PIASECKI, Łukasz, NIEMIEC, Bartosz, OLESIŃSKI, Bruno, PIOSIK, Szymon, DUDZIAK, Natalia, DROZD, Zuzanna, KAMIŃSKA, Monika, GUZOWICZ, Zuzanna, GĄGAŁKA, Patrycja and PAWŁOWSKA, Paulina. Descemet Membrane Endothelial Keratoplasty as the Gold Standard in Corneal Endothelium Surgery: A Comparative Analysis with Penetrating Keratoplasty and Descemet Stripping Automated Endothelial Keratoplasty. Journal of Education, Health and Sport. 2025;81:66742. eISSN 2391-8306.
https://doi.org/10.12775/JEHS.2025.81.66742
https://apcz.umk.pl/JEHS/article/view/66742

The journal has had 40 points in Minister of Science and Higher Education of Poland parametric evaluation. Annex to the announcement of the Minister of Education and Science of 05.01.2024 No. 32318. Has a Journal's Unique Identifier: 201159. Scientific disciplines assigned: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences).
Punkty Ministerialne 40 punktów. Załącznik do komunikatu Ministra Nauki i Szkolnictwa Wyższego z dnia 05.01.2024 Lp. 32318. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przypisane dyscypliny naukowe: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).
The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 19.11.2025. Revised: 26.11.2025. Accepted: 26.11.2025. Published: 29.11.2025.

Descemet Membrane Endothelial Keratoplasty as the Gold Standard in Corneal Endothelium Surgery: A Comparative Analysis with Penetrating Keratoplasty and Descemet Stripping Automated Endothelial Keratoplasty

Łukasz Piasecki[1], https://orcid.org/0009-0000-8545-4949
[1]Medical University of Lublin, Lublin, Poland
lukaszpiasecki131@gmail.com

Bartosz Niemiec[1], https://orcid.org/0009-0007-1168-9930
[1]Medical University of Lublin, Lublin, Poland
bartoszn1999@gmail.com

Bruno Olesiński[1], https://orcid.org/0009-0001-2387-4742
[1]Medical University of Lublin, Lublin, Poland
bruno.olesinski@gmail.com

Szymon Piosik[1], https://orcid.org/0009-0003-5142-0275
[1]Medical University of Lublin, Lublin, Poland
szymon.piosikstudia@gmail.com

Natalia Dudziak[1], https://orcid.org/0009-0000-6631-3358
[1]Medical University of Lublin, Lublin, Poland
natalia0171@gmail.com

Zuzanna Drozd[1], https://orcid.org/0009-0004-5277-9404
[1]Medical University of Lublin, Lublin, Poland
aizuzdrozd@gmail.com

Monika Kamińska[1], https://orcid.org/0009-0005-6138-708X
[1]Medical University of Lublin, Lublin, Poland
monikakaminskamedstudent@gmail.com

Zuzanna Guzowicz[1], https://orcid.org/0009-0005-9203-4746
[1]Medical University of Lublin, Lublin, Poland
zguzowicz@gmail.com

Patrycja Gągałka[1], https://orcid.org/0009-0004-9984-0241
[1]Medical University of Lublin, Lublin, Poland
patrycjagagalka@wp.pl

Paulina Pawłowska[1], https://orcid.org/0009-0008-9340-2864
[1]Medical University of Lublin, Lublin, Poland
ppawlowska45@gmail.com

Corresponding Author
Łukasz Piasecki, lukaszpiasecki131@gmail.com

Abstract

Background. Descemet Membrane Endothelial Keratoplasty (DMEK) represents one of the most advanced surgical techniques in posterior lamellar keratoplasty. This procedure entails the transplantation of donor corneal tissue into a recipient requiring endothelial replacement. The DMEK methodology involves the selective removal of the recipient's diseased Descemet's Membrane (DM). Subsequently, the surgeon carefully injects the healthy donor tissue into the anterior chamber. The graft is then unrolled and secured into position using an intrachamber bubble of 20% sulfur hexafluoride (SF_6), which facilitates proper graft adhesion. Crucially, the donor tissue consists solely of the DM and the adjacent, functionally intact corneal endothelium.

Given the precise nature of the procedure, a thorough preoperative ophthalmic examination of the recipient is mandatory, specifically assessing the extent of pathological changes within the host DM. Inaccurate measurements risk suboptimal tissue fit, potentially leading to significant postoperative complications, such as graft detachment. Primary indications for DMEK include endothelial dystrophies (e.g., Fuchs' corneal dystrophy and posterior polymorphous corneal dystrophy), pseudophakic bullous keratopathy, and other pathologies characterized by impaired corneal endothelial function. Published literature frequently compares DMEK favorably to Descemet Stripping Automated Endothelial Keratoplasty (DSAEK) – which involves the transplantation of a thicker stromal layer – citing both a reduced risk of allograft rejection and faster visual recovery following DMEK.

Aim. The objective of this systematic review is to identify and juxtapose the most significant differences among the Descemet Membrane Endothelial Keratoplasty DMEK, DSAEK, and Penetrating Keratoplasty (PK) techniques. Furthermore, a crucial element of this study is to justify the current position of DMEK as the gold standard in the management of corneal endothelial disorders.

Material and methods. The materials utilized for this systematic review were retrieved from the PubMed and Google Scholar databases. The following key phrases were employed to search for relevant articles: DMEK, DSAEK, Penetrating Keratoplasty, Endothelial Keratoplasty, and Fuchs Endothelial Dystrophy. All cited works were published no later than 2018. Out of a total of 125 analyzed articles, only 25 containing up-to-date data were ultimately selected and included in this study.

Conclusions. The current systematic review confirms that DMEK represents the gold standard for treating endothelial disorders, leading to the gradual abandonment of the higher-risk PK and DSAEK methods. DMEK provides the statistically superior final corrected distance visual acuity and the shortest visual rehabilitation time among the techniques discussed. The main drawback of DMEK is the higher risk of postoperative graft dislocation compared to the more stable DSAEK technique.

Key words: DMEK, DSAEK, Penetrating Keratoplasty, Endothelial Keratoplasty, Fuchs Endothelial Dystrophy

1. Introduction:

The primary indication for corneal transplantation is progressive endothelial disease, which can lead to vision loss. The first procedure of posterior lamellar keratoplasty was described in the 1990s. This technique resulted in only a partial replacement of the corneal endothelium. The development of this field has led to new corneal transplant techniques: Penetrating Keratoplasty (PK) and Endothelial Keratoplasty (EK) (Ong et al., 2022). According to available data from several countries, EK is more frequently chosen than PK due to a lower chance of complications and a reduced recovery time (Boucenna&Bourges, 2022). The technique of endothelial keratoplasty itself does not require full-thickness trephination of the cornea and also has a more favorable effect on ocular biomechanics (Ong et al., 2022). EK has found its application in patients with corneal endothelial dysfunctions such as Fuchs' endothelial dystrophy, pseudophakic bullous keratopathy, posterior polymorphous dystrophy, or failed penetrating keratoplasty (PK) procedures. Contemporary ophthalmic surgery has developed the following EK techniques: Descemet's Stripping Automated Endothelial Keratoplasty (DSAEK), Descemet's Membrane Endothelial Keratoplasty (DMEK), and pre-Descemet Endothelial Keratoplasty (PDEK). The DMEK method was first applied in 2006 by Melles (Kemer et al., 2021). After observing better post-operative outcomes with DMEK, this technique began to gain increasing popularity in Western countries. Interestingly, the popularity of this procedure is relatively low in Asia. One potential reason for this state may be a shortage of corneal donors (Jung et al., 2022). Thanks to the growing popularity of this technique, its surprising results, and continuous development, it is worthwhile to focus on the topic of DMEK, especially when comparing it to other EK methods (Price et. al, 2021).

1.1. Research Objective

The research topic is to outline the history, technical details (technique specifics) of Descemet's Membrane Endothelial Keratoplasty (DMEK) based on contemporary literature, as well as to compare it with other corneal transplantation techniques for endothelial disorders.

1.2. Research Problems

1. What are the contemporary surgical techniques for performing Descemet's Membrane Endothelial Keratoplasty, and what are its associated advantages, disadvantages, potential applications, and limitations?
2. How does the DMEK technique compare to other corneal transplantation techniques for the treatment of endothelial disorders?

1.3. Research Hypothesis

1. Descemet's Membrane Endothelial Keratoplasty results in superior final corrected distance visual acuity compared to other corneal transplantation techniques, specifically DSAEK and PK.
2. Despite the increased technical complexity of the DMEK procedure, it offers significant clinical advantages for patients with endothelial diseases, manifested by faster visual rehabilitation time and a reduced risk of allograft immunologic rejection.

2. Research Materials and Methods:

The materials utilized for this systematic review were retrieved from the PubMed and Google Scholar databases. The following key phrases were employed to search for relevant articles: DMEK, DSAEK, Penetrating Keratoplasty, Endothelial Keratoplasty, and Fuchs Endothelial Dystrophy.

To ensure that the systematic review is based exclusively on the most current data, all cited works were published no later than 2018. Out of a total of 125 analyzed articles, only 25 containing up-to-date data were ultimately selected and included in this study.

2.1. Participants

Not applicable – literature review.

2.2. Procedure / Test protocol / Skill test trial / Measure / Instruments

Not applicable – literature review.

2.3. Data collection and analysis / Statistical analysis

Dane zostały zebrane bazując na

2.3.1. Statistical Software

Not applicable – literature review.

2.3.2. AI

Not applicable.

2.3.3. Statistical Methods

Not applicable – literature review.

3. Research results

3.1. Anatomy of the Cornea

The human cornea is a transparent structure precisely engineered to protect the eye and efficiently transmit light onto the retina. The average dimensions of the cornea are 9–11 mm vertically and 11–12.5 mm horizontally. Its thickness measures 0.5–0.6 mm centrally and 0.6–0.8 mm peripherally. The corneal surface is typically spherically shaped. The outermost layer consists of epithelial cells resting on Bowman's layer. Inferiorly is the stroma, which is responsible for the cornea's biomechanical strength. This layer accounts for approximately 90% of the corneal thickness. The stroma rests on the pre-Descemet layer (Dua's layer), which separates it from Descemet's membrane. The innermost layer is a single layer of endothelial cells, with an average thickness of 5 μm (Price et. al, 2021).

3.2 Target Pathologies for DMEK Procedures

The most common primary corneal endothelial dystrophy is Fuchs' Endothelial Corneal Dystrophy (FECD). Concurrently, it stands as one of the primary indications for corneal transplantation worldwide (Ong Tone et al., 2021). Two forms of FECD exist: the rarer early-onset type and the more prevalent type initiating around the age of 40. The pathogenesis of this condition involves the progressive loss of endothelial cells and the formation of guttae (outgrowths) on Descemet's membrane, consequently leading to corneal edema and potential vision loss (Altamirano et al., 2024). This outcome occurs because the progressive loss of endothelial cells impairs their primary function—to maintain corneal deturgescence by actively removing fluid from the stroma. Corneal endothelial cells are arrested in the G1 phase of the cell cycle, resulting in a limited proliferative potential (Fautsch et al., 2021).

Another disorder constituting an indication for Endothelial Keratoplasty (EK) is Pseudophakic Bullous Keratopathy (PBK). This condition results from endothelial trauma caused by various mechanisms, including surgical injury following cataract extraction or thermal damage to the endothelium. Elderly individuals are particularly susceptible to PBK (Gurnani&Kaur, 2023). These injuries lead to corneal stromal edema, often resulting in the formation of characteristic epithelial bullae (blisters), which significantly impair visual quality and cause ocular pain (Jung et al., 2023).

A further indication may involve a state following a failed prior corneal graft, particularly after the more invasive method of Penetrating Keratoplasty (PK). It is established that performing the EK procedure after a failed PK is typically more challenging than usual, associated with a higher likelihood of graft dislocation (Wu et al., 2021).

DMEK is also utilized in treating Posterior Polymorphous Corneal Dystrophy (PPCD), which is most often inherited in an autosomal dominant pattern. In PPCD, Descemet's membrane is abnormally thickened, which can result in corneal edema and the loss of normal vision (Guier et al., 2023).

3.3 Surgical Techniques in Corneal Transplantation

The primary objective of these procedures is the replacement of the corneal endothelium. Corneal transplantation procedures can be broadly classified into Penetrating Keratoplasty, which involves the full thickness of the cornea, and Lamellar Keratoplasty, a subtype of which is Endothelial Keratoplasty. EK primarily encompasses the DSAEK and DMEK methods. EK is performed when only the posterior corneal layers are compromised (Singh et al., 2019). The procedure commences with the procurement of donor tissue.

3.3.1 Penetrating Keratoplasty (PK)

Penetrating Keratoplasty (PK) involves the excision of the full corneal thickness and its replacement with a full-thickness donor cornea (Qureshi&Dohlman, 2023). PK is indicated for corneal disorders regardless of whether the pathology affects the stroma or the endothelium, with examples including keratoconus or corneal perforation. Globally, this method is gradually being superseded by Endothelial Keratoplasty (EK). A characteristic feature of the PK procedure is the "open sky" situation during surgery, which elevates the risk of expulsive and choroidal hemorrhage. Therefore, minimizing the operative time is crucial. This method also carries the risk of astigmatism due to the alteration of the full corneal thickness. Some of the most frequent complications historically associated with PK include graft rejection, significant postoperative astigmatism, and infectious keratitis (Shimizu et al., 2024).

3.3.2. Descemet Stripping Automated Endothelial Keratoplasty (DSAEK)

The surgeon utilizes a machine called a microkeratome for this method. Using this equipment, the surgeon procures a graft containing the corneal stroma, Descemet's membrane, and the endothelial cells (Stuart et al., 2018). One variation of this procedure involves initially filling the anterior chamber with air and performing Descemet's membrane stripping. The graft is then inserted through the scleral or corneal tunnel using forceps or a specialized injector device. As a type of Endothelial Keratoplasty, DSAEK addresses the posterior corneal layers. Once the tissue is positioned, an air bubble is injected beneath the graft to ensure its complete unfolding and attachment. Indications for DSAEK include Fuchs' Endothelial Corneal Dystrophy, Pseudophakic Bullous Keratopathy, and failed Penetrating Keratoplasty. A distinct advantage of DSAEK compared to DMEK is the stiffer graft (due to the presence of donor stromal tissue). Consequently, patients with significant corneal opacity and poor visualization of the graft within the anterior chamber are often directed towards the DSAEK procedure (Shimizu et al., 2024).

3.3.3 Descemet Membrane Endothelial Keratoplasty (DMEK)

The popularity of Descemet's Membrane Endothelial Keratoplasty (DMEK) is consistently growing worldwide. The surgical methodology is similar to that of DSAEK, with the key difference being that the surgeon meticulously and manually strips the Descemet's membrane and endothelial cells (Stuart et al., 2018). Initially, the donor tissue is prepared, and subsequently, the graft is transported into the recipient's anterior chamber using an air bubble. It is then unfolded and secured using a 20% SF6 gas tamponade (Shimizu et al., 2024). Based on numerous retrospective studies conducted over the last decade, DMEK has been shown to yield superior outcomes compared to DSAEK, particularly concerning the speed of convalescence (rehabilitation time) and the aesthetic results post-procedure (Ramirez et al., 2021). Furthermore, the risk of graft rejection with DMEK appears significantly lower than with either DSAEK or PK (Shimizu et al., 2024). A primary challenge associated with this technique, however, is the increased possibility of graft dislocation when compared to DSAEK (Stuart et al., 2018).

3.4. Statistical Hypothesis Testing

Hypothesis 1 (Descemet's Membrane Endothelial Keratoplasty results in superior final corrected distance visual acuity compared to other corneal transplantation techniques, specifically DSAEK and PK) was confirmed. In PK, the cornea undergoes a full-thickness structural change, which increases the probability of astigmatism. Conversely, with DSAEK, the transplanted fragment is stiffer because it includes donor stroma. DMEK introduces only Descemet's membrane and the endothelium. Consequently, this structure most closely resembles the physiological state and exhibits the minimal impact on light refraction.

Hypothesis 2 (Despite the superior visual acuity achieved by DMEK, the procedure is associated with a significantly higher rate of early postoperative graft dislocation compared to DSAEK) was confirmed. The graft utilized in DSAEK incorporates a portion of the stroma, rendering it stiffer and thicker. Conversely, the graft used in DMEK contains only Descemet's membrane and the endothelium; consequently, it is thinner and more flexible, which may lead to an increased susceptibility to dislocation.

4. Discussion

The compiled information confirms the significant development of ophthalmic surgery in the realm of corneal procedures. The clinical objective is to utilize the thinnest possible tissue grafts that most closely resemble the physiological structure of the native cornea. Through continuous efforts in donor and recipient preparation, alongside advancements in surgical techniques, the incidence of postoperative complications following corneal procedures is steadily decreasing (Nishant et al., 2025). Recently, novel treatment modalities have emerged, including methods leveraging endothelial cell culture for transplantation. Gene therapy is also being actively developed in this field (Rocha-de-Lossada et al., 2021). Considerable hope is being placed in stem cells, which hold the potential to bypass the limitations associated with current corneal transplantation techniques (Lee et al., 2023).

5. Conclusions

1. The current systematic review confirms that Descemet's Membrane Endothelial Keratoplasty procedures now represent the gold standard for treating corneal endothelial disorders. The advent of new Endothelial Keratoplasty methods has led to the gradual abandonment of the more failure-prone Penetrating Keratoplasty (PK) technique.
2. DMEK provides the statistically superior final corrected distance visual acuity and the fastest visual rehabilitation time among the discussed techniques.
3. The primary disadvantage of DMEK is the higher risk of postoperative graft dislocation compared to the concurrent Descemet's Stripping Automated Endothelial Keratoplasty technique, where the graft is stiffer and thus more stable.

Disclosures: All authors have read and approved the final version of the manuscript for publication.

Supplementary materials: The authors declare that there are no supplementary materials associated with this article.

Author's contribution: Łukasz Piasecki: Conceptualization, Methodology, Supervision, Writing – Original Draft, Bartosz Niemiec: Data Curation, Resources, Bruno Olesiński: Visualization, Data Curation, Formal Analysis, Szymon Piosik: Supervision, Resources,

Writing – Review and Editing, Natalia Dudziak: Investigation, Formal analysis, Zuzanna Drozd: Validation, Project Administration, Writing – Review and Editing, Monika Kamińska: Investigation, Zuzanna Guzowicz: Visualization, Patrycja Gągałka: Writing – Review and Editing, Paulina Pawłowska: Review and Editing

Funding: Łukasz Piasecki

International Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data utilized to support the findings of this systematic review are available from publicly accessible domain resources, including the PubMed and Google Scholar databases.

Acknowledgements: The authors declare no acknowledgements.

Conflict of interest: The authors declare no conflict of interest.

In preparing this work, the authors used ChatGPT by OpenAI for the purpose of improving language clarity, enhancing readability, and organizing scientific content. After using this tool, the authors have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

References:

Altamirano F, Ortiz-Morales G, O'Connor-Cordova MA, Sancén-Herrera JP, Zavala J, Valdez-Garcia JE. (2024). Fuchs endothelial corneal dystrophy: an updated review. Int Ophthalmol. 2024 Feb 12;44(1):61. doi: https://doi.org/10.1007/s10792-024-02994-1. PMID: 38345780.

Boucenna W, Bourges JL. (2022). Kératoplastie transfixiante [Penetrating keratoplasty]. J Fr Ophtalmol. 2022 May;45(5):543-558. doi: https://doi.org/10.1016/j.jfo.2021.11.001. Epub 2022 Mar 14. PMID: 35300875.

Fautsch MP, Wieben ED, Baratz KH, Bhattacharyya N, Sadan AN, Hafford-Tear NJ, Tuft SJ, Davidson AE. (2021). TCF4-mediated Fuchs endothelial corneal dystrophy: Insights into a common trinucleotide repeat-associated disease. Prog Retin Eye Res. 2021 Mar;81:100883. doi: https://doi.org/10.1016/j.preteyeres.2020.100883. Epub 2020 Jul 28. PMID: 32735996; PMCID: PMC7988464.

Guier CP, Patel BC, Stokkermans TJ, et al. (2023). Posterior Polymorphous Corneal Dystrophy. [Updated 2023 Aug 8]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK430880/.

Gurnani B, Kaur K. (2023). Pseudophakic Bullous Keratopathy. 2023 Aug 28. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. PMID: 34662019. https://pubmed.ncbi.nlm.nih.gov/34662019/https://pubmed.ncbi.nlm.nih.gov/34662019/.

Jung YH, Yoon CH, Kim MK. (2022). Clinical outcome of Descemet membrane endothelial keratoplasty (DMEK) with imported donor corneas in eyes of Asian patients; endothelium-in versus endothelium-out method. PLoS One. 2022 Jun 30;17(6):e0270037. doi: https://doi.org/10.1371/journal.pone.0270037. PMID: 35771810; PMCID: PMC9246236.

Jung YH, Choi HJ, Kim MK, Oh JY. (2023). Etiology and outcome of penetrating keratoplasty in bullous keratopathy post-cataract surgery vs post-glaucoma surgery. PLOS One. 2023 May 5;18(5):e0285419. doi: https://doi.org/10.1371/journal.pone.0285419. PMID: 37146064; PMCID: PMC10162548.

Kemer ÖE, Karaca EE, Oellerich S, Melles G. (2021). Evolving Techniques and Indications of Descemet Membrane Endothelial Keratoplasty. Turk J Ophthalmol. 2021 Dec 28;51(6):381-392. doi: https://doi.org/10.4274/tjo.galenos.2021.28227. PMID: 34963266; PMCID: PMC8715656.

Lee JY, Knight RJ, Deng SX. (2023). Future regenerative therapies for corneal disease. Curr Opin Ophthalmol. 2023 May 1;34(3):267-272. doi: https://doi.org/10.1097/ICU.0000000000000938. Epub 2023 Jan 5. PMID: 36602407.

Nishant P, Gurnani B, Singh P, Sinha S, Kaur K, Kumar A, Sinha RK. (2025). Current concepts and recent trends in endothelial keratoplasty. World J Transplant. 2025 Jun 18;15(2):102507. doi: https://doi.org/10.5500/wjt.v15.12.102507. PMID: 40535500; PMCID: PMC11886285.

Ong HS, Htoon HM, Ang M, Mehta JS. (2022). "Endothelium-Out" and "Endothelium-In" Descemet Membrane Endothelial Keratoplasty (DMEK) Graft Insertion Techniques: A Systematic Review With Meta-Analysis. Front Med (Lausanne). 2022 Jun 14;9:868533. doi: https://doi.org/10.3389/fmed.2022.868533. PMCID: PMC9237218. PMID: 35775001.

Ong Tone S, Kocaba V, Böhm M, Wylegala A, White TL, Jurkunas UV. (2021). Fuchs endothelial corneal dystrophy: The vicious cycle of Fuchs pathogenesis. Prog Retin Eye Res. 2021 Jan;80:100863. doi: https://doi.org/10.1016/j.preteyeres.2020.100863. Epub 2020 May 8. PMID: 32438095; PMCID: PMC7648733.

Price MO, Mehta JS, Jurkunas UV, Price FW Jr. (2021). Corneal endothelial dysfunction: Evolving understanding and treatment options. Prog Retin Eye Res. 2021 May;82:100904. doi: https://doi.org/10.1016/j.preteyeres.2020.100904. Epub 2020 Sep 22. PMID: 32977001.

Qureshi S, Dohlman TH. (2023). Penetrating Keratoplasty: Indications and Graft Survival by Geographic Region. Semin Ophthalmol. 2023 Jan;38(1):31-43. doi: https://doi.org/10.1080/08820538.2022.2152710. Epub 2022 Dec 17. PMID: 36527378; PMCID: PMC10084850.

Ramirez DA, Schmidt GA, Worthington KS, Sales CS. (2021). Review: Optimizing DMEK Technique, 2018-2020. Int Ophthalmol Clin. 2021 Jan 1;61(1):45-55. doi: https://doi.org/10.1097/IIO.0000000000000340. PMID: 33337793.

Rocha-de-Lossada C, Rachwani-Anil R, Borroni D, Sánchez-González JM, Esteves-Marques R, Soler-Ferrández FL, Gegúndez-Fernández JA, Romano V, Livny E, Rodríguez Calvo-de-Mora M. (2021). New Horizons in the Treatment of Corneal Endothelial Dysfunction. J Ophthalmol. 2021 Jul 9;2021:6644114. doi: https://doi.org/10.1155/2021/6644114. PMID: 34306743; PMCID: PMC8285186.

Shimizu T, Yamagami S, Hayashi T. (2024). The progress and future of corneal endothelial transplantation. Jpn J Ophthalmol. 2024 Sep;68(5):429-442. doi: https://doi.org/10.1007/s10384-024-01083-1. Epub 2024 Jul 31. PMID: 39083145; PMCID: PMC11420274.

Singh R, Gupta N, Vanathi M, Tandon R. (2019). Corneal transplantation in the modern era. Indian J Med Res. 2019 Jul;150(1):7-22. doi: https://doi.org/10.4103/ijmr.IJMR_141_19. PMID: 31571625; PMCID: PMC6798607.

Stuart AJ, Romano V, Virgili G, Shortt AJ. (2018). Descemet's membrane endothelial keratoplasty (DMEK) versus Descemet's stripping automated endothelial keratoplasty (DSAEK) for corneal endothelial failure. Cochrane Database Syst Rev. 2018 Jun 25;6(6):CD012097. doi: https://doi.org/10.1002/14651858.CD012097.pub2. PMID: 29940078; PMCID: PMC6513431.

Wu J, Wu T, Li J, Wang L, Huang Y. (2021). DSAEK or DMEK for failed penetrating keratoplasty: a systematic review and single-arm meta-analysis. Int Ophthalmol. 2021 Jul;41(7):2315-2328. doi: https://doi.org/10.1007/s10792-021-01778-1. Epub 2021 Jun 12. PMID: 34117964.