke OH, Eddy M, Bednarz J, Druchkiv V, Kaulfers P, et al. Risk factors for donor cornea contamination: retrospective analysis of 4546 procured corneas in a single eye bank. Cornea. 2013;32:141–8.
19. Linke SJ, Eddy M, Fricke OH, Wulff B, Schro A, Hassenstein A, et al. Thirty years of cornea cultivation: long-term experience in a single eye bank. Acta Ophthalmol. 2013;91:571–8.
20. Zanetti E, Bruni A, Mucignat G, Camposampiero D, Frigo AC, Ponzin D. Bacterial contamination of human organ-cultured corneas. Cornea. 2005;24:603–7.
21. Rauen MP, Goins KM, Sutphin JE, Kitzmann AS, Schmidt GA, Wagoner MD. Impact of eye bank lamellar tissue cutting for endothelial keratoplasty on bacterial and fungal corneoscleral donor rim cultures after corneal transplantation. Cornea. 2012;31:376–9.
22. Mian SI, Aldave AJ, Tu EY, Ayres BD, Jeng BH, Macsai MS, et al. Infections in the cornea preservation time study. Cornea. 2018;37:1102–9.
23. Palma-Carvajal F, Morales P, Salazar-Villegas A, Figueroa-Vercellino JP, Spencer F, Peraza-Nieves J, et al. Trends in corneal transplantation in a single center in Barcelona, Spain. Transitioning to DMEK. J Fr Ophtalmol. 2020;43:1–6. https://doi.org/10.1016/j.jfo.2019.06.026.
24. Tsui E, Luong PM, Fogel J, Fogel ES, Zegans ME. Microbial analysis of donor corneoscleral rims and storage media. Ocul Immunol Inflamm. 2019;27:817–20.
25. Nan-ni C, Pei-Lun W, Hung-Chi C, Tsung-Yu H, Li-Ju L. Prevalence of microbial contamination in donor corneas. Taiwan J Ophthalmol. 2019;9:179–84.
26. Röck T, Hofmann J, Thaler S, Bramkamp M, Bartz-Schimdt K, Yoeruek E, et al. Factors that influence the suitability of human organ-cultured corneas. Graefe's Arch Clin Exp Ophthalmol. 2016;254:135–41.
27. Devasahayam R, Georges P, Hodge C, Treloggen J, Cooper S, Petsoglou C, et al. Implementation of organ culture storage of donor corneas: a 3 year study of its impact on the corneal transplant wait list at the Lions New South Wales Eye Bank. Cell Tissue Bank. 2016;17:377–85.
28. Cunningham WJ, Moffatt SL, Brookes NH, Twohill HC, Pendergrast DGC, Stewart JM, et al. The New Zealand National Eye Bank Study: trends in the acquisition and storage of corneal tissue over the decade 2000 to 2009. Cornea. 2012;31:538–45.
29. Fontana L, Errani PG, Zerbinati A, Musacchi Y, Di Pede B, Tassinari G. Frequency of positive donor rim cultures after penetrating keratoplasty using hypothermic and organ-cultured donor corneas. Cornea. 2007;26:552–6.