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Original Research

Evaluating Refractive Errors Post-Cataract Surgery: The Role of Pre-Operative IOL Power Formulas in a Tertiary Care Hospital

Dr. Neeti R. Sheth[1], Dr. Vaibhav Kapadia[2], Dr. Pankti V.Shah[3], Dr. Anjali Padaya[4]

[1]Assistant Professor, Dept. of Ophthalmology, PDU Govt. Medical College, Rajkot
[2] Post Graduate Student, Dept. of Ophthalmology, PDU Govt. Medical College, Rajkot
[3] Post Graduate Student, M and J Institute of Ophthalmology, B.J.Medical College, Ahemdabad
[4]Senior Resident, Dept. of Ophthalmology, PDU Govt. Medical College, Rajkot

Corresponding Author
Dr. Shubhra Dubey
Senior Resident, Dept. of Community Medicine, Govt. Medical College, Satna

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ABSTRACT

Introduction:-Cataract surgery is a major cause of reversible blindness worldwide, with the primary goal of restoring vision and achieving optimal refractive outcomes. Advancements in surgical techniques and intraocular lens (IOL) technology have shifted focus towards refining the accuracy of post-surgery refractive outcomes. The precise calculation of IOL power pre-operatively is crucial for determining the refractive status of the eye post-surgery. The success of cataract surgery is not solely dependent on the removal of the cataract and the implantation of the IOL. The refractive outcome is largely influenced by the accuracy of the IOL power calculation performed before the surgery. Formulas have evolved over the years to improve the accuracy of IOL power calculations, but achieving accurate refractive outcomes remains a challenge, particularly in eyes with extreme axial lengths or other unusual anatomical features. This study aims to evaluate refractive errors observed in post-operative cataract patients and correlate these errors with the pre-operative IOL power calculated using various formulas.

Material and Methods:- This study was conducted at a tertiary care hospital in Rajkot from 2023 to 2024, involving 300 patients who visited the Outpatient Department for cataract surgery. The research aimed to compare the accuracy of five IOL power calculation formulas using the A Scan machine. Patients were selected based on their attendance at the OPD and evaluated for various ocular parameters. The study included patients with visually significant cataracts, primary implantation of posterior chamber intraocular lens, and willingness for participation. Patients with co-existing pathology, combined cataract surgery, previous intraocular or corneal surgery, corneal astigmatism greater than 1.5 D, traumatic cataract, uveitic cataract, pediatric cataract, corneal opacity, intraoperative complications, and other ocular pathology causing visual impairment were excluded. All patients underwent a comprehensive ophthalmic examination, including preoperative A scan biometry, postoperative autorefraction, and slit lamp evaluation. The mean absolute error (MAE) was calculated and compared in three groups of axial length.

Results:- The study analyzed the refractive outcomes of cataract surgery in 300 participants, focusing on the accuracy of various IOL power calculation formulas. The participants were divided into three groups based on axial length: Group I (< 22 mm), Group II (22 to 24 mm), and Group III (> 24 mm). The HOLLADAY-II formula consistently provided the most accurate predictions across all axial length groups, while the BINKHORST-II formula had the highest error. The SRK-T and HOLLADAY-II formulas performed best in Group I, Group II, and Group III, with the HOLLADAY-II formula being the most reliable, producing the smallest postoperative refractive errors, particularly in average and long axial lengths.

Conclusions:-The study emphasizes the importance of choosing the right IOL power calculation formula based on a patient's axial length. The HOLLADAY-II formula is the most accurate, while the SRK-T formula is reliable for average axial lengths. Preoperative planning and patient counseling are crucial for optimal refractive outcomes.

Keywords:- Cataract surgery, IOL power, IOL formula

INTRODUCTION

Cataract is one of the leading causes of reversible blindness globally, and its surgical removal is one of the most performed procedures worldwide[1]. The primary goal of cataract surgery is not only to restore vision by removing the opacified lens but also to achieve optimal refractive outcomes. With advancements in surgical techniques and intraocular lens (IOL) technology, the focus has increasingly shifted toward refining the accuracy of refractive outcomes post-surgery[2]. An essential aspect of this is the precise calculation of IOL power pre-operatively,

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as it plays a pivotal role in determining the refractive status of the eye post-operatively.

Cataract surgery involves the removal of the cloudy natural lens of the eye, which is replaced by an artificial intraocular lens (IOL)[3]. Over the past few decades, the evolution of cataract surgery has been remarkable, transitioning from intracapsular cataract extraction (ICCE) to extracapsular cataract extraction (ECCE), and now to phacoemulsification, which is currently the most widely used technique. This transition has significantly reduced surgical complications and enhanced visual outcomes, making cataract surgery a safe and effective procedure[4].

However, the success of cataract surgery is not solely dependent on the removal of the cataract and the implantation of the IOL[5]. Achieving the desired refractive outcome, which allows patients to have a good quality of vision without relying on glasses or contact lenses, is a critical measure of the surgery's success. The refractive outcome is largely influenced by the accuracy of the IOL power calculation performed before the surgery[6].

The IOL power calculation is crucial because it determines the refractive outcome of the eye after cataract surgery. The calculation involves estimating the power of the IOL that will best suit the patient's eye, providing the desired refractive outcome[7]. This process is influenced by several factors, including the axial length of the eye, the curvature of the cornea, the anterior chamber depth, and the refractive index of the lens material[8].

Various formulas have been developed over the years to improve the accuracy of IOL power calculations. These formulas have evolved from the early theoretical models to more sophisticated regression-based formulas and, more recently, to modern third- and fourth-generation formulas that incorporate multiple biometric parameters. Despite these advancements, achieving accurate refractive outcomes remains a challenge, particularly in eyes with extreme axial lengths or other unusual anatomical features[9,10].

IOL power calculation formulas can be broadly categorized into two types: theoretical formulas and empirical or regression-based formulas. Theoretical formulas, such as the SRK/T, Hoffer Q, and Holladay 1 formulas, are based on geometrical optics and require accurate measurements of the eye's biometric parameters. These formulas estimate the effective lens position (ELP) post-operatively, which is critical for determining the IOL power[7].

Empirical formulas, on the other hand, are derived from regression analyses of large datasets of post-operative outcomes. These formulas, such as the SRK II, use simpler mathematical models but may be less accurate for eyes that deviate significantly from the norm. More recently, hybrid formulas, which combine elements of both theoretical and empirical approaches, have been developed. These include the Barrett Universal II and the Olsen formulas, which are known for their accuracy in a wide range of eyes[7].

One of the most common challenges is the accurate measurement of the axial length, which is a critical parameter in IOL power calculation. Even small errors in axial length measurement can lead to significant refractive errors post-operatively(11).

Given the importance of accurate IOL power calculation in achieving optimal refractive outcomes, this study aims to evaluate the refractive errors observed in post-operative cataract patients and correlate these errors with the pre-operative IOL power calculated using various formulas. By analyzing the refractive outcomes of patients, this study seeks to identify patterns and trends that can inform clinical practice and improve the accuracy of IOL power calculations.

MATERIAL & METHODS

Study Setting and Duration: This study was conducted at the tertiary care hospital of Rajkot. The study spanned from year 2023, to 2024, involving patients who visited the Outpatient Department (OPD) of the hospital during this period for cataract surgery.

Study Population: The study involved a total of 300 participants. These participants were selected based on their attendance at the OPD and were evaluated for various ocular parameters as part of the study.

Study Design: This research was designed as a observational study. It aimed to compare the accuracy of five IOL power calculation formulas as calculated by the A Scan machine.

Inclusion and Exclusion Criteria

Inclusion Criteria: Visually significant cataract Primary implantation of posterior chamber intraocular lens

Willing for participation in study

Exclusion Criteria: Patients with the following conditions were excluded from study:

Eyes with co-existing pathology Combined cataract surgery Previous intraocular or corneal surgery

Corneal astigmatism greater than 1.5 D Traumatic cataract Uveitic cataract Pediatric cataract Corneal Opacity

Intraoperative complications Other ocular pathology causing visual impairment that was revealed after surgery.

Clinical Examinations and Data Collection

All patients who met the inclusion criteria underwent a comprehensive ophthalmic examination as part of the study protocol. The following assessments were performed:

300 Patients who are going to be operated for cataract surgery were included in the study.Informed valid consent obtained from patients.Patients were chosen according to inclusion and exclusion criteria.Detailed history recorded along with visual acuity assessment. Anterior segment and posterior segment examined through slit lamp, 90 D lens and B scan (if required)

Intra ocular tension recorded through non-contact tonometry machine (NCT).Preoperative A scan biometry done and intraocular lens power calculated through 5different formulae:

o SRK-T
o BINKHORST-II
o HOLLADAY-II
o HOFFER Q
o HAIGIS

Post operative autorefraction done after cataract surgery.Based on post operative autorefraction, error in IOL power calculated through differentformulas is recorded and analysed. Autorefraction were performed. Slit lamp evaluation of the anterior segment and fundus wasdone. The actual post operative refraction was compared with the predicted post operativeerror determined for the different axial length groups. All values were classified accordingto 3 axial length subsets:

Group I **-** < 22 mm
Group II **-** 22 to 24 mm
Group III **-** >24 mm

The mean absolute error (MAE) was defined as the average absolute error which was the actual postoperative spherical equivalence (SE) minus predicted postoperative refractive error. Comparison of the MAE in three groups of axial length was done

Data Analysis: After the collection of data, it was entered in *MS Excel*. Proportion and percentage were calculated for qualitative data. Mean (SD), median was calculated for quantitative data and appropriate statistical tests was applied wherever needed. P-value of less than 0.05 was taken as statistically significant.

RESULTS

The results of this study provide insight into the refractive outcomes of cataract surgery in a diverse group of patients, focusing on the accuracy of various IOL power calculation formulas. The study involved 300 participants who were categorized into three axial length groups.

Table 1: Demographic Variables of Study Participants

Variables	Frequency(n=300)	Percentage (%)
Age Group		
<50 years	45	15
50-60 years	120	40
>60 years	135	45
Gender		
Male	165	55
Female	135	45
Residence		
Urban	137	45.7
Rural	163	54.3

The study included 300 participants, with a nearly equal distribution of males (55%) and females (45%). The age of the participants ranged widely, with 15% under 50 years, 40% between 50-60 years, and 45% over 60 years.

Table 2: Distribution of Axial Length in Study Participants

Axial Length Group	Frequency(n=300)	Percentage (%)
Group I: < 22 mm	75	25
Group II: 22 to 24 mm	150	50
Group III: > 24 mm	75	25

Participants were categorized based on their axial length into three groups Group I (< 22 mm) had 25% of the participants, Group II (22 to 24 mm) had 50% of the participantsand Group III (> 24 mm) had 25% of the participants

Table 3: Mean Absolute Error (MAE) in Different Axial Length Groups

Axial Length Group	SRK-T	BINKHORST-II	HOLLADAY-II	HOFFER Q	HAIGIS
Group I	0.48D	0.51D	0.46D	0.50D	0.49D
Group II	0.36D	0.38D	0.34D	0.37D	0.35D
Group III	0.52D	0.54D	0.50D	0.53D	0.51D

Table 3 shows that inGroup I (< 22 mm) the MAE was slightly higher across all formulas, with the lowest error observed with the HOLLADAY-II formula (0.46 D) and the highest with BINKHORST-II (0.51 D).In Group IIthe lowest MAE, indicating better accuracy across all formulas, particularly with the HOLLADAY-II formula (0.34 D) and in Group IIIthe MAE was again slightly higher, with the lowest error observed with the HOLLADAY-II formula (0.50 D) and the highest with BINKHORST-II (0.54 D).These results suggest that the

HOLLADAY-II formula consistently provided the most accurate predictions across all axial length groups, while the BINKHORST-II formula had the highest error.

Table 4: Postoperative Refractive Error Based on Formula Used

Axial Length Group	SRK-T	BINKHORST-II	HOLLADAY-II	HOFFER Q	HAIGIS
Group I	+0.25D	+0.30D	+0.20D	+0.28D	+0.24D
Group II	+0.15D	+0.18D	+0.10D	+0.16D	+0.14D
Group III	+0.35D	+0.40D	+0.30D	+0.38D	+0.32D

Postoperative refractive errors were measured to assess the precision of each IOL calculation formula**Table 4** shows that in Group Ithe SRK-T and HOLLADAY-II formulas resulted in the least hyperopic shift (+0.25 D and +0.20 D, respectively), indicating better prediction accuracy, in group IIagain, the HOLLADAY-II formula performed the best with the smallest refractive error (+0.10 D) and in Group IIIthe HOLLADAY-II and SRK-T formulas showed better performance (+0.30 D and +0.35 D), though errors were more pronounced compared to Group II.Overall, the HOLLADAY-II formula was the most reliable across all axial length groups, producing the smallest postoperative refractive errors, particularly in average and long axial lengths.

DISCUSSION

The results of this study provide important insights into the effectiveness of various intraocular lens (IOL) power calculation formulas across different axial lengths in cataract surgery patients. The primary focus in the studywas on the comparison of mean absolute error (MAE), postoperative refractive errors, and visual outcomes among different axial length groups.

One of the most significant findings of this study is the consistent performance of the HOLLADAY-II formula across all axial length groups. This formula demonstrated the lowest mean absolute error (MAE) in each group, particularly in eyes with average axial lengths (22 to 24 mm). The HOLLADAY-II formula's superior performance suggests that it may be more robust and reliable across a broader range of biometric parameters compared to other formulas like BINKHORST-II, which showed higher errors, especially in extreme axial lengths.

The SRK-T formula also performed well, particularly in Group II, where the axial length was between 22 to 24 mm. This supports the common clinical practice of using SRK-T in eyes with average axial lengths, as it provides a balance between simplicity and accuracy. However, its performance was slightly less optimal in eyes with shorter (< 22 mm) or longer (> 24 mm) axial lengths, where the MAE was higher compared to the HOLLADAY-II formula.

The BINKHORST-II formula, on the other hand, consistently showed higher MAEs across all axial length groups. This may be attributed to the fact that BINKHORST-II is a regression-based formula that might not adequately account for the variations in effective lens position (ELP) or other factors in eyes with extreme biometric values. The limitations of this formula, particularly in eyes with short or long axial lengths, suggest that it may not be the best choice for these cases.

The study also highlighted the postoperative refractive errors associated with each formula. The HOLLADAY-II formula again demonstrated the smallest refractive errors, particularly in terms of hyperopic shifts, across all axial length groups. This finding is crucial as it suggests that the HOLLADAY-II formula is effective in minimizing postoperative surprises, especially in eyes with more predictable biometric profiles (Group II).

Similarly, **Narvaez et al.,** employed immersion ultrasonography and manual keratometry to evaluate 25 eyes with axial length less than 22.0 mm, suggesting no statistically significant difference between Holladay 1, Holladay 2, Hoffer Q, and SRK/T[12].

Interestingly, the SRK-T formula, while performing well in Group II, showed a tendency for slightly higher hyperopic shifts in Groups I and III. This indicates that while SRK-T is generally reliable, it may not be the best choice for eyes at the extremes of axial length, where more sophisticated formulas like HOLLADAY-II or HAIGIS might be preferred.

Accordingly, **Roh et al.,** suggested that Haigis formula provided the best results as far as the postoperative power prediction is concerned in 25 eyes with axial length less than 22.0 mm[13].

The BINKHORST-II formula, with its higher postoperative refractive errors, particularly in terms of both hyperopic and myopic shifts, further reinforces its limited utility in modern cataract surgery, particularly in cases where precision is critical. Given the growing expectations of patients for spectacle independence post-surgery, the choice of formula that minimizes these refractive errors is increasingly important.

The HOLLADAY-II formula emerges as the most reliable across all axial lengths, making it a strong candidate for routine use, particularly in eyes with average to long axial lengths. The SRK-T formula remains a solid option for average axial lengths but should be used with caution in eyes with extreme biometric values.

In study by **Day et al.,** it was reported that by using standard IOL constants the MAE for Hoffer Q (0.62D, ±0.52D) and Holladay 1 (0.66D ± 0.52D) were significantly lower than SRK/T (MAE 0.91D ± 0.64D; *P* = <0.0005 and *P* = 0.001 respectively), but not Haigis (MAE 0.82D ±

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0.83D, $P = 0.071$ and 0.22 respectively). Increasing MAE was significantly associated with reducing axial length and increasing IOL power for all formulae[14].

In contrast, **Rastogi et al.,** in their study reported that Barrett Universal II had the lowest MAE and thus was predictable for the highest number of eyes in our study, although this was not statistically significant (p=0.176)[15].

In another study by **Kuthirummal et al.,** it was documented that Barrett Universal-II performed as the most accurate formula in the prediction of postoperative refraction over a wide range of Axial lengths[16].

Limitations of the Study

While the study provides valuable insights, it is important to acknowledge its limitations. The study was conducted in a single tertiary care hospital, which may limit the generalizability of the results to other populations or settings. Additionally, the follow-up period was relatively short (10 days), which might not fully capture the long-term refractive stability or changes in visual acuity. Longer follow-up would be beneficial to assess the stability of refractive outcomes and the potential impact of factors such as posterior capsular opacification (PCO) on visual acuity.

CONCLUSION

In conclusion, this study reinforces the importance of selecting the appropriate IOL power calculation formula based on the patient’s axial length. The HOLLADAY-II formula consistently provided the most accurate predictions and should be considered the formula of choice for a wide range of patients. However, for eyes with average axial lengths, the SRK-T formula remains a reliable option. Given the challenges in achieving optimal refractive outcomes in eyes with extreme axial lengths, careful preoperative planning and patient counseling are essential to meet the growing expectations for postoperative visual acuity. The findings of this study can serve as a guide for clinicians in optimizing IOL power selection, ultimately improving patient satisfaction and visual outcomes in cataract surgery.

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