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Original Article

The comparison of three different correction formulas and the modified Ehler's algorithm in the evaluation of intraocular pressure after LASIK

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Abstract

Aim: The aim of this study is to assess the correlation between the preoperative intraocular pressure (IOP) and the postoperative corrected IOP values calculated by using the modified Ehler's algorithm and the three formulas after laser asisted in situ keratomileusis (LASIK) surgery.

Material and Methods: The medical records of the patients to whom LASIK was performed to correct myopia and/or astigmatism between June 2018 and December 2018 were analyzed. The corrected preoperative and postoperative IOP values calculated with modified Ehler's correction factor algorithm were compared. In addition, the corrected postoperative IOP values were calculated with Formula 1, Formula 2 and Formula 3 and the corrected postoperative IOP values were compared with the uncorrected preoperative IOP. Paired t-test was performed to compare the preoperative and postoperative IOP values. The Pearson correlation coefficients were calculated to analyze the correlation between preoperative IOP values and postoperative corrected IOP values.

Results: The statistically significant difference was not observed between preoperative IOP and postoperative corrected IOP for formula two and formula 3 (p=0.42 and 0.80, respectively). There was significant difference between preoperative and postoperative IOP corrected with modified Ehler's algorithm (p=0.03). In addition, a significant difference between preoperative IOP and postoperative IOP corrected with formula 1 was observed (p<0.01). The mean of the difference between preoperative IOP and postoperative IOP corrected with formula was 3.1±1.4 mmHg (ranging 1.99 to 4.35 mmHg) and the mean of the difference between preoperative and postoperative IOP corrected with modified Ehler's algorithm was 1.4±1.5 mmHg (ranging 0.1 to 2.6 mmHg). There was no correlation between preoperative IOP and postoperative corrected IOP values for Ehler algorithm and three formulas.

Conclusion: Formulas 2 and 3 could be used to acquire a hint about the increased IOP, but none of them is the exact way to assess IOP correctly following LASIK. There is need for new solutions in this field.

Keywords: LASIK; intraocular pressure; correction formula; the modified Ehler's algorithm.

INTRODUCTION

The measurement of intraocular pressure (IOP) is so important in the diagnosis and treatment of glaucoma. Goldmann applanation tonometry (GAT) has been accepted as a gold standard in the measurement of IOP (1-3). The measurement of IOP by GAT depends on the structure of cornea and GAT is adjusted for a cornea following parameters: 7.8 mm, central corneal thickness (CCT): 550 µm (1). The measurement of IOP has been affected especially from the change in CCT. Refractive laser surgeries have become a popular modality to correct refractive errors in the last two decades. Laser in situ keratomileusis (LASIK) and photorefractive keratectomy (PRK) are the most frequently performed methods. The decrease in CCT is a well-known effect of refractive surgeries (4). In addition to this, refractive surgeries change the corneal structure and the biomechanics (5-7). The measurement of IOP by GAT, Tonopen and pneumotonometer have been found significantly lower than the preoperative measurement. This result is probably related to the decrease in CCT and the structural changes in the cornea following laser surgery (8,9). The machines, which measure IOP independent of the corneal structure such as dynamic contour tonometer, and ocular response analyzer, have been developed in recent years. There are controversies about ocular response analyzer. While some studies (10,11) reported that corneal compensated IOP (ccIOP) may not be effected by the CCT,

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the other (12) established a positive correlation of ccIOP with the CCT The high correlation between preoperative and postoperative IOP measurements by dynamic contour tonometer was detected in various studies (13-15). Unfortunately, these machines are not attainable for most of the ophthalmologists. Thus, the evaluation of IOP after laser surgery remains as a big problem for ophthalmologists. Several solutions have been intended to overcome this problem. The measurement of IOP on the periphery of cornea where laser has not applied is one of these solutions but this has been inapplicable since the treatment zone as large as 9.0 mm has been started to be used (16). Then, many authors developed formulas to estimate postoperative IOP after the laser surgery was applied correctly (17-28). Schallhorn et al., Kohlhaas at al., Bahadir Kilavuzoglu et al. are three of them. It has been purposed to estimate true IOP value via calculating corrected postoperative IOP with these formulas. The aim of this study is to assess the correlation between the preoperative IOP and the postoperative corrected IOP value calculated by using the formulas of Schallhorn et al., Kohlhaas et al., Bahadir Kilavuzoglu et al. and modified Ehler's correction algorithm after LASIK surgery.

MATERIAL and METHODS

The medical records of the patients to whom LASIK was performed to correct myopia and/or astigmatism between June 2018 and December 2018 were analyzed. The inclusion criteria included the following: aged 18 years or more, myopia less than 6.0 D and astigmatism less than 3.0 D. The patients having any ocular or systemic disease, the history of any surgical operation except from LASIK and any drug use were excluded from the study The measurements of preoperative spherical and cylindrical refraction, IOP, K1, K2, Km, CCT were present in the records. IOP had been measured with pneumotonometer (NIDEK). Corneal topography had been assessed by using Pentacam (Oculus, Germany). The corrected preoperative and postoperative IOP values calculated with modified Ehler's correction factor algorithm were compared (25). In addition, the corrected postoperative IOP values were calculated with Formula 1 (26), Formula 2 (28) and Formula 3 (27) and the corrected postoperative IOP values were compared with the uncorrected preoperative IOP. In the comparison of these formulas preoperative IOP values were not corrected because these formulas were designed to correlate with uncorrected preoperative IOP. However, modified Ehler's algorithm is a calculation only based on CCT and it will be more convenient to compare preoperative and postoperative IOP after the correction of both.

SPSS 20.0 Software was used for statistical analysis. The normal distribution of data was assessed with the Kolmogorov Smirnov test. Paired t-test was performed to compare the preoperative and postoperative IOP values. The Pearson correlation coefficients were calculated to analyze the correlation between preoperative IOP values and postoperative corrected IOP values. P value less than 0.05 was assessed as statistically significant.

RESULTS

The mean age of the patients involved in the study was 26±4.9 years. The spherical equivalents of the patients range between, 1.5 D and -7.0 D. The means of preoperative IOP and postoperative IOP measurements were 18.2±0.9 mmHg and 12.7±2.75 mmHg, respectively. The means of preoperative and postoperative central corneal thickness were 557±27µm and 491±34µm, respectively. There was statistically significant difference between preoperative and postoperative measurements (p<0.001, for both).

The means of corrected postoperative IOP values for modified Ehler's algorithm, formula 1, formula 2 and formula 3 together with uncorrected and corrected preoperative IOP value were shown at Table 1. The statistically significant difference was not observed between preoperative IOP and postoperative corrected IOP for formula 2 and formula 3 (p: 0.42 and 0.80, respectively). There was significant difference between preoperative and postoperative IOP corrected with modified Ehler's algorithm (p:0.03). In addition, a significant difference between preoperative IOP and postoperative IOP corrected with formula 1 was observed (p<0.001). The mean of the difference between preoperative IOP and postoperative IOP corrected with formula 1 was 3.1±1.4 mmHg (ranging 1.99 to 4.35 mmHg) and the mean of the difference between preoperative and postoperative IOP corrected with modified Ehler's algorithm was 1.4±1.5 mmHg (ranging 0.1 to 2.6 mmHg).

The Pearson correlation coefficients calculated for formula1, formula 2, formula 3 and modified Ehler's algorithm were shown in table 2. There was no correlation between preoperative IOP and postoperative corrected IOP values for Ehler's algorithm and three formulas. The Pearson correlation coefficients were shown in Table 2.

Table 1. The Preoperative and Postoperative Corrected Intarocular Pressure Values

	Preoperative IOP (mmHg)	Postoperative IOP (mmHg)	p
Formula 1 (Kohlhaas E et al)	18.5±1.0	15.3±1.2	<0.001
Formula 2 (Schallhorn JM et al)	18.5 ± 1.0	18.5 ± 1.0	0.80
Formula 3 (Bahadir Kilavuzoglu AE et al)	18.5 ± 1.0	18.8 ± 1.3	
Modified Ehler's algorithm	17.7±1.0*	16.3±1.4	0.03

IOP: Intraocular pressure
*:The preoperative IOP value corrected by the modified Ehler's correction algorithm

Table 2. The Pearson Correlation Coefficients Calculated for Three Formulas and The Modified Ehler's Algorithm

	r	p
Formula 1(Kohlhaas E et al)	0.29	0.48
Formula 2 (Schallhorn JM et al)	0.45	0.25
Formula 3 (Bahadir Kilavuzoglu AE et al)	0.41	0.31
Modified Ehler's algorithm	0.34	0.40

r : The Pearson correlation coefficient

DISCUSSION

The Goldmann applanation tonometry has been accepted as a gold standard in IOP measurements. In recent days, the reliability of GAT becomes discussible upon the widespread use of refractive laser surgeries. There are a lot of studies reporting the disparity in IOP measured with GAT after refractive laser surgeries (8,15,29). Pneumotonometer and Tonopen were considered to be more reliable methods of IOP estimation than GAT in eyes with the history of refractive surgery (8,30). In other words, the underestimation of IOP following refractive surgery by using these tonometers is less than that related to GAT (30-34). Unfortunately, IOP measured with pneumotonometer and Tonopen following refractive surgery was also reported as significantly lower than the preoperative IOP measurements in various studies (8,35-38). Different solutions have been produced to overcome the underestimation of IOP following refractive surgery. The invention of the machines measuring IOP independent of the corneal structure is an important footstep in this field. Dynamic contour tonometer and ocular response analyzer are examples of these machines. The studies conducted by using dynamic contour tonometer and ocular response analyzer have showed that IOP values measured with this machine remain unaffected after refractive surgery (13-15). Also the dynamic Scheimpflug analyzer handles stable biomechanically corrected IOP measurement after refractive surgery (13) but these are not easily accessible for all patients with the history of refractive surgery. Then, the formulas were developed to estimate IOP correctly by using postoperative IOP and several parameters. In this study, we used three different formulas evolved for the estimation of IOP in patients with the history of LASIK (25-28). Also, the modified Ehler's algorithm was used to estimate IOP postoperatively (25). The formula 1 was reported from the study of Kohlhaas et al. The formula 1 handles the corrected IOP by using postoperative IOP, central corneal thickness, mean keratometry in the calculation (GİB+(540-SKK)/71+(43-K value) 2.7+0.75) (26). Formula 1 is easily applicable because it is composed of postoperative measurements. Formula 2 uses IOP and preoperative spherical equivalent in the calculation of corrected IOP (GİB +3.6-0.4* preoperative spherical equivalent) (28). The inclusion of preoperative spherical equivalent is a limitation for formula 2 because most of the patients do not have preoperative medical records. Formula 3 firstly calculates the predicted IOP value (IOPpredicted=6.194+0.448* (IOPpreop)+0.012* (CCTpreop) +0.554* (SE-ac) -1.009 (OZ diameter)). In this calculation, preoperative IOP, CCT, spherical equivalent and optic zone diameter was used. Secondly, IOP constant value was calculated and this value was added to postoperative IOP to handle corrected postoperative IOP (IOPpreop-IOPpredicted=IOPcons) (27). Formula 3 is not practical and the requirement for preoperative measurements is a limitation. Finally, the modified Ehler's correction factor algorithm has been applied to preoperative and postoperative IOP measurements and these corrected IOP values have been compared. In this way, the correction based on CCT has been performed for both of preoperative and postoperative IOP because the modified Ehler's algorithm was developed to estimate the correct IOP based on CCT in all eyes without separating the eyes with previous refractive surgery. In this way, to compare preoperative and postoperative IOP after the correction of both is the true approach. In our study we found that there was no significant difference between the corrected IOP values by using formula 2 and formula 3 and preoperative IOP, but the correlation was not observed between the corrected IOP values and preoperative IOP for both of the formulas. As a result, the application of formula 2 and 3 in eyes with LASIK is controversial. The significant difference was observed between the corrected IOP values by using formula 1 and the modified Ehler's algorithm and preoperative IOP. Formula 1 and the modified Ehler's algorithm should not be used for the corrected IOP estimation following LASIK. Especially, the range of the difference between 1.99 to 4.35 mmHg in Formula 1 is thought provoking. The results of another study from the literature is similar to our results. Bernardo MD et al. assessed nine different formulas to estimate the corrected IOP following PRK. They calculated the Pearson correlation coefficients ranging 0.10 to 0.85 for these formulas (39). They reported that the use of different formulas following PRK is not the exact solution to the assessment of IOP correctly, but the use of formulas might be beneficial in detecting the patients who need to be followed up closely because of measured IOP value in normal range and increased corrected IOP value. Jethani et al. involved 346 eyes with previous LASIK surgery and they applied the modified Ehler's algorithm to correct preoperative and postoperative IOP. They did not find any significant difference between preoperative and postoperative corrected IOP together with strong correlation ($r:0.7$, $p<0.01$). They reported that the modified Ehler's correction algorithm could be effectively applied in the patients with the normal IOP after LASIK surgery (40).

There were some limitations of this study. Firstly, the number of the patients involved in the study is low but also it is enough to detect the difference at least formula 1 and the modified Ehler's algorithm. Secondly, the formulas were not analyzed after grouping according to preoperative SE values, postoperative IOP and CCT measurements. We did not find any correlation for any formula but one of these formulas might show the correlation in a classified range of IOP or CCT. There is need for studies in this design.

CONCLUSION

In conclusion, formulas 2 and 3 could be used to acquire a hint about the increased IOP, but none of them is the exact way to assess IOP correctly following LASIK. There is need for new solutions in this field.

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