INTRAOCULAR LENS POWER CALCULATION USING SHAMMAS PL NO HISTORY FORMULA IN EYES WITH PREVIOUS LASER IN SITU KERATOMILEUSIS

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The study evaluated the results of IOL power calculation using Shammas PL no history formula in eyes with previous laser in situ keratomileusis (LASIK). This was a longitudinal follow-up descriptive analysis study. IOL power was calculated with Shammas PL formula with the ASCRS online calculator. Results: 41 eyes of 27 patients matched the inclusion and exclusion criteria. The mean uncorrected distance vision acuity (UDVA) and corrected distance vision acuity (CDVA) 3 months after surgery were 0.42 ± 0.23; 0.25 ± 0.19 logMAR, respectively. The number of eyes within ± 0.5 D; ± 1.0 D accounted for 48.8%, 75.6%, respectively. Mean absolute error (MAE) 3 months after surgery was 0.68 ± 0.59. Of the 41 eyes, 20 eyes were relatively myopic-shifted (<-0.5 D), 20 eyes showed an emmetropic shift (-0.5 D → +0.5 D), and one eye showed a hyperopic shift (> 0.5 D). There was no statistically significant difference in MAE between axial length groups. 82.7% were satisfied and very satisfied. Conclusion: Shammas PL formula may be a suitable option for eyes after previous LASIK with all different axial length with the high rate of satisfaction. With Shammas PL no history formula, myopic shifting was more common than emmetropic and hyperopic shifting.

Keywords: Shammas PL no history formula, eyes previous LASIK.

I. INTRODUCTION

In Vietnam, the number of patients presenting for cataract surgery after laser in situ keratomileusis (LASIK) is increasing. However, intraocular lens power calculations are still difficult because there are some LASIK related errors which can deviate the formulas for IOL power calculation. The first error involves the evaluation of the correct post-LASIK Keratometry (K) values which are required for accurate IOL power calculations.[1-3] Post-LASIK Keratometry was measured not centrally but a little toward the periphery, where the corneal radius of curvature may be steeper than in the center. Additionally, in LASIK eyes, the ratio between the anterior and posterior corneas was altered, but in reality, measuring with the standard corneal index will lead to incorrect corneal power causing hyperopic refractive error because the corneal value will be steeper. The last error is related to the over-estimated lens position (ELP) that is commonly used in third-generation IOL power formulas.[2-4] For normal eyes, these formulas show to be accurate, because flatter corneal radii are usually linked to smaller ELP than steeper radii. An eye after refractive surgery for myopia has a new anterior radius of curvature, one that is not intrinsic to the eye's original internal geometry. The resulting calculated ELP

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is much smaller than the actual lens position, then causing a hyperopic error. There were many methods for these IOL power calculation which including clinical history methods, double K and no history methods. However, the history data of patients were not noted and remembered, so no history methods were more popular. Shammas PL no history formula was introduced in 2007 by John Shammas and Maya C. Shammas, using corrected mean corneal power and estimated postoperative anterior chamber depth. According to Shammas' research, there was 93.3% eyes within 1.00 diopter.[4] In another research, the mean absolute error (MAE) was 0.55 and 93.5% eyes were within ± 1.0 D.[5] In 2010, American Society of Cataract and Refractive Surgery invented the software calculates IOL power on eye with previous refractive surgery: https://iolcalc.ascrs.org.[6] The software provided other methods which calculated IOL power in eye that underwent LASIK or PRK or RK. After entering the parameters, the results will be displayed with different formulas. Formulas using historical data: Adjusted EffRP, Adjusted Atlas 9000, Adjusted Atlas Ring Value, Masket formula, Improved Masket formula, Adjusted ACCP/ACP/APP, Barrett True K. Formulas that do not use historical data: Wang-Koch-Maloney, Shammas PL no history, Haigis-L, Galiei, Potvin-Hill Pentacam, OCT, Barrett True K no history. In our study, we used the software and the Shammas PL no history to calculate IOL power. In these studies, the authors had evaluated mean absolute error and percent of eyes within 1.00 diopter, ± 0.5 diopter and ± 0.25 diopter. However, they had not compared between axial length group and evaluated the shifts of refraction residual.[2,3] Therefore, we conducted this study to evaluate the results of IOL power calculation using Shammas PL formula in eyes with previous laser in situ keratomileusis.

II. PATIENTS AND METHODS

1. Study object

This study included all eyes of patients with previous LASIK for myopia that had IOL implantation at On-demand Department, National Eye Hospital and High-tech Eye center, Dong Do Hospital from June 2015 to January 2024.

Inclusion criteria were uneventful phacoemulsification with implantation IOL. Exclusion criteria were eyes which had complication after LASIK (flap dislocation, ectasia and corneal scar, glaucoma, AMD, retinal detachment, retinal pathology, complications during and after cataract surgery such as capsular rupture and patients did not cooperate during the study.

2. Methods

Design study: This was a longitudinal follow-up descriptive analysis study.

Sample size: $n = [(Z\alpha+Z\beta)/C]2 + 3$

where:n: Sample size to choose

C: constant related to α and β errors.

Taking $\alpha = 0.05$ then $Z\alpha = 1.96$ $\beta = 0.20$ then $Z\beta = 0.8416$

With correlation ratio $r = 0.5$

$C = 0.5*\ln|(1+r) \times (1-r)| = 0.5493$

After incorporating the above indices into the calculation formula, n was calculated to be 29 eyes. In this study, 41 eyes were investigated.

• Sampling method: purposive sampling

Study instrument: Snellen vision chart, glasses test box, automatic refractometer, IOL master 700 or 500, non-contact ultrasound machine, ASCRS online intraocular lens power calculation software https://iolcalc.ascrs.org/wbfrmCalculator.aspx, medical record.

Study process: Patients were examined

before and at 1 day, 1 week, 1 month and 3 months after surgery.

Biometry data were obtained with the IOL Master 500 or 700 or non-contact ultrasound. Shammas PL no history formula on the ASCRS online post-refractive calculator was used for IOL power calculation. IOL power was chosen based on target which was zero or myopia. Refractions were measured with Visuref 100 (Carl Zeiss). Uncorrected distance visual acuity and corrected distance visual acuity were measured.

Study variables:

The visual acuity was divided into three groups according to Kohnen T[7]: 20/25; from 20/40 to 20/30, and < 20/40.

Axial length was divided into four groups according to Whang: AL < 26.0mm, from 26.0 to 28.0 mm, from 28.0 to 30.0 mm, and > 30.0 mm[5].

Postoperative residual spherical equivalent refraction (RSE) was divided into three groups according to LeeES[8]:

- Myopia: RSE < - 0.5 D
- Emmetropia: RSE from - 0.5 D to + 0.5 D
- Hyperopia: RSE > + 0.5 D

The refractive prediction error was calculated for each AL group as the difference between the actual postoperative refraction and the predicted postoperative refraction. The mean prediction error (ME), mean absolute error (MAE), and percentage of eyes within 0.5 D, 1.00 D of the predicted refraction was calculated and MAE between groups were compared.

Statistical analysis:

All statistical analyses were performed using SPSS 23.0 software (SPSS Inc., Chicago, IL, USA). Qualitative and continuous variables were described as percentages and medians. Quantitative variables were compared using the One-way ANOVA test, Homogeneity of variance test and Tamhane's T2 test and T-test. *P*-values < 0.05 were considered significant.

3. Ethics

The study has been approved by hospital ethical board (Ref: 886/GCN-HDDDNCYSH-DHYHN, dated April 06, 2023)

III. RESULTS

This study included 41 eyes of 27 patients (14 men and 13 women) with a mean age of 43.85 8.33 (Range 25 to 65) years. The mean time after LASIK surgery which required cataract surgery was 14.594.34 years (from 4 to 23 years). High myopia (> 6.0 diopter or < -6.0 diopter) before LASIK surgery accounted for 85.4 % (35 eyes). The mean keratometry (K) was 37.79 2.79 diopter from 31.34 to 45.55. The mean axial length (AL) was 29.65 2.99 mm from 22.96 mm to 34.55 mm.

Table 1. Visual acuity before and after surgery 3 months (logMAR)

Visual acuity	Mean ± SD	Range	p
Preoperative UDVA (logMAR)	1.7 ± 0.79	3 – 0.4 (20/20000 – 20/50)	0.002
Postoperative UDVA (logMAR)	0.42 ± 0.04 (20/50)	1 – 0.1 (20/200 – 20/25)	
Postoperative CDVA (logMAR)	0.25 ± 0.19	0.7 – 0 (20/100 – 20/20)	

UDVA: uncorrected distance visual acuity, CDVA: corrected distance visual acuity.

Table 1 showed the change of visual acuity after cataract surgery with IOL implantation. Uncorrected distance visual acuity after cataract surgery 3 months was better than one before surgery with p = 0.002 (Paired-Sample T test).

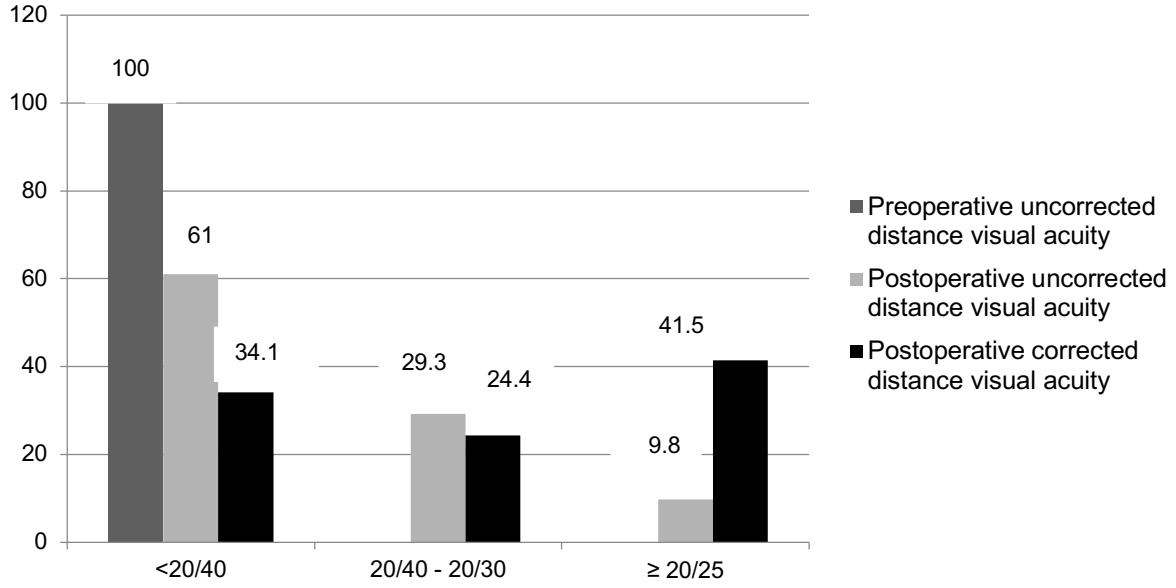

Figure 1. Distance visual acuity before and after cataract surgery 3 months

100% eyes before surgery were under 20/40. After cataract surgery, distance visual acuity was better with 9.8% at 20/25 and over, 29.3% from 20/40 to 20/30, and after correction, 42.5% eyes had VA at 20/25 and over.

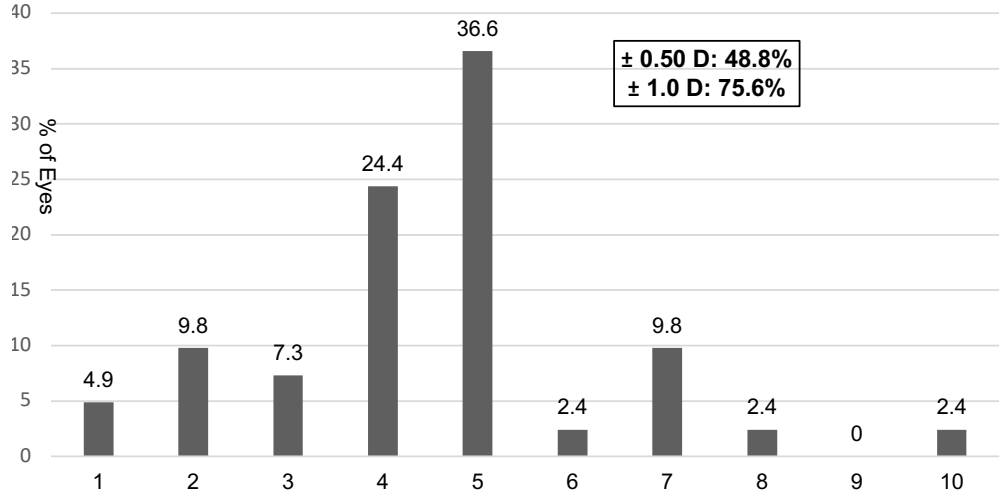

Figure 2. Spherical equivalent refractive accuracy (Residual spherical equivalent refraction: *(1: < -2.5D; 2: -2.5D to -1.51 D; 3: -1.50 D to -1.01 D; 4: -1.0 D to -0.51D; 5: -0.5 D to -0.25 D; 6: -0.24 D to 0 D; 7: 0D to 0.25 D; 8: 0.26 to 0.5 D; 9: 0.51 to 1 D;10: 1.01 to 2 D; 11: >2.0 D)*

Figure 2 shows the refractive accuracy, residual spherical equivalent refraction after surgery within ± 0.5 D; ± 1.0D accounts for 48.8 % and 75.6 %.

Table 2. Classification of residual spherical equivalent refraction after surgery

Residual spherical equivalent refraction (D)	Hyperopia (RSE>0.5)	Myopia (RSE < -0.5)	Emmetropia (-0.5 ≤ 0.5)	Total
n	1	20	20	41
%	2.4	48.8	48.8	100
MAE	3.25	0.85 ± 0.45	0.38 ± 0.28	0.68 ± 0.59

Table 2 shows the overall mean absolute error was 0.68 ± 0.59 D, and the mean absolute error for those who transitioned to myopia was 0.85 ± 0.45 D and for those who was emmetropia, it was 0.38 ± 0.28 D.

Table 3. Patient characteristics and data in 4 axial length groups

AL groups / Characteristics	< 26 mm (4 eyes)	26 mm ≤ AL < 28 mm (11 eyes)	28 mm ≤ AL < 30 mm (7 eyes)	≥ 30 mm (19 eyes)	p
Age	35.75 ± 3.78	40.64 ± 7.19	44.29 ± 7.85	47.26 ± 8.33	0.028
AL	24.7 ± 1.43	27.22 ±0.42	28.75 ± 0.47	32.42 ± 1.41	< 0.001
K	40.18 ± 1.27	38.85 ± 1.22	39.11 ± 3.97	36.18 ± 2.36	0.003
IOL power	23.19 ± 4.01	18.55 ± 2.66	14.57 ± 5.29	12.69 ± 4.20	< 0.01
MAE	0.44 ± 0.22	0.58 ± 0.43	0.67 ± 0.36	0.79 ± 0.78	0.680

Table 3 showed the demographics and data of the 4 AL groups. We used one-way ANOVA test, Homogeneity of variance test and Tamhane's T2 test to analyse these data. There was no statistically significant difference in age and preoperative astigmatism but there was statistically significant difference in axial length, corneal power and IOL power. In 19 eyes with AL over 30 mm, the corneal power was the flattest (36.18 ± 2.36 D). To evaluate the predictive accuracy between difference AL, we compared MAE of each group. The table showed no statistically significant difference in MAE with p = 0.680.

Table 4. The patients' satisfaction rate

Residual spherical equivalent refraction / Satisfaction		Very satisfied	Satisfied	Dissatisfied	Total
Emmetropia	n	12	7	1	20
	%	29.3	17.1	2.4	48.8

Residual spherical equivalent refraction \ Satisfaction		Very satisfied	Satisfied	Dissatisfied	Total
Myopia	n	3	16	1	20
	%	7.3	39.0	2.4	48.8
Hyperopia	n	0	0	1	1
	%	0	0	2.4	2.4
Total	n	15	23	3	41
	%	36.6	56.1	7.3	100

Table 4 illustrated the patients' satisfaction rate with 36.6% very satisfied, 56.1% satisfied and 7.3% dissatisfied. In the emmetropic group, there were 29.3% very satisfied, 17.1% satisfied and 2.4% dissatisfied. In the myopia group, there were 7.3% very satisfied, 39.0% satisfied and 2.4% dissatisfied.

IV. DISCUSSION

In this study, we evaluated the result of applying Shammas PL no history formula to calculate IOL power in eyes with previous LASIK. There were several reasons why we chose Shammas PL no history formula instead of other formulas such as the history methods. The first reason was that the formula does not use history data but it corrects the post LASIK corneal power measurement. Shammas PL formula corrected keratometric value was based on clinical findings and used a regression equation to modify the measured post LASIK K readings:[1] Kc.cd = 1.14Kpost – 6.8. The second reason was that most formulas require the use of axial length and corneal curvature values when calculating the effective lens position, but Shammas PL formula has the advantage of being able to calculate the effective lens position without using the central corneal curvature value. Moreover, the Shammas PL no history formula was used in Lenstar 9000, IOL Master 700 and the ASCRS calculator. In 2010, American Society of Cataract and Refractive Surgery developed an online calculator for eye after corneal refractive laser surgery. This tool was not only easy to use but also effective and economical. Therefore, when eye hospital or center have did not have Lenstar 9000 or IOL Master 700, they can calculate IOL power for eyes with previous refractive corneal laser with ASCRS calculator. Besides, the accuracy of Shammas PL no history formula was studied in many researches. In 2007, Shammas prospectively evaluated the Shammas PL no history for IOL calculation in 15 cataractous eyes with previous LASIK and for which the pre-LASIK K- readings were not available. The results showed that the mean arithmetic IOL prediction error was -0.003 D ± 0.63 and the MEA was 0.55 ± 0.31 and 93.3% eyes were within ± 1.00D. The Shammas PL no history was better than the optimized SRKT formula[4]. However, Shammas's research had small sample size. Whang et al studied 107 eyes with after myopic corneal laser refractive surgery, the results were similar to Shammas' research.[5] The MAE was 0.55 and 93.5% eyes were within ± 1.0D. This study showed that the Shammas PL formula was the best option

when the AL was ≥ 30.0 mm[3]. In Jun Zhang et al study of 38 eyes of 26 patients MAE was higher than the aforementioned studies (0.83 ± 1.02) and percentages of eyes with refractive PE within ± 0.50 and ± 1.00 D were 45.5% and 78.8%.[9] Christoph Lwowski et al evaluated IOL calculation formulas provided by an online calculation tool from the ASCRS for twenty-five eyes after LASIK. MAE with Shammas was 0.7 ± 0.75 D and 80% eyes were within ± 1.0 D.[10] In studies with larger sample size how MAE and percentages of eyes within ± 0.50 and ± 1.00 D changed. In 2016, Adi Abulafia et al compared the accuracy of the Barrett true K formula with other methods available on ASCRS online calculation with eighty-eight eyes and showed that mean absolute error of Shammas PL no history was 0.60 ± 0.51 and percentage of eyes within ± 0.50 and ± 1.00 D were 55.2% and 82.8%, respectively.[11] In 2020, Helga P. Sandoval et al studied 101 eyes undergoing cataract surgery after myopic LASIK to determine which formula was the best for calculating IOL power. The results about percentage of eyes within ± 0.50 and ± 1.00 D were 43% and 84%, respectively[12] when using Shammas PL.

In this study, the mean age of research subjects was 43.85 ± 8.33 years which was lower than one of other studies. In other studies, the mean age was 60.64 ± 8.80 years, 50.3 ± 10 years, 51.27 ± 7.31 years, 61.5 ± 8.0 years and 56.4 ± 8.3 years . Our patients had high myopia and long length with mean AL was 29.65 2.99 and 85,4% eyes were over 6 diopter. Kubo et al concluded that an increase in axial length or myopia of the eye was associated with a lower mean age at the time of surgery and higher grade of nuclear cataract.[17] Therefore, the patients in our study could have early cataract and had low vision before Phacoemulsification surgery. Visual acuity after Phacoemulsification surgery increased significantly, was different from before surgery with p = 0.002. Residual spherical equivalent refraction 3 months after surgery within ± 0.5 D; ± 1.0 D accounted for 48.8 % and 75.6 %. The rate was no significant difference with other researches.[10, 11, 14]

According to classification of residual spherical equivalent refraction after surgery, of the 41 eyes, 20 eyes (48.8%) were relatively myopic-shifted after surgery compared to the predicted refractive error before surgery, 20 eyes (48.8%) showed an emmetropic shift, and only one eye (2.4%) showed a hyperopic shift with respect to the previous refractive predicted error. The MAE when transitioning to myopia was 0.85 ± 0.45 D which was larger than MAE when transitioning to emmetropia (Table 3). In our study, 85.4% of eyes had high myopia. Although these eyes had undergone LASIK surgery to correct myopia and astigmatism, the patient's tendency to prefer near vision was still high. In our study, there were 3 patients who needed near vision after surgery and wore glasses for distance vision, so the residual myopia for the patients was calculated. After cataract surgery, 7.3% in myopia group were very satisfied. Only one patient was not satisfied in the myopic group. Therefore, it can be seen that the tendency for minus residual in Shammas's formula can be much better if there is a plus residual because if the patient has hyperopia, it may be more uncomfortable because both far and near vision are unclear.

In our study, there was no significant difference in MAE between 4 axial length groups (table 3). Although when looking at the table 3, the AL < 26 mm group had the lowest MAE of 0.44 ± 0.22 and the highest in the AL ≥ 30 mm group was 0.79 ± 0.78, but when using One-way Anova test, there was no difference with p = 0.680. Therefore, Shammas PL no history was a suitable option for all LASIK

eyes with different axial lengths. However, the research of Whang et all in 2020 showed that the Shammas PL no history formula was the best option when the AL was ≥ 30 mm. For AL ≥ 30 mm, the formula produced the lowest MAE (0.50 D) when compared with Barrett true-K, Haigis-L, Triple-S.[5]

Limitations of our study include a small number of research subjects and was collected in two hospitals. In the future, we will continue to research and evaluate with a larger sample size and compare between different formulas.

In conclusion, the study demonstrated that Shammas PL no history formula may be a suitable option for eyes after previous LASIK with all different axial length with the high rate of satisfaction. With Shammas PL no history, myopic shifting was more common than emmetropic and hyperopic shifting.

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