Research Article

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Impact of Trabeculectomy on Corneal Endothelium Health: A Quantitative Specular Biomicroscopy Study

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ABSTRACT

Purpose: *To assess the impact of trabeculectomy on corneal health by quantitatively analyzing changes in corneal endothelial parameters using non-invasive specular biomicroscopy.*

Methods: *A cross sectional, non interventional study was conducted on 30 patients in the Department of Ophthalmology at a tertiary eye care centre in central India. All patients attending the glaucoma clinic were evaluated using specular biomicroscopy to measure corneal endothelial cell loss both before and after trabeculectomy surgery over a period of 12 months.*

The following parameters were recorded before surgery and at 1,3, and 6 months post-trabeculectomy during specular biomicroscopy: endothelial cell density (ECD), percentage of hexagonal cells(6A), coefficient of variation in cell area (CV) and central corneal thickness (CCT).

Results: *In this study, most glaucoma patients were aged 61–70 years (36%) with a female predominance (70%). Of 30 patients, 53.3% had Primary Angle Closure Glaucoma (PACG) and 46.7% had Primary Open-Angle Glaucoma (POAG). Specular microscopy revealed statistically significant ($P<0.05$) post-trabeculectomy reductions in endothelial cell density (from 2186.24 ± 225 to 1877 ± 236 cells/mm²), central corneal thickness, and hexagonality, along with increases in endothelial cell area and coefficient of variation (CV). ECD loss showed a positive correlation with CV and negative correlations with hexagonality, ECD, and CCT, indicating structural compromise of the corneal endothelium after trabeculectomy.*

Conclusion: *This study highlights that trabeculectomy significantly affects the corneal endothelium, with notable reductions in endothelial cell density (ECD), central corneal thickness (CCT), and hexagonality, along with increased in cell area and coefficient of variation (CV). A positive correlation with CV and negative correlations with ECD, CCT, and hexagonality indicate compromised endothelial integrity. As endothelium maintains corneal clarity and hydration, monitoring it before and after trabeculectomy is crucial to prevent long-term visual complications.*

Keywords

Trabeculectomy, Endothelial cell count (ECD), Specular biomicroscopy, Corneal transperency, Coefficient of variation (CV).

Introduction

The corneal endothelium plays a vital role in maintaining corneal clarity by regulating stromal hydration through its barrier and pump functions.

Loss of corneal endothelial cells (CECs) can result from various factors, including intraocular surgery, ocular trauma, diseases such as glaucoma, corneal endothelial dystrophy, intraocular inflammation, and systemic conditions like diabetes, Graves' disease, chronic kidney disease, tuberculosis, Marfan's syndrome etc. [1-3]. Under normal conditions, endothelial cell density (ECD) declines by approximately 0.6% per year in the central cornea. When ECD drops below a critical level, it can no longer adequately maintain corneal hydration [4] and transparency.

Glaucoma, a common ocular condition causing endothelial cell loss, is a progressive optic neuropathy often associated with elevated intraocular pressure (IOP). Several mechanisms contribute to endothelial damage in glaucoma, including direct compression from elevated IOP, long term use of anti-glaucoma medications and surgical procedures like filtration surgery (trabeculectomy) [5,6]. Since IOP is the primary modifiable risk factor, it is primarily controlled with anti-glaucoma medications. However, if IOP remains poorly controlled or if visual field damage progresses despite medical treatment, surgical interventions become necessary. Trabeculectomy, the gold standard surgical treatment for glaucoma, can cause corneal damage and is often associated with the rapid decline in corneal endothelial cell density and thus affecting the corneal health. Corneal endothelial cell density and morphology is measured using specular biomicroscopy, a non-invasive technique for quantitative analysis of the corneal endothelium.

The purpose of this study is to assess the impact of trabeculectomy on corneal endothelial health by comparing patient outcomes before and after the procedure.

Material and Methods

A cross sectional, non-interventional study was conducted on 30 patients in the Department of Ophthalmology at a tertiary eye care centre in central India. After receiving approval from the institutional ethical committee, all primary glaucoma patients attending the glaucoma clinic were evaluated using specular biomicroscopy to measure corneal endothelial cell loss both before and after trabeculectomy surgery over a period of 12 months (January 2024 -February 2025).

A detailed history, including the duration of the disease and anti-glaucoma medications used, was recorded for each patient. The evaluation include slit lamp biomicroscopy, Perimetry by Humphrey perimeter, intraocular pressure (IOP) measurement using the Goldmann applanation tonometer, indirect gonioscopy with a 4-mirror gonio lens and a thorough fundus examination to assess disc changes to identify the types of glaucoma and primary glaucoma patients were taken and included in the study. Specular biomicroscopy was performed on each subject. Images were captured from the central cornea and quantitively analyzed using EM- 4000 software (TOMEY) and the following parameters were assessed and compared, Endothelial Cell Density (ECD), hexagonal cells (6A), Central Corneal Thickness (CCT), and Coefficient of Variation (CV) pre operatively and 1, 3, and 6 months post- trabeculectomy. The fornix based trabeculectomy was performed in all patients by the same surgeon and the same technique to avoid the biasing.

Table 1

PARAMETER	NORMAL VALUE
Endothelial cell density	2000-3000 cells/mm
Percentage of hexagonal cells (6A)	46± 8 %
Central corneal thickness (CCT)	554.78+/-32.61
Coefficient of variation	0.22 - 0.31

Inclusion Criteria

- Primary glaucoma patients not achieving target intraocular pressure with maximum medical therapy
- Poor drug compliance
- On multiple anti-glaucoma therapy.

Exclusion Criteria

- Paediatric patients
- Secondary glaucoma patients
- Patients underwent trabeculectomy combined with any other procedure
- Uncontrolled diabetes and hypertension
- Patients with other ocular comorbidity.

Figure 1: Specular microscope.

Surgical Procedures and Follow Up

All patients underwent trabeculectomy surgery under aseptic precautions. Postoperative care was administered as per protocol. At 1,3 and 6 months postoperatively, repeat specular readings were obtained to assess corneal endothelial cell density.

Postoperative specular indices —including corneal endothelial cell count, morphology and postoperative at 1,3 and 6 months were statistically analyzed and correlated with the corneal endothelial cell count preoperatively. Comparisons were also taken into consideration with preoperative hexagonality, Endothelial cell density, coefficient of variation and central corneal thickness to 1,3 and 6 months postoperatively.

Statistical Analysis

All data collected during the study were systematically compiled and entered into Microsoft Excel and subsequently analyzed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were expressed as mean ± standard deviation (SD) for continuous variables such as corneal endothelial cell count, percentage of hexagonality, coefficient of variation and central corneal thickness.

Figure 2: Specular microscopy parameters.

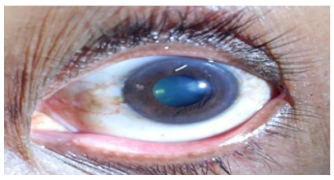


Figure 3a: Preoperative.

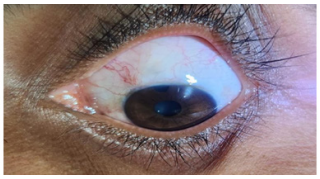


Figure 3b: 1 month post trab.

For normally distributed variables, comparisons between preoperative and postoperative corneal endothelial cell count were made using the paired t-test.

Correlation analyses between ECD loss and the changes in post-operative corneal ECD loss were performed. Pearson's correlation coefficient was used for parametric data. The strength of the correlation was interpreted based on standard thresholds, ranging from very weak (r = 0.00–0.19) to very strong (r = 0.80–1.00). A p-value of less than 0.05 was considered statistically significant in all analyses.

Results

In the present study majority of glaucoma patients belonged to the elder age group i.e., 61-70 years (36%) (Chart 1) as compared to only 13.3% in middle aged group of 40 to 50 years. A slightly higher female preponderance was observed with 70% female and 30% male patients (Figure 4). It was seen that out of 30 primary glaucoma patients 16 patients (53.3%) were diagnosed as Primary Angle Closure Glaucoma (PACG) and 14 patients (43%) had Primary Open-Angle Glaucoma (Chart 2). Correlation between Endothelial cell density (ECD), hexagonality (6A), coefficient of variation (CV) and central corneal thickness (CCT) was studied in pre and post trabeculectomy primary glaucoma patients using specular examination, and it was observed that patients had a statistically significant (P<0.05) reduction in corneal endothelial cell density ECD, hexagonality (6A) and Central Corneal Thickness (CCT) and increase in coefficient of variation (CV) after trabeculectomy surgery. The average endothelial cell density was decreased from (2186.24± 225 cells/mm2) before surgery as compared to 6 months after trabeculectomy surgery 1877± 236 mm2) similarly a negative correlation was also found between hexagonality (6A) and Central corneal thickness CCT i.e., the value of ECD, hexagonality (6A) and CCT decreased after post trabeculectomy , however we observed positive correlation with Coefficient of Variation (CV) i.e. post surgery increased value of CV the details of all the above parameters had shown in (Table 2).

Chart 1:

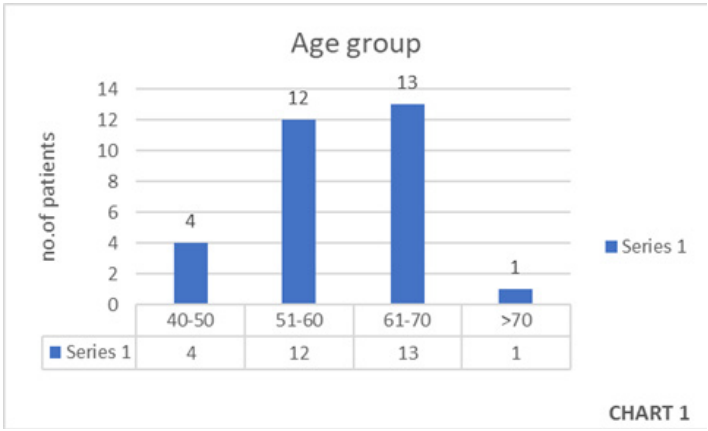


Figure 4

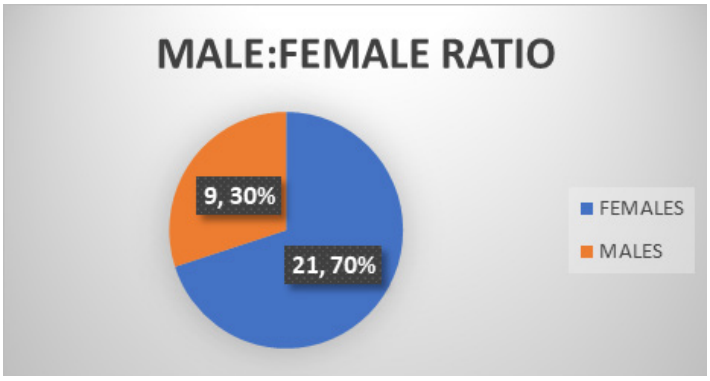
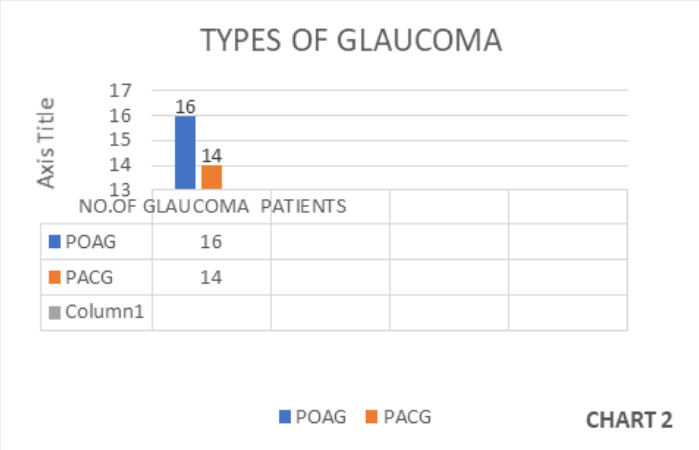


Table 2:

GLAUCOMA PATIENTS	PRE TRAB	POST TRAB (1MONTH)	(3MONTH)	(6MONTH)
CCT	499.86	497.10	487.14	464.83
CDE	2186.24	2184.93	2007.72	1877.69
CV	35.41	39.21	43.76	44.41
6A	46.03	43.47	42.24	38.97

Chart 2:



Discussion

The corneal endothelium plays a vital role in maintaining corneal transparency and overall ocular health. For optimal function, a critical threshold of endothelial cell density and normal cellular morphology must be preserved, as these parameters serve as sensitive indicators of endothelial integrity and function. Consequently, the preservation of endothelial cell structure and count is essential for sustaining long-term corneal clarity.

In current study, we observed the impact of trabeculectomy on corneal endothelial health before and after surgical intervention on primary glaucoma patients. We observed that the majority of glaucoma patients (36%), had the mean age of 65 years, which is consistent with the study of Natalie Si-Yi Lee et al. [7] in which mean age was 67 years, suggesting that progression of glaucoma, leads to anatomical and physiological changes which contribute to the higher prevalence observed in the elderly population. Furthermore, a female preponderance (70%) was observed, in Contrast, to male preponderance (59.3%) which was noted in a study of Natalie Si-Yi Lee et al. [7]. In current study we evaluated 30 primary glaucoma patients, among them primary angle closure glaucoma (PACG) was diagnosed in 53.3% 16 of cases, whereas 46.7% 14 were diagnosed with Primary Open-Angle Glaucoma (POAG). The predominance of PACG in this cohort further supports regional and demographic trends observed in certain populations, particularly in Asian communities where PACG is more common compared to POAG. In contrast, study of Natalie Si-Yi Lee et al., Hirooka K, et al., conducted in Australian and European population the primary open angle glaucoma was common [7,8].

Analysis of study showed a statistically significant reduction in endothelial cell density (ECD), central corneal thickness (CCT), and the percentage of hexagonal cells (hexagonality) postoperatively ($P < 0.05$). The mean preoperative ECD was 2186.24 ± 225 cells/ mm², which declined to 2184.93± 224 cells/ mm² (1.9%) in 1 month, 2007.72 ± 212 cells/ mm² (9.2%) in 3 months, 1877 ± 236 cells/mm² (15.2%) in 6months postoperatively. Similar reports have identified ECD losses ranging from 1.9% at 6 months after trabeculectomy, by Kim Ms et al., 3.2% at 3 months [9] and by Soro-Martínez MI et al. [10], 10% after 12 months by Storr-Paulsen et al. [11] and 9.88% at 6 months post-operatively in study of Natalie Si-Yi Lee et al. [7]. The mechanisms underlying the decline in ECD after trabeculectomy are multifactorial It is hypothesised that after corneal endothelial injury, remaining viable cells migrate and enlarge to compensate for the area damaged, thereby reducing overall cell density [12,13]. These changes are indicative of corneal endothelial cell stress or loss, which is a recognized postoperative impact following trabeculectomy. Additionally, there was a significant postoperative decrease in CCT from 499.86 ± 14.6 before surgery 497.10 ± 12.8 after 1 month, 487.14 ± 14.8 after 3 months, 464.83 ± 13.7 after 6 months coherent with results of other study conducted by Natalie Si-Yi Lee et al. showed decrease in CCT 6 months after trabeculectomy compared to a pre-operative baseline ($p=0.008$)., [7] however few studies by Soro-Martínez et al. Casini G et al., Flaxman SR et al. [10,14,15] and CCT has not demonstrated any significant change after surgery, further more hexagonality (6A) also showed significant reduction in our study from 46.03 to 43.47, 42.24 and 38.97 in 1,3 and 6 month respectively similar to the study of Mohamed Abd El-Aziz et al. [16] which showed the mean decrease in hexagonal cells was 50.50 ± 3.95before surgery which decreased to 47.10 ± 3.78 at 1 month and 45.00 ± 3.65 at 6 months after surgery.

Endothelial cell remodelling and loss of uniformity in cell morphology results in increase polymegathism and pleomorphism after intraocular surgeries, including trabeculectomy.

Apart from above parameters conversely coefficient of variation (CV) was increased from 50.07±15.8 before surgery to 52.30±16.10 after 1 month, by ~4%; 53.47±15.95 after 3 months, by ~6.8%; and 53.93±15.89 after 6 months, by ~7.71%.however the study by María Isabel Soro-Martínez et al. [17] showed CV or polymegathism decreased non-significantly after trabeculectomy surgery.

Correlation analysis of our study revealed a positive correlation between trabeculectomy and CV values postoperatively, indicating increased endothelial cell size variability. Conversely, a negative correlation was observed with hexagonality, ECD, and CCT, implying that these parameters decreased after surgery. This suggests that trabeculectomy has a measurable impact on the integrity and function of the corneal endothelium, which may have implications for long-term corneal health.

Conclusion

Trabeculectomy significantly affects the corneal endothelium, with notable reductions in endothelial cell density (ECD), central corneal thickness (CCT), and hexagonality, along with increases in cell area and coefficient of variation (CV). These changes suggest endothelial cell loss, morphological alterations, and reduced stability. A positive correlation with CV and negative correlations with ECD, CCT, and hexagonality indicate compromised

endothelial integrity. As the endothelium is vital for corneal clarity and hydration, such alterations may impact long-term visual outcomes. Thus, monitoring endothelial health before and after trabeculectomy is crucial in managing potential risks to corneal function.

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