Original Article

Central Corneal Thickness and Intraocular Pressure Changes After Phacoemulsification and Their Association with Cataract Density

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ABSTRACT

Purpose: To assess the changes in central corneal thickness and intraocular pressure following phacoemulsification and find their association with cataract density.

Study Design: Observational analytical study.

Place and Duration of Study: Benazir Bhutto Hospital, Rawalpindi Medical University, from January 2024 to December 2024.

Methods: The study was conducted on 80 eyes undergoing uneventful phacoemulsification. Preoperative and postoperative central corneal thickness(CCT) and intraocular pressure (IOP) were measured using ultrasound pachymetry and Goldmann applanation tonometry, respectively, at day 1, week 1, and week 4. Cataract density was graded using the Lens Opacification Classification System III. Visual acuity was recorded pre- and postoperatively using the decimal notation Snellen chart. Data was analyzed using paired t-tests, repeated measures ANOVA, and Spearman correlation.

Results: The mean preoperative Best corrected visual acuity (BCVA) was 0.208 ± 0.17 (range: 0.01–0.50) using the Snellen decimal notation chart. At four weeks postoperatively, the mean BCVA significantly improved to 0.823 ± 0.16. Mean CCT increased from 524.15 ± 40.54 µm preoperatively to 574.92 ± 44.72 µm on day 1 postoperatively, reducing to 525.89 ± 40.50 µm by week 4. IOP showed a transient rise from 15.59 ± 2.19 mmHg to 17.99 ± 2.17 mmHg at week 1, returning to baseline at week 4. A significant positive correlation was found between cataract density and both postoperative day 1 CCT (ρ=0.421) and IOP (ρ=0.430).

Conclusion: Phacoemulsification results in reversible changes in CCT and IOP. Cataract density is moderately associated with early postoperative corneal edema and IOP elevation.

Keywords: Cataract, Central corneal thickness, Corneal edema, Endothelium, Intraocular pressure, Phacoemulsification, Pachymetry.

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INTRODUCTION

Corneal endothelium is vital for preserving corneal transparency and ensuring optimal visual function. This single layer of cells actively pumps fluid out of the corneal stroma, a process essential for corneal Deturgescence and transparency.[1] Measuring central corneal thickness (CCT) offers an indirect yet valuable assessment of endothelial function, as the layer's pumping activity directly influences stromal hydration and thickness.[2] Studies have shown that CCT rises immediately following intraocular procedures, such as cataract surgery, gradually returning to baseline over a few weeks.[3] Notably, an increase in CCT can lead to falsely elevated IOP readings, which is clinically significant since accurate IOP measurement is essential in diagnosing and managing post-operative glaucoma.[4]

Phacoemulsification, a widely practiced method for cataract removal, is known to affect the corneal endothelium due to factors like ultrasonic energy, incision techniques, and the use of irrigation solutions and viscoelastic substances.[5,6] While cornea can compensate for transient increases in CCT after cataract surgery, extensive damage to endothelial cells may prolong this recovery, potentially impacting patient outcomes.[7,8] Despite understanding these effects, a gap remains in literature regarding how variations in cataract density influence CCT following phacoemulsification and their subsequent impact on IOP.[9] There is limited data on the timeframe for endothelial recovery in different patients, particularly in our local population.[10]

This study explored changes in CCT following uncomplicated phacoemulsification using ultrasound pachymetry. Relationship among cataract density, CCT and IOP were also studied. By focusing on a local population and addressing cataract density variations, this investigation aims to enhance understanding of the timeline of endothelial recovery and its influence on postoperative IOP measurements. A better understanding of CCT recovery dynamics and their correlation with IOP fluctuations is essential for optimizing postoperative care and achieving better visual outcomes in cataract surgery.

METHODS

This study employed an observational analytical design to assess changes in CCT and IOP following phacoemulsification. The study was conducted in the ophthalmology department of Benazir Bhutto Hospital, RMU. The duration of study was 12 months following ethical approval from ERB of institution **(Ref.No.408/IREF/RMU/2023)**. A sample size of 80 was calculated based on 95% confidence level, a 6% margin of error, and an 80% study power, considering an expected cataract prevalence of 8%in Pakistan.[11]

After taking informed written consent, patients were selected through non-probability consecutive sampling, with inclusion criteria covering 35-75 years of age, either gender and presenting with pre-senile or senile cataracts without zonular weakness. Complicated or traumatic cataracts, pre-existing corneal pathologies, history of intraocular surgery, contact lens wearers or prior refractive surgeries, and cataracts with concurrent ocular diseases such as glaucoma or uveitis were excluded.

BCVA was measured using the Snellen's chart, converted to decimal notation, while IOP was assessed with Goldman applanation tonometer. A detailed slit lamp examination was done for anterior and posterior segments, and the cataract density was recorded using Lens Opacification Classification System III.[12]

- **Stage 1:** Few opacities as scattered spots in the red reflex, translucent.
- **Stage II:** <50% of lens opacity, part of red reflex obscured.
- **Stage III:** >50% of lens opacity, part of red reflex obscured.
- **Stage IV:** Total lens opacity, no red reflex through.

CCT measurements were obtained using an ultrasound pachymeter (Opticon-Janus)under topical anesthesia with 0.5% proparacaine HCl. Pupil dilation prior to surgery was achieved with Mydriacyl eye drops (containing 1% Tropicamide) and Ethifrin eye drops (Phenylephrine 10%) if pupils did not dilate sufficiently. Under topical anesthesia with 0.5% Proparacaine HCl and a retrobulbar block, a 3.2-mm clear corneal incision was made. Sodium hyaluronate was used as a viscoelastic agent. Phacoemulsification was performed by a single experienced surgeon using the ‘Stop and Chop’ technique with the Millennium Phaco machine (Bausch and Lomb). A single-piece foldable acrylic intraocular lens (IOL) was implanted, and the primary incision was sealed with stromal hydration. Postoperatively, patients received antibiotic-steroid eye drops in a tapering dose for four weeks to prevent infection and inflammation. Patients were followed up on day one and at the first week to monitor IOP and CCT, with additional evaluations at the first month after surgery.

Statistical analysis was conducted using SPSS software, version 21.0. Quantitative variables such as age, BCVA, CCT, and IOP were summarized using mean and standard deviation. Categorical variables, including gender and cataract density, were presented as frequencies and percentages. The association between cataract density and variations in CCT and

IOP was assessed using Spearman's rank correlation. Paired t-tests were applied to compare preoperative and one-month postoperative measurements of BCVA, CCT, and IOP. Repeated measures ANOVA were used to evaluate changes in IOP and CCT over the follow-up period. In cases where the assumption of sphericity was violated, as indicated by Mauchly's test, the Greenhouse-Geisser correction was implemented. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Mean age of patients was 57.20±8.19 (range 39-72) years. There were 40 males and 40 females. Right eye was operated in 53.1%of patients and left eye was operated in 45.7% patients. The frequency of various stages of cataract is shown in figure 1.

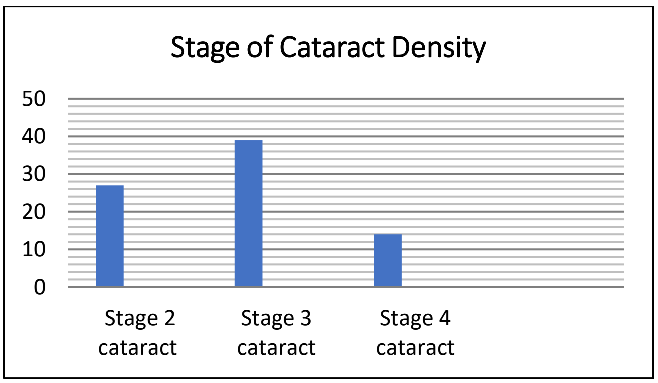

Figure 1: Frequencies of stages of cataract.

The mean preoperative BCVA was 0.208 ± 0.17 (range: 0.01–0.50) using the Snellen decimal notation chart. At four weeks postoperatively, the mean BCVA significantly improved to 0.823 ± 0.16. This represents a mean gain of 0.61, which was statistically significant ($t(79) = –37.899$, $p < 0.001$), indicating substantial visual recovery following phacoemulsification. The narrow 95% confidence interval (–0.64690 to –0.58235) suggests that the true mean improvement lies within this range. The large *t*-value reflects a strong effect size and consistent improvement across participants.

The mean CCT prior to phacoemulsification was 524.15 ± 40.54 µm. A significant increase to 574.92 ± 44.72 µm was observed on the first postoperative day, likely due to transient endothelial dysfunction or surgical trauma. CCT decreased to 554.03 ± 41.73 µm by the end of the first week, indicating partial resolution of corneal edema, and further declined to 525.89 ± 40.50 µm at four weeks, closely approaching baseline values and reflecting progressive endothelial recovery, as illustrated in the bar graph.

Repeated measures ANOVA revealed a statistically significant change in CCT over time (Wilk's Lambda = 0.067, $F = 359.697$, $p< 0.001$), with a large effect size (partial eta squared = 0.933). Due to violation of the sphericity assumption ($\chi^2 = 569.375$, $p < 0.001$), the Greenhouse-Geisser correction was applied, confirming a significant within-subject difference across time points ($F = 387.088$, $p < 0.001$). Percentage increase in CCT from baseline is shown in table 1.

Table 1: *Percentage increase in Post-operative CCT.*

Time Point	Mean CCT (µm)	% Increase from Baseline
Pre-operative	524.15 ± 40.54	—
1st Post-op Day	574.92 ± 44.72	**9.68%**
1st Post-op Week	554.03 ± 41.73	**5.70%**
4th Post-op Week	525.89±40.50	**0.33%**

The difference between preoperative and four-week postoperative CCT was not statistically significant ($p = 0.124$), with a 95% confidence interval of –1.869 to 1.606 µm. These findings support the transient nature of postoperative corneal edema and the recovery of endothelial function within four weeks.

The mean preoperative IOP was 15.59 ± 2.19 mmHg, which increased to 17.99 ± 2.17 mmHg during the first postoperative week and subsequently decreased to 15.36 ± 2.70 mmHg by the fourth week, as illustrated in the line plot. By week four, IOP values returned close to baseline, paralleling the normalization of CCT.

Repeated measures ANOVA further confirmed a statistically significant change in IOP over time (Wilk's Lambda = 0.190, $F = 109.075$, $p < 0.001$), with a large effect size (partial eta squared = 0.810). Due to violation of the sphericity assumption ($\chi^2 = 25.848$, $p < 0.001$), the Greenhouse-Geisser correction was applied, which also demonstrated a significant time effect ($F = 112.599$, $p < 0.001$), indicating that IOP varied significantly across postoperative time points.

Paired samples t-test revealed no statistically significant difference between preoperative and fourth

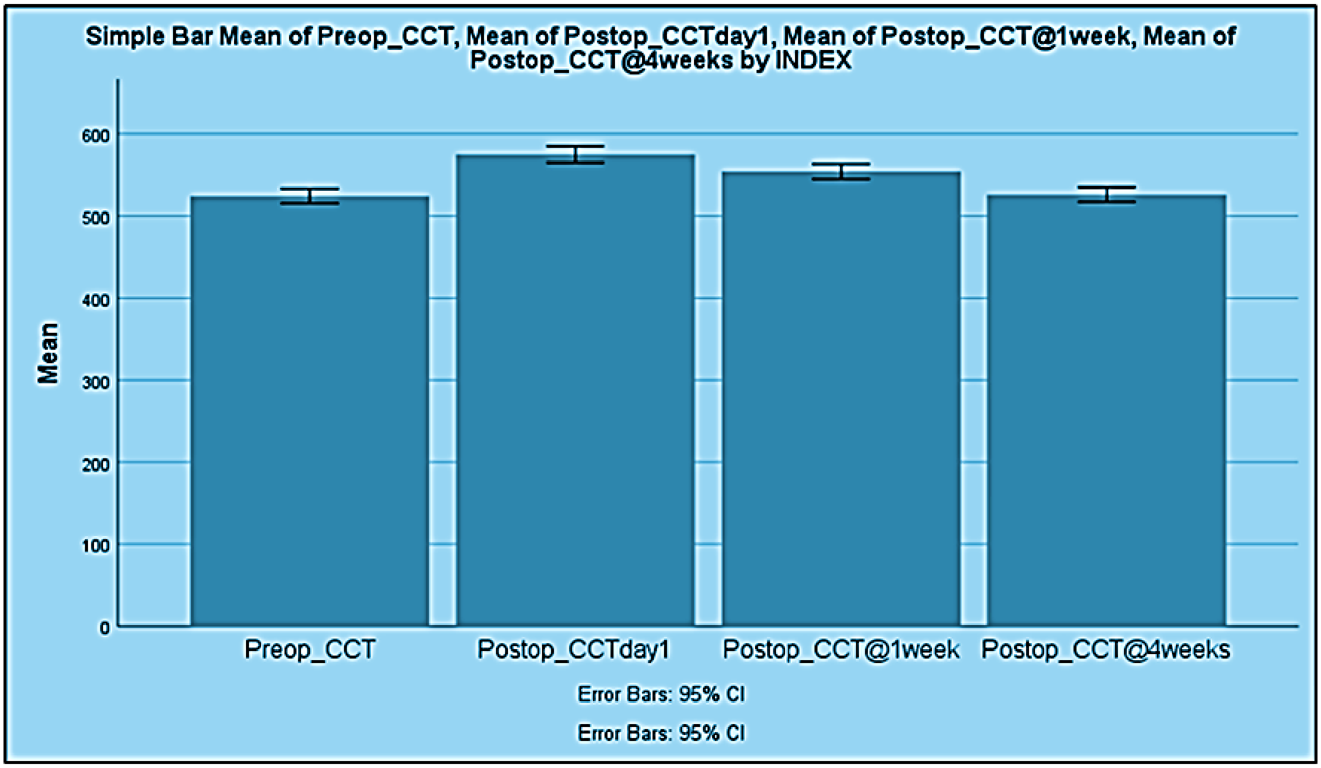

Figure 2: Bar Graph of Pre- and Post-operative Mean Central Corneal Thickness CCT

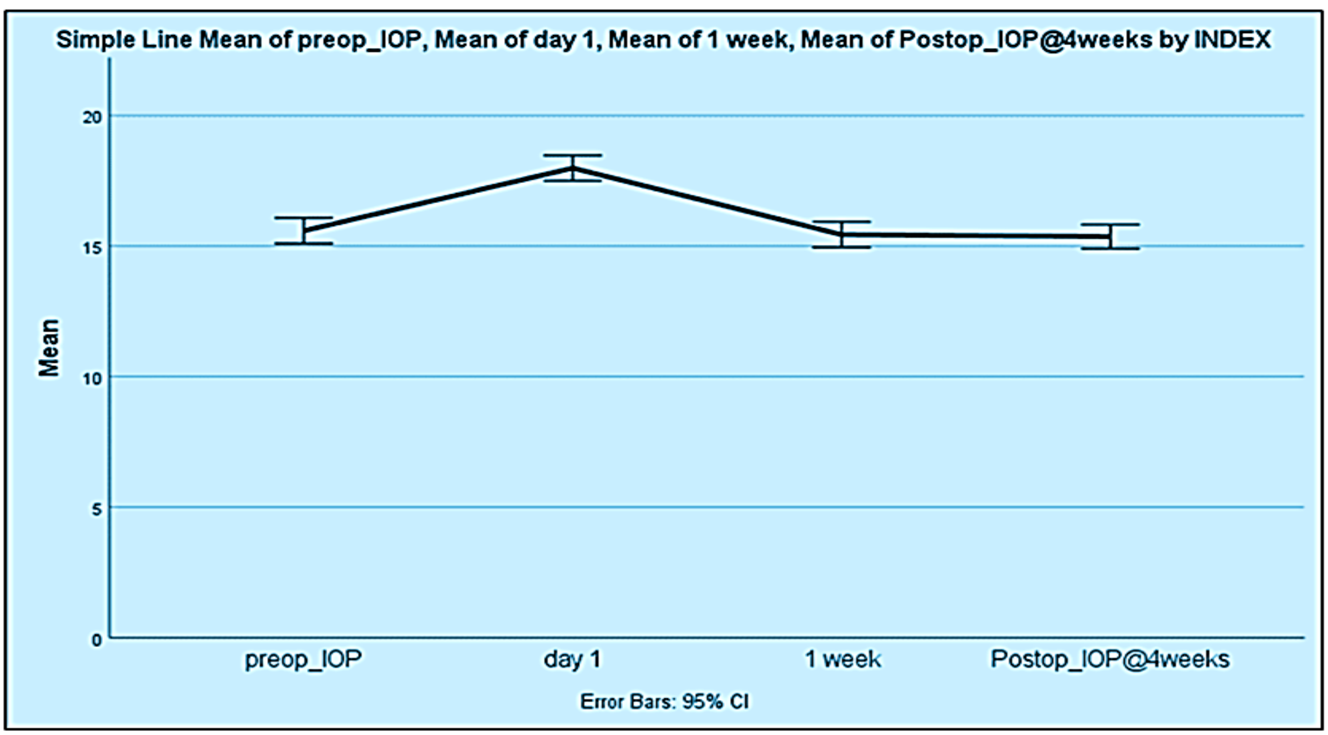

Figure 3: Line plot of Pre- and Post-operative Mean Intraocular Pressure IOP

week IOP values (p = 0.181), with a 95% confidence interval of –0.107 to 0.557 mmHg. These findings indicate that IOP, like CCT, returned to near baseline by the fourth postoperative week, suggesting restoration of corneal and intraocular homeostasis following phacoemulsification.

Spearman's rho revealed a moderate, statistically significant positive correlation between cataract density and both CCT ($\rho = 0.421$, p=0.000, $p < 0.01$) and IOP ($\rho = 0.430$, p=0.000, $p < 0.01$) on the first postoperative day. These findings indicate that patients with denser cataracts tend to have greater corneal thickening and higher IOP immediately after surgery. This is likely due to the increased ultrasound energy and longer surgical duration required for denser cataracts, leading to greater endothelial stress, postoperative corneal edema, and overestimation of IOP due to increased CCT.

DISCUSSION

The present study evaluated CCT, IOP and visual outcomes following phacoemulsification with a specific focus on their association with cataract density. Our findings demonstrated significant but transient increase in both CCT and IOP, with values returning close to baseline by the fourth postoperative week. BCVA improved significantly during this period. CCT rose by 9.68% on the first postoperative day, declined to 5.70% at one week, and normalized to just 0.33% above baseline by week four. A parallel trend was observed in IOP, which peaked at 17.99 mmHg in the first week before returning to 15.36 mmHg in four weeks, close to the preoperative value of 15.59 mmHg. These trends were statistically significant over time (as shown by repeated measures ANOVA), yet the paired sample t-tests showed no significant difference between preoperative and week-four values for either CCT or IOP, indicating recovery of endothelial and intraocular homeostasis.

Our results closely mirror those reported in the literature. Wali et al, observed a 10.2% rise in CCT on day 1 postoperatively, which decreased to 3.1% at one week and 0.7% by one month.[13] Noronha found a similar pattern, with CCT increasing from 538.23 µm to 583.22 µm on day 1 and returning to 539.9 µm at one month.[14] Chaudhry et al, also reported a return to baseline CCT within four weeks, from 542.81 µm preoperatively to 544.42 µm postoperatively.[15] These findings support our interpretation that postoperative corneal edema is transient and due to temporary endothelial dysfunction from phacoemulsification ultrasound energy and fluid turbulence.

Our results are further corroborated by Meng J et al, who reported a 13.81% increase in CCT at one hour, 6.44% at day 1, and a return to baseline by one week.[16] Likewise, Memon et al, reported a 44 µm increase in CCT on day 1, comparable to our observed 51 µm rise.[17] Both studies emphasized that such early thickening can lead to overestimation of IOP due to altered corneal biomechanics, aligning with our observation of transient IOP elevation in the first postoperative week. The consistency across other studies also strengthens the validity of our findings and supports the notion that early IOP spikes are often artefactual in origin, rather than a sign of true ocular hypertension.[18]

A key strength of our study is the assessment of cataract density as a predictor of early postoperative changes, a parameter not examined in the comparative studies. We observed statistically significant moderate positive correlation between cataract stage and both CCT ($\rho = 0.421$) and IOP ($\rho = 0.430$) on postoperative day 1. This suggests that denser cataracts, which require more phacoemulsification ultrasound energy and longer surgical manipulation, may lead to greater endothelial trauma, resulting in increased corneal edema and transient IOP elevation. These findings carry important clinical implications for surgical planning and early postoperative assessment, particularly in dense mature cataracts.

Long-term implications of early CCT changes were highlighted in Lundberg's 2024 seven-year prospective study, which found that greater early postoperative CCT increase was associated with more endothelial cell loss at three months, but these differences disappeared by seven years.[19] Eyes with less initial edema experienced continued cell loss over time, while those with more pronounced early swelling stabilized. This suggests that early postoperative corneal edema, though indicative of short-term stress, does not necessarily predict long-term endothelial decompensation, especially in eyes with healthy preoperative endothelium.[20-22] Our findings are consistent with this conclusion, offering further reassurance that early corneal changes after phacoemulsification are largely reversible in otherwise healthy eyes.

This study has several limitations. The follow-up period was limited to four weeks, which may not capture long-term corneal endothelial changes or delayed complications. Endothelial cell analysis using specular microscopy was not performed, limiting the ability to directly assess endothelial cell loss. The use of ultrasound pachymetry, while practical, may be less accurate than optical methods. Furthermore, although cataract density was evaluated, intraoperative factors such as cumulative Phaco-ultrasound energy and surgical duration were not recorded, which could influence corneal outcomes.

Future studies are recommended to include longer follow-up durations and incorporate endothelial cell count analysis for more comprehensive evaluation. The use of optical pachymetry or anterior segment OCT is encouraged to improve measurement precision. Recording detailed intraoperative parameters could provide better insight into the relationship between surgical technique, cataract density, and postoperative corneal changes.

CONCLUSION

Phacoemulsification-induced changes in CCT and IOP are transient and clinically self-limiting in eyes with intact endothelial function. The positive correlation between cataract density and early postoperative changes highlights the importance of individualized surgical planning and careful interpretation of postoperative measurements. This is particularly relevant in dense cataracts, where early IOP elevation may not reflect true pathology. These insights contribute to better risk stratification and more precise postoperative management in cataract surgery.

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Patient's Consent: Researchers followed the guide lines set forth in the Declaration of Helsinki.

Conflict of Interest: Authors declared no conflict of interest.

Ethical Approval: The study was approved by the Institutional review board/Ethical review board **(Ref.No.408/IREF/RMU/2023).**

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Authors Designation and Contribution

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Muhammad Imran Janjua; Assistant Professor: *Concepts, Design, Literature Search, Data Acquisition, Data Analysis, Statistical Analysis, Manuscript Preparation, Manuscript Editing, Manuscript Review.*

Tehmina Imdad; Assistant Professor: *Concepts, Design, Literature Search, Data Acquisition, Data Analysis, Statistical Analysis, Manuscript Preparation, Manuscript Editing, Manuscript Review.*