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CALCULATION OF LENS POWER WITH NEW BIOMETRIC FORMULAS

LENS GÜCÜNÜN YENİ BİOMETRİ FORMÜLLERİ İLE HESAPLANMASI

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ABSTRACT

Objective: Comparison of the accuracy of six biometric formulas based on refractive findings using patients' biometric and refractive data before phacoemulsification surgery.

Material and Method: A retrospective analysis was conducted of the data of 65 eyes of 43 patients who underwent phacoemulsification at the Ophthalmology Department of Istanbul University Istanbul Faculty of Medicine between January 2016 and July 2019. The intraocular lens (IOL) power corresponding to the target refraction value in patients was calculated using the SRK/T formula. The patients' final refraction values were obtained by examinations conducted after the third postoperative month. After implanting IOLs with the same refractive power, target refraction values were calculated using the optical biometry measurements of the patients and the Hoffer Q, T2, Ladas Super Formula (Ladas), Barrett Universal II (BU II), and Hill-RBF formulas. The refractive refraction deviation values between the formulas were compared, as well as the difference between the target refraction values determined by the formulas and the spherical equivalents of the patients' result refractions.

Result: The normal age of the 43 patients in the study was 64.65±8.23 (47-86) years. The mean axial length was 23.5±0.7mm (22.01-24.5). The refractive deviation was 0.29±0.29 D with SRK/T, 0.27±0.27 D with T2, 0.3±0.24 D with Hoffer Q, 0.3±0.26 D with Ladas, and 0.33±0.28 D with BU II, and 0.27±0.29 D with Hill-RBF. The refractive deviation percentages of the formulas in the range of -1.00 D to +1.00 D were as follows: 98.5% Hoffer Q and Hill-RBF; 96.9% T2, Ladas, BU II, and SRK/T. In terms of refractive deviation values, there was no statistically significant difference between the formulas ($p>0.05$).

ÖZET

Amaç: Hastaların fakoemülsifikasyon cerrahisi öncesindeki biometrik ve refraktif verileri kullanılarak, altı biometrik formülün refraktif sonuçlara göre doğruluklarının karşılaştırılması.

Gereç ve Yöntem: Retrospektif olarak 2016 Ocak ve 2019 Temmuz tarihleri arasında İstanbul Üniversitesi İstanbul Tıp Fakültesi Göz Hastalıkları kliniğinde fakoemülsifikasyon uygulanan 43 hastanın 65 gözünün verileri retrospektif olarak incelendi. Hastalarda hedeflediğimiz refraksiyon değerine karşılık gelen göz içi lens (GİL) gücü SRK/T formülüne göre hesaplandı. Postoperatif 3. aydan sonra yapılan muayenelerde hastaların sonuç refraksiyon değerleri saptandı. Hastaların optik biometri ölçümleri kullanılarak, aynı kırma gücüne sahip GİL implante edildiğinde, Hoffer Q, T2, Ladas Süper Formülü (Ladas), Barrett Universal II (BU II) ve Hill-RBF formüllerine göre hedef refraksiyon değerleri hesaplandı. Formüllerin saptadığı hedef refraksiyon değerleriyle, hastaların sonuç refraksiyonlarının sferik eşdeğerleri arasındaki fark alındı ve formüller arasındaki refraktif sapma değerleri karşılaştırıldı.

Bulgular: Çalışmaya alınan 43 hastanın yaş ortalaması 64,65±8,23 (47-86) yıl idi. Ortalama aksiyel uzunluk 23,5±0,7mm (22,01-24,5) olarak saptandı. SRK/T ile refraktif sapma 0,29±0,29 D, T2 ile 0,27±0,27 D, Hoffer Q ile 0,3±0,24 D, Ladas ile 0,3±0,26 D, BU II ile 0,33±0,28 D, Hill-RBF ile 0,27±0,29 D idi. Formüllerin -1,00 D ile +1,00 D aralığında bulunan refraktif sapma yüzdeleri şu şekildeydi: %98,5 Hoffer Q ve Hill-RBF; %96,9 T2, Ladas, BU II ve SRK/T. Refraktif sapma değerleri açısından formüller arasında istatistiksel olarak anlamlı bir farklılık izlenmedi ($p>0,05$).

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Conclusion: The probability of obtaining the target refractive value with a refractive deviation within ±1 D of the six biometry formulas included in the study is 96.9% and higher. Any of these formulas can be employed safely to compute preoperative IOL power in the eyes of normal length.

Keywords: Cataract surgery, biometrics, new generation formulas

Sonuç: Çalışmada yer alan altı biometri formülünün ±1 D içinde refraktif sapma ile hedef refraktif değere ulaşma şansı %96,9 ve üzerindedir. Bu formüllerin her biri normal uzunluktaki gözlerde preoperatif GİL gücünü hesaplamak için güvenli bir şekilde kullanılabilir.

Anahtar Kelimeler: Katarakt cerrahisi, biometri, yeni jenerasyon formüller

INTRODUCTION

Intraocular lens (IOL) implantation, performed for almost 60 years, is modern medicine's most prevalent and successful surgical procedure. This procedure's success and safety result from ongoing advancements in surgical and measuring techniques (1). Today, cataract surgery is becoming a refractive surgery method (2). Patients with cataract surgery expect to gain visual ability independently of glasses after cataract surgery (3, 4).

Obtaining the target refractive outcome has become a fundamental component of cataract procedures. Thankfully, the advent of optical biometrics and the development of new-generation IOL calculation formulas have enhanced our ability to anticipate refractive outcomes following cataract surgery correctly (5). Accurate estimation of refractive results is important as it will also eliminate patient dissatisfaction (6).

The SRK/T formula, which is a third-generation formula we used in our study, is a more customized form of the SRK formula developed by Sanders, Retzlaff, and Kraff (7). It represents a combination of a theoretical eye model and a linear regression method. SRK/T also includes empirical regression methodology for optimization, providing greater precision. It can be calculated using the same constants A used with the SRK formula, or with anterior chamber depth (ACD) estimates.

Sheard et al. observed a non-physiological behavior while calculating the corrected axial length and corneal height in the SRK/T formula. Therefore, they developed the T2 formula using a regression formula for corneal height obtained from the growth subset. They concluded that the accuracy of refractive results can be increased by 10% with the T2 formula (8).

In 2015, Ladas et al. introduced the concept of an IOL 'super formula' and developed a solution to address the need for a single formula that can be adapted to any eye (9). They introduced a new methodology for displaying previous-generation IOL formulas in three dimensions. Based on peer-reviewed literature, they developed an IOL 'super surface' by selecting the best parts of each of the modern IOL formulas. The 'super formula' is derived from this super surface.

In 1993 and 2000, Hoffer tried to analyze the most accurate formula using AU measurements taken by immersion ultrasound in long and short eyes and showed that the Hoffer Q formula gave the most reliable results in short eyes (AU<22.0 mm) (10). Hoffer Q; personalized ACD is a formula based on AU and corneal curvature.

The Barrett formula was developed based on a theoretical model eye in which anterior chamber depth is related to axial length and keratometry (11). In this formula, the user does not need to know the material and constant of the lens. The principle of refraction of the intraocular lens and the position of its planes is preserved as a relevant variable in the formula.

Unlike other formulas, the Hill-RBF formula is a pattern recognition algorithm that uses some kind of data interpolation. This formula provides potential independence by eliminating computational errors from biometrics and the need to customize constants (12).

This study compares the success of these six biometry formulas in reaching the target refractive value in normal-length eyes.

MATERIAL and METHODS

The data from 196 eyes of 118 patients diagnosed with cataracts and who underwent phacoemulsification surgery at the Ophthalmology clinic of the Istanbul University Istanbul School of Medicine between January 2016 and July 2019 were retrospectively evaluated. Amblyopic eyes, eyes with any pathology affecting refraction in the optic axis, retina, or optic disc, and eyes that had undergone eye surgery (keratoplasty, refractive surgery, vitrectomy, etc.) were excluded from the study. Also, eyes in which sutures were placed at the incision site during surgery, with surgery-related astigmatism (SRA) above 0.5 D, and with postoperative tilt and decentralization in the IOL were excluded from the study. Eyes with an axial length of 22-25 mm were included in the study. All study patients had surgery scheduled using the SRK/T calculation. Ethics committee approval was obtained from Istanbul Medical Faculty's Ethics Committee (Date: 28.05.2021, No: 11).

The gender of the patients who underwent surgery, age at the time of surgery, the side of the eye undergoing surgery, preoperative uncorrected visual acuity (UVA) and best corrected visual acuity (BCVA), biomicroscopic examination and the degree of existing cataract according to LOCS III were recorded (13). UVA and BCVA levels of the patients at the earliest three months after surgery were determined according to the logMAR chart. Targeted refractive values were recorded according to the biometry results obtained through measurements made using the IOL Master 500 (Carl Zeiss AG, Germany). IOL power calculation with a biometric formula was performed for AcrySof SN60WF in 31 eyes and for AcrySof SA60AT IOL in 34 eyes.

The power of the IOL planned to be implanted was calculated preoperatively with the help of the SRK/T formula. Axial length (AU), anterior chamber depth (ACD), K1 (flat keratometry value), K2 (vertical keratometry value), corneal astigmatism, white-to-white (WTW) included in the biometric measurements were recorded. In the postoperative examinations of the patients, the new K1, K2, and corneal astigmatism values obtained with the Topcon TRK-1P auto-refractometer device were recorded. Spherical equivalents of UVA, BCVA, and subjective refractions were taken. The difference between the targeted refraction's spherical equivalent (TRSE) and the postoperative refraction's spherical equivalent (PRSE) and the absolute value of this difference (AVD) was recorded. The size and axis of astigmatism developed due to surgery were calculated. HRSE, the difference between PRSE and HRSE, and AVD were recorded individually with Hoffer Q, T2, Ladas Super Formula, Barrett Universal II, and Hill-RBF formulas according to the power of the IOL implanted during surgery. The website of the User Group for Laser Interference Biometry (ULIB) was used to obtain the A constant and pACD constant values of the implanted IOLs (14).

The surgeries were performed through a 2.4 mm transparent corneal incision in the temporal quadrant with the Infiniti Vision system (Alcon Laboratories, Inc., Fort Worth, TX, USA) using a 30º Kelman 0.9 mm TurboSonics Mini-Flared ABS phaco handpiece tip and Alcon MicroSmooth Ultra Infusion Sleeve. An Alcon Monarch III injector and D cartridge were utilized for IOL insertion.

Anterior segment examination was performed in all postoperative controls, dilated fundus examinations were performed at the first and third postoperative follow-ups, other pathologies that may impact vision were assessed, and eyes with pathology in the optic axis were eliminated from the study. At the postoperative third-month examination, the PRSE of the patients was calculated.

While calculating the SRA, the vectorial analysis program was used (15).

IBM® SPSS (Statistical Package for Social Sciences) version 23.0 was used for the statistical analysis of the data. Pearson chi-square test was used when comparing nominal data, the Shapiro-Wilk test to determine whether the data were normally distributed, the ANOVA test was used when comparing continuous variables with normal distribution, the Mann-Whitney U test was used for correlation analysis, and the Spearman test was used for correlation analysis. Continuously variable data with normal distribution were expressed as mean ± standard deviation, and non-normally distributed data were expressed as median, mode, or range. In categorical measurements, numbers and percentages were given. Statistical significance was accepted as $p<0.05$.

RESULTS

Sixty five eyes of 43 patients met all the criteria and were included in the study. The mean age of the patients included in the study was 64.6±8.3 years. Of these patients, 24 (55.8%) were male, and 19 (44.2%) were female. Of the 65 eyes that underwent surgery, 29 (44.6%) were right, and 36 (55.4%) were left eyes.

The refraction data (Table 1) and biometric data (Table 2) obtained in the preoperative period and the patients' third postoperative month control exams were recorded - the calculated mean values of the obtained data.

To compare the target refraction with the final refraction, the spherical equivalent values of the final refraction obtained at the last examination of the patients were utilized. The mean spherical equivalent value of the resulting refraction was calculated as -0.04±0.44 D.

Table 1: Mean refraction data of patients before and after phacoemulsification surgery

Mean Values	UVA (logMAR)	Spherical value (D)	Astigmatism value (D)	Astigmatism Axis (degrees)	BCVA (logMAR)	LOCS-NO
Pre-op	0.9±0.45	-1.17±2.6	-0.9±0.6	87.9±40.43	0.44±0.4	3.97±0.97
Post-op	0.05±0.14	0.27±0.4	-0.62±0.4	73.45±29.9	0.08±0.04	-
P value	P<0.001	P<0.001	P=0.098		P<0.001	-

D: Diopter, UVA: Uncorrected visual acuity, logMAR: logarithm of the Minimum Angle of Resolution, BCVA: Best corrected visual acuity, LOCS-NO: Lens Opacities Classification System III - Grade of nuclear opacification

After surgery, there was a significant increase in the UVA values of the patients ($p<0.001$), but there was also a significant decrease in the spherical values ($p<0.001$). The difference between the astigmatism values before and after surgery was insignificant ($p=0.098$). BCVAs were significantly higher after surgery ($p<0.001$) (Table 1).

Table 2: Normal biometric data of patients before and after phacoemulsification surgery

Mean Values	Pre-operative	Post-operative
AL (mm)	23.44±0.64	-
SNR	21.71±57.48	-
K1 (D)	43.18±1.42	43.44±1.56
K1 axis (degree)	90.83±57.26	127.02±64.06
K2 (D)	43.91±1.51	43.62±1.55
K2 axis (degree)	90.83±50.78	82.02±20.44
Astigmatism (D)	-0.74±0.37	-0.58±0.37
Astigmatism axis (degree)	90.83±57.26	97.98±62.64
WTW (mm)	11.93±0.29	-
ACD (mm)	3.19±0.4	-

AL: Axial Length, SNR: Signal to Noise Ratio, K1: Mean flat keratometry, K2: Mean steep keratometry, WTW: white-to-white distance, ACD: Anterior Chamber Depth

Table 3: Target and result refractive measurements measured with the biometry device

Formula	Normal target refractive value	Mean refractive deviation	Standard deviation	Maximum refractive deviation
Hoffer Q	-0.07 D	0.302 D	0.237	1.43 D
T2	-0.10 D	0.269 D	0.259	1.52 D
LADAS	-0.04 D	0.296 D	0.255	1.36 D
Barrett	-0.14 D	0.316 D	0.267	1.47 D
Hill-RBF	-0.06 D	0.271 D	0.278	1.38 D
SRK/T	-0.13 D	0.286 D	0.283	1.52 D

D: Diopter

The mean SRA value was 0.43±0.35 D, and the mean axis of astigmatism due to SRA was 84.5±45.17 degrees. Mean refractive deviation Hoffer Q formula 0.3 D±0.24, T2 formula 0.27 D±0.26, Ladas Super Formula 0.3 D±0.26, Barret Universal II 0.32 D±0.27 D±0.28 in Hill-RBF, 0.29 D±0.28 in SRK/T formula. The formulas had no statistically significant difference regarding mean refractive deviation values ($p>0.05$) (Table 3).

The lowest refractive deviation was obtained in Ladas Super Formula with 1.36 D. Hill-RBF followed this with 1.38 D, Hoffer Q with 1.43 D, Barrett Universal II with 1.47 D, T2 and SRK/T formula with 1.52 D (Table 3).

The percentages of the refractive deviations of the formulas in the range of ±0.50 and ±1.00 Diopters are shown in Figure 1. When the results of the formulas were compared within the range of ±0.50 D, no statistically significant difference was found between each other ($p>0.05$ for all, Table 4).

When the results of the formulas in the range of ±1 D are compared, there was no statistically significant difference

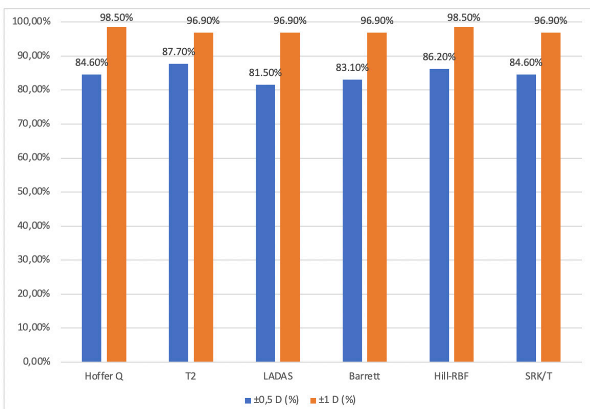

Figure 1: The percentages of the resultant refractive values of the formulas in the range of ±0.50 D and ±1 D

between the Hoffer Q and Hill-RBF formulas and the T2, Ladas Super Formula, Barrett Universal II, and SRK/T formulas (p=0.708).

Table 4: Comparison of the results of the formulas in the range of ±0.50 D

T2	Hill-RBF	P=0.875
T2	Hoffer Q	P=0.649
T2	SRK/T	P=0.649
T2	Barrett U. II	P=0.284
T2	Ladas S. F.	P=0.059
Hill-RBF	Hoffer Q	P=0.719
Hill-RBF	SRK/T	P=0.719
Hill-RBF	Barrett U. II	P=0.627
Hill-RBF	Ladas S. F.	P=0.198
Hoffer Q	Barrett U. II	P=0.819
SRK/T	Barrett U. II	P=0.819
Hoffer Q	Ladas S. F.	P=0.204
SRK/T	Ladas S. F.	P=0.204
SRK/T	Barrett U. II	P=0.819
Hoffer Q	Ladas S. F.	P=0.204
SRK/T	Ladas S. F.	P=0.204
Barrett U. II	Ladas S. F.	P=0.586

Barrett U. II: Barrett Universal II, Ladas S. F.: Ladas Super Formula

DISCUSSION

Today, achieving the optimal refraction and the maximum uncorrected visual acuity after cataract surgery is just as crucial as removing a condenser lens. The precise estimation of preoperative IOL power is one of the most critical elements impacting the success of cataract surgery, which has reached a level that may be deemed refractive surgery due to technological breakthroughs in biometry devices and the improvement of IOL quality (16).

This study compared the success of new-generation formulas in eyes with normal axial length. According to the results of our study, the T2 formula has the lowest normal refractive deviation with the IOL Master 500 device, followed by Hill-RBF, SRK/T, Ladas Super Formula, Hoffer Q, and Barrett Universal II. However, when the mean refractive deviation values of these formulas were compared, no statistically significant difference was discovered (p>0.05).

In their study, Sánchez-Liñan et al. showed that Kane, SRK/T, Hoffer Q, Haigis, Holladay I, and Barrett formulas were not statistically superior to each other in eyes with an axial length of 22-25 mm (17). Our findings are consistent with this study. They suggested that in this axial length range, ±0.50 diopters postoperative refractive error range was the highest in the eyes with biometry calculated according to Holladay I (88.9%). After Holladay I, the highest rate was obtained from Hoffer Q and SRK/T formulas (87.1%). The percentage of biometrics performed with Barrett in the range of ±0.50 diopters (82.5%) was similar to our study (83.1%).

The refractive formulas of Olsen, Haigis, Holladay 1, Hoffer Q, SRK/T, and SRK II formulas were compared in a study by Cooke et al. utilizing optical low coherence reflectometry (OLCR) and partial coherence interferometry (PCI) methodologies (18). The study utilized the Olsen formula, showing that the OLCR method outperformed the PCI method. Compared to other formulas, the Olsen method with the OLCR formula produced more accurate results for both short and long eyes. Some formulas performed similarly with either method.

Barrett Universal II, Olsen, Holladay 2, Haigis, Ladas Super Formula, Holladay 1, and SRK/T were compared in a different study by Cooke et al. (19). When measured with PCI, including all axial-length formulas, the refractive deviation percentage of the Barrett Universal II formula within the eyes' range of 1 D was found to be 99.3%. Haigis and T2 were followed by Holladay 1 (98.4%), Ladas Super Formula (98.3%), Holladay 2 and SRK/T (98.1%), and Hoffer Q (97.4%), respectively. The Olsen formula produced the most accurate results with the OLCR, significantly superior to the formula that performed best with PCI. It was determined that Barrett Universal II provided the best results with the PCI method.

Unlike the Cooke et al. study, in our study, only eyes with normal axial length were included, and only the PCI method was used. The formulas compared in our study are Hoffer Q, T2, Ladas Super Formula, SRK/T, Hill-RBF, and Barrett Universal II formulas. Percentages of the refractive values of these formulas in the range of 1 D were as follows: 98.5% for Hoffer Q and Hill-RBF and 96.9% for T2, Ladas, Barrett, and SRK/T.

In their study, Kane et al. compared the measurements made using the PCI method with the formulas of Barrett Universal II, Haigis, Hoffer Q, Holladay 1, Holladay 2, SRK/T, and T2 (20). A study involving 3241 patients found that Barrett Universal II produced results with less refractive deviation than other formulas in eyes with regular, medium-long, and long axial lengths (p<0.001).

In their study, Nemeth G. et al. compared the refractive results of the SRK/T, Hill-RBF, and Barrett Universal II formulas after cataract surgery with the biometric data obtained by the Optical Low Coherence Interferometry (ODCI) method (21). The study included 186 eyes with axial lengths between 20.72 and 28.78 mm. When all eyes of these axial lengths were evaluated, the percentage of eyes within an estimation error of ±0.5 D was 74.01% using the SRK/T formula, 79.66% using the Barrett Universal II formula, and 83.62% using the Hill-RBF method. Statistically, the mean and median absolute refractive errors were not different.

In our study, the percentage of eyes with an estimation error of 0.5 D was found to be 86.2% using the Hill-RBF method, 84.6% using the SRK/T formula, and 83.3% using the Barrett Universal II formula.

In their study utilizing the PCI method, Aristodemou et al. compared the refractive results of the Hoffer Q formula with the SRK/T formula in normal-length eyes; however, they did not find a statistically significant difference in mean absolute error, as we found (22).

Sheard et al. established the T2 formula with their study to understand the causes of non-physiological behaviors of the SRK/T formula and to propose solutions for it (23). They compared the performance of the T2 and SRK/T formulas with their study and found that the estimation error in the T2 formula was 9.7% less than in the SRK/T formula. Moreover, they found that significantly higher eye rates were achieved within the ±0.50 D range ($p<0.0001$). They concluded that significantly improved prediction accuracy was achieved with the T2 formula, which is a modification of the SRK/T formula algorithm.

In our study, the mean refractive deviation value of the T2 formula was found to be 0.269 D, whereas that of the SRK/T formula was found to be 0.286 D. Nonetheless, it was concluded that this difference was not statistically significant ($p>0.05$).

The cases in our study underwent micro coaxial phacoemulsification surgery, and the mean postoperative SRA value was 0.43±0.35 D. Similar results had been observed in the literature after micro coaxial phacoemulsification surgery (24).

This study shows that the Hoffer Q, T2, Ladas Super Formula, Barrett Universal II, Hill-RBF, and SRK/T formulas can be safely favored by the surgeon before phacoemulsification surgery in eyes with normal axial length (22-25 mm), as measured by the PCI method. Using these formulas, the chance of reaching the target refractive value with a refractive deviation within ±1 D is 96.9% and above. A refractive deviation rate remaining within the range of ±0.50 D will be at the lowest level of 81.5%.

One of the areas for improvement in our study is the limited number of cases covered. Another drawback of our study is the inclusion of both eyes of some patients.

CONCLUSION

In conclusion, our study group had a limited sample size, with six biometer formulas, in more than 95% of the eyes' final refractive outcome was within the ±1 diopter. Targeting fewer standard deviations and results in different patient populations can help us to compare biometry formulas more accurately.

Ethics Committee Approval: This study was approved by Istanbul Faculty of Medicine Clinical Research Ethics Committee (Date: 28.05.2021, No: 11).

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