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Surgical Correction of Different Severities of Astigmatism Using Wavefront-Optimized Photorefractive Keratectomy

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Abstract--

Background and Objective: *Astigmatism is a prevalent refractive error. One of the most common methods of refractive surgery is photorefractive keratectomy (PRK) surgery. The aim of this study is to determine the effectiveness of PRK on three types of astigmatism (mild, moderate, and severe).*

Methods: *This prospective interventional case series was performed on 46 eyes of 25 patients with astigmatism ranging from 1-6 diopter with ≤1D sphere. After obtaining informed written consent, demographic information of patients and the results of the examination were recorded. The patients undergoing surgery were followed up for 12 months and their data were then collected and statistically analyzed.*

Results: *The mean preoperative and postoperative refractive astigmatism was -3.01±1.42 and -0.40±0.37 (D), respectively (p<0.001). The mean preoperative and postoperative sphere was also -0.12±0.51 and -0.00±0.16 (D), respectively (P=0.11). while the mean preoperative refractive astigmatism in the sever, moderate and mild groups was -5.00±0.57 (D), -3.27±0.49 (D) and -1.79±0.42 (D), respectively, the mean postoperative refractive astigmatism in the sever, moderate and mild groups was -0.70±0.45 (D), -0.37±0.37 (D) and -0.26±0.21 (D), respectively. The effect of PRK on astigmatism correction in sever astigmatism was better than mild and moderate astigmatism (p<0.001). There was no significant relationship between age and correction of refractive astigmatism using PRK (p=0.75). In adittion, refractive stability and keratometric astigmatism was achieved at 3 and 1 month postoperatively, respectively. The mean SIA and IOS was also 3.11±1.52 and 0.14±0.08, respectively.*

Conclusion: *PRK with Allegretto WaveLight Eye-Q 400 is a successful surgery to correct and decrease all types of astigmatism. The RPK effect on the severe astigmatism was significantly higher than mild and moderate types.*

Key words--*Astigmatism, PRK, Refractive Error.*

I. INTRODUCTİON

Visual impairment has been one of the major concerns of the WHO in recent years. In developing countries, visual impairment is mostly because of the inability of national health care systems to provide adequate prevention and treatment, while approximately 80% of the cases can be prevented and treated (1).

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Astigmatism is one of the relatively common refractive errors that decreases the patient's vision and causes a number of chronic problems such as dizziness, headache, and most importantly amblyopia and strabismus (in childhood, if left untreted). Astigmatism may occur in combination with other refractive errors such as hyperopia and myopia. The goal of treating astigmatism is to correct the uneven curvature of the cornea (1-3).

Photorefractive Keratectomy (PRK) was first used in 1980, and 10 years later Laser In Situ Keratomileusis (LASIK) was suggested as a treatment method. The advantages of PRK over LASIK include its application in thin cornea, having no complications related to flap, reducing corneal deep stromal inflammation, its suitability for people vulnerable to trauma, and its needlessness of microkeratome and related technologies. Disadvantages of the PRK method include long duration of recovery, and long duration of pain, treatment and recovery (4, 5).

Recently, the use of femtolaser to correct astigmatism is also developing (6), one of the drawbacks of which is its high cost and unavailability in underdeveloped countries.

Due to the importance of ophthalmic refractive errors such as astigmatism, and the lower number of people with astigmatism undergoing PRK surgery, and few studies on the correction of astigmatism by PRK in Iran and especially Ardabil province, the present study aimed to investigate the effectiveness of PRK on correction of astigmatism in patients referring to Ardabil Noor surgery Center (northwestern Iran). In addition, while most previous studies were conducted on astigmatism with relatively high sphere, the present study investigated the astigmatism with ≤1D sphere.

II. METHODS AND MATERİALS

This prospective interventional case series was performed on 46 eyes of 25 patients with astigmatism ranging from 1-6 diopter with ≤1D sphere, who referred to Ardabil Noor Surgery Center from January 2018 to December 2018 and were candidates for PRK.

In addition to willingness to participate, inclusion criteria included patients with refractive astigmatism between 1-6 D and a hyperopia or myopia of ≤1D, who referred to surgery center for PRK.

Exclusion criteria also included hyperopia or myopia of >1 D, unwillingness to participate, uncontrolled connective tissue diseases such as rheumatoid arthritis, Sjogren's syndrome, uncontrolled systemic lupus and dry eye, corneal sensory dysfunction (herpes simplex, herpes zoster and corneal dystrophy) corneal ectasia (keratoconus), uncontrolled diabetes, history of previous corneal surgery, and age less than 18 years.

The written informed consent for prospective data analysis was obtained from patients during their recruiting process. The study was approved by Ethics Committee of Ardabil University of Medical Sciences (NO: IR. ARUMS.REC.1396.258) and adhered to the principles of the declaration of Helsinki.

The questionnaire included demographic informations. In all preoperative patients, refraction was performed by the CANON (Canon Full Auto Ref_keratometer RK_F2, TOKYO, JAPAN) 30 minutes after administration of two drops of cyclopentolate 5 minutes apart. Also, keratometry, BCVA & UCVA, and eye examination was performed using an autorefractometer (Canon Full Auto Ref_Keratometer RK-F2), a snellen chart, and indirect ophthalmoscope, respectively. In all patients, due to the possibility of cyclotorsion, the cornea was marked with Jentian violet at 6 and 12 o'clock before the surgery. After obtaining written consent, the patients underwent surgery using Allegretto Wave Light Eye-Q 400 (Erlangen, Germany) by Wavefront Optimized method

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with Optical zone, Transition Zone, and Ablation Zone of 6.50 mm, 1.25 mm, and 9 mm, respectively. After surgery, all patients treated with betamethasone drop 0.1% (Sina Daru Pharmaceuticals, Iran) every 2 hours, which gradually tapered within 1.5 months, Artelac drop 0.2% (BAUSCH & LOMB, France) every 4 hour for 1 month and then every 6 hours for 2 months, levofloxacin drop 0.5% mg (SANTEN OY, Finland) every 4 hours for 10 days, and dicloptin drops 0.1% mg (Sina Daru Pharmaceuticals, Iran) every 6 hours for 2 days. Also, cycloplegic refraction and visual acuity testing were performed. Patients were examined periodically 6 hours, 1 week, 1 month, 3 months, 6 months, and 12 months after surgery.

Patients were divided into 3 groups based on the severity of myopic astigmatism: Mild (1.00-2.50 D); moderate (2.75-4.00); severe (4.25-6.00 D).

Based on preoperative steep meridian of cornea, they were also divided into 3 groups: with the rule (70-110 degree); against the rule (0-20 and 160-180 degree); oblique (21-69 and 111-159 degree).

The classification of corneal opacity was as follows: Grade 0 (without opacity); grade 0.5 (with trace opcity); grade 1(with minimal opacity); grade 2: (with mild opacity); grade 3 (with moderate opacity); grade 4 (with severe opacity) (7).

Data were also analyzed by Alpins method (8, 9). The surgically induced astigmatism (SIA) vector is the astigmatic change the surgery actually induced. The target induced astigmatism (TIA) vector represents the change (by magnitude and axis) the surgery was intended to induce. The correction index was calculated as the ratio of the magnitude of SIA to the magnitude of TIA. The correction index is preferably 1.0. It is greater than 1.0 if overcorrection occurred and less than 1.0 if undercorrection occurred. The difference vector (DV) represents the vector that enables the achieved astigmatic outcome to achieve target astigmatism. This is an absolute measure of success and is preferably zero. The magnitude of error (ME) is the arithmetic difference between the magnitudes of the SIA and TIA. The ME is positive for overcorrection and negative for undercorrection. The angle of error (AE) is the angle between the SIA and TIA vectors. The flattening effect (FE) is the magnitude of astigmatism reduction achieved at the intended meridian of treatment (TIA meridian). The flattening index is calculated by dividing the FE by the magnitude of TIA and is preferably 1.0.

Statistical analysis

Patient information was recorded in a checklist at all stages of the study and the collected data was entered into SPSS software version 25. After encoding by descriptive statistics methods in the form of tables, charts, and statistical indicators, data were analyzed using statistical tests including Friedman test, Mann-Whitney U-test, and Chi square test. The relationship between variables was also investigated ($p < 0.05$).

III. RESULTS

In this study, 46 eyes from 25 patients with astigmatism including 15 female (60%) and 10 male (40%) were examined (Table 1). The mean age of the patients was 29.72±7.23 years ranging from18 to 43 years. Out of 25 patients, 9 (36%), 10 (40%), and 6 (24%) were 18-25, 26-35, and over 35 years old, respectively.

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Table 1: Demographic and pre & postoperative characteristics of patients

Characteristics	**Preoperative**	**Postoperative 12 months**	**P**
No. of eyes (R/L)	46(23/23)	46(23/23)	
Sex (M/F)	10/15	10/15	
Age (year)			
Mean±SD	29.72±7.23		
Range	18-43		
Sphere (D)			
Mean±SD	-0.12±0.51	-0.00±0.16	**0.11**
Median (Range)	0.00(-1.00 to +1.00)	0.00(-0.50 to+0.50)	
Mean diff±SD		-0.11±0.50	
SE (D)			
Mean±SD	-1.63±0.71	-0.20±0.18	**<0.001**
Median (Range)	-1.43(-3.12to -0.50)	-0.18(-0.62 to+0.13)	
Mean diff±SD		-1.42±0.64	
Ref. Ast. (D)			
Mean±SD	-3.01±1.42	-0.40±0.37	**<0.001**
Median (Range)	-2.75(-6.00 to-1.00)	-0.25(-1.00 to 0.00)	
Mean diff±SD		-2.60±1.26	
Ker. Ast. (D)			
Mean±SD	2.90±1.11	0.97±0.48	**<0.001**
Mean K (D)			
Mean±SD	43.44±1.59	42.12±1.71	**<0.001**
Median (Range)	43.68(39.49-46.18)	42.09(37.81-45.56)	
Mean diff±SD		1.31±1.02	
UCVA (LogMAR)			
Mean±SD	0.57±0.25	0.02±0.05	**<0.001**
Median (Range)	0.60(0.1-1.00)	0.00(0.00-0.18)	
Mean diff±SD		0.55±0.25	
BCVA(LogMAR)			**0.002**
Mean±SD	0.06±0.12	0.00±0.00	
Median (Range)	0.00(0.00-0.48)	0.00(0.00-0.00)	
Mean diff±SD		0.06±0.12	

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No: Number; R: Right; L; Left; M; Male; F; Female; SD: Standard Deviation; D: Diopter; SE: Spherical Equivalent; Ref: Refractive; Ast: Astigmatism; Ker: Keratometric; diff: difference; K: Keratometry; UCVA: Un Corrected Distance Visual Acuity; BCVA: Best Corrected Distance Visual Acuity.

As shown in Table 1, the mean Sphere before and 12 months after the surgery was 0.00±0.51 and 0.00±0.16, respectively. There was no significant difference between the mean of sphere before and 12 months after the surgery (P=0.11).

Also, the mean spherical equivalent before and 12 months after the surgery was 1.63±0.71 and 0.20±0.18, respectively, which statistically was significant (P<0.001).

Table 1 shows the significant difference between the Mean LogMAR of UCVA before (0.57±0.25) and 12 months after the surgery (0.02±0.05) (P<0.001). Also, the difference between the the Mean LogMAR of BCVA before (0.06±0.12) and 12 months postoperatively (0.00±0.00) was statistically significant (P=0.002)

The mean *k* before the and 12 months after the surgery was 43.44±1.59 and 42.12±1.71, respectively, which statistically was significant (P<0.001).

According to the results of the present study, although the mean of refractive astigmatism has decreased until 12 months after the surgery, it was significant only until 3 months after the surgery (P <0.001) (Figure 1).

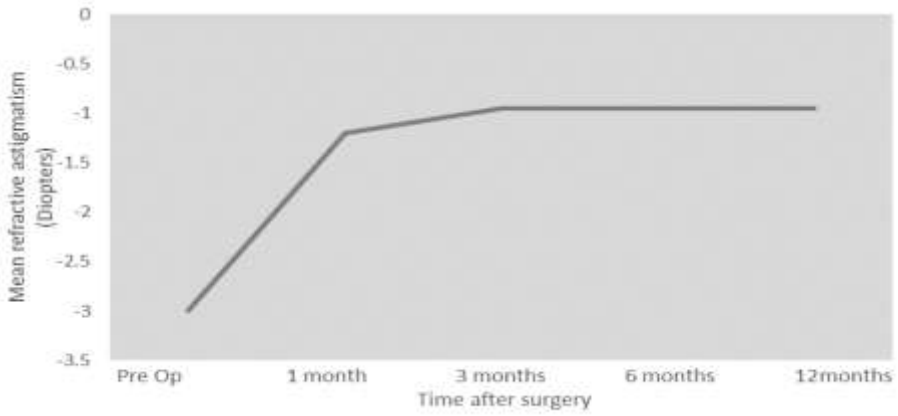

Figure 1: Refractive Astigmatism over time

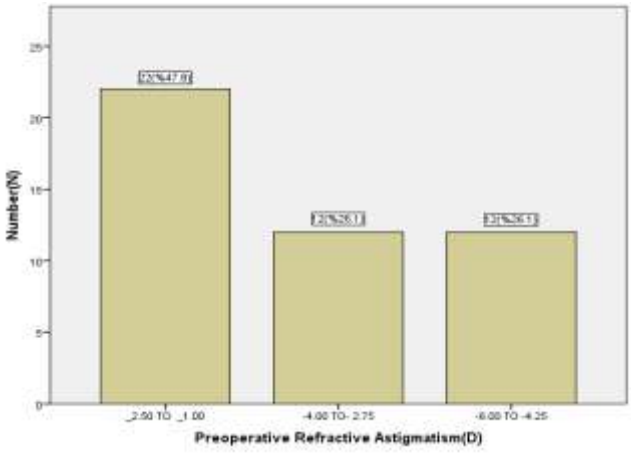

Figure 2: Preoperative Refractive Astigmatism

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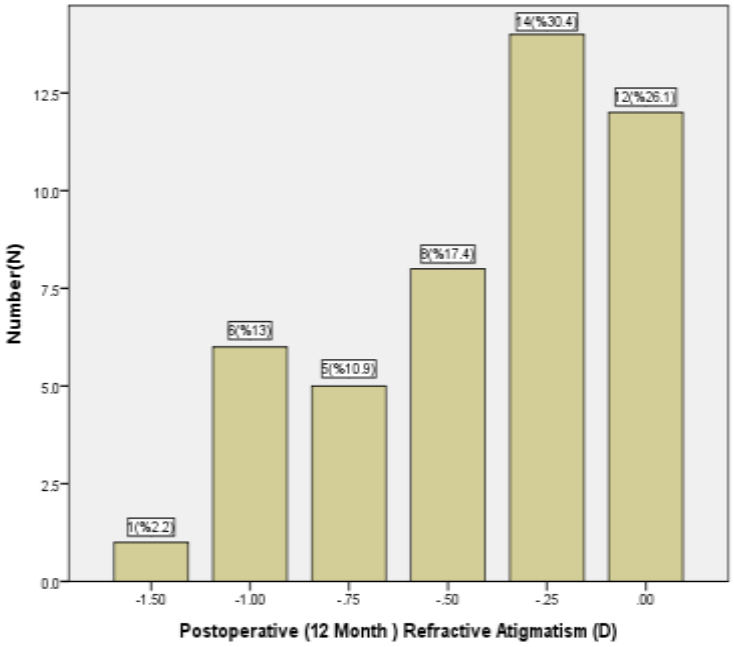

Figure 3: Postoperative (12 months) Refractive Astigmatism

Figures 2 and 3 show the number of eyes with different severities of astigmatism before and 12 months after the surgery. As shown in figure 3, 12 eyes (26.1%) have a refractive astigmatism of zero D until 12 months after the surgery.

Although the mean keratometric astigmatism decreased at 12 months after the surgery, it was significant only until 1 month after the surgery. (P<0.001) (Figure 4).

In the present study, comparison of keratometric and refractive astigmatism indicated the stability of keratometric astigmatism occurred earlier than refractive astigmatism.

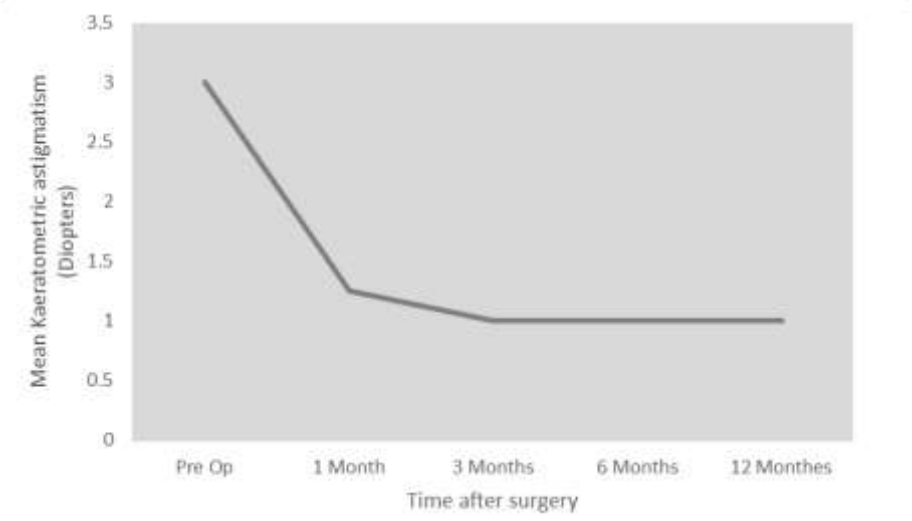

Fıgure 4: Keratometric Astigmatism over time

In the study of refractive astigmatism, 22 eyes (47.8%) had mild astigmatism. PRK has decreased the mean of mild refractive astigmatism (Table 2), though it was significant only until 6 months after the surgery (P = 0.02).

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Also, there was no significant difference between the mean of astigmatism at 6 and 12 months after the surgery (P = 0.74). Therefore, it can be concluded that significant changes have occurred in the mild type until 6 months after the surgery. The difference between the mean of astigmatism before and 12 month after the surgery was 1.33±0.45 (P <0.001), indicating the effectiveness of PRK in reducing mild refractive astigmatism.

In refractive astigmatism, 12 eyes (26.1%) had moderate astigmatism. PRK has also decreased the mean of moderate refractive astigmatism (Table 2), though it was significant only until 3 months after the surgery (P=0.002). It can be concluded that significant changes have occurred in the moderate type until 3 months after the surgery. The difference between the mean of astigmatism before and 12 months after the surgery was -2.89±0.51 (P <0.001), indicating the effectiveness of PRK in reducing moderate refractive astigmatism.

In refractive astigmatism, 12 eyes (26.1%) had severe astigmatism. PRK has significantly decreased the severe refractive astigmatism until 3 months after the surgery. (P = 0.01). At 6 months after the surgery, there was a slight increase in the mean of severe astigmatism (P = 0.15). At 12 months after the surgery, the mean of severe refractive astigmatism decreased compared to that of the six months after the operation (P = 0.43). In addition, the mean of astigmatism at12 months after the surgery was slightly different from that of 3 months after surgery. It can be concluded that significant changes occurred until 3 months after the surgery in severe refractive astigmatism. The significant difference between the mean of astigmatism before and 12 months after the surgery was -4.29±0.68 (P <0.001), indicating the effectiveness of PRK in reducing svere refractive astigmatism (Table 2).

Table 2: Effect of PRK according to astigmatism severity

Parameters	**Preoperative**	**Postoperative 12 months**	**P**
Ref. Ast (D)			
Mild			**<0.001**
Mean±SD	-1.79±0.42	-0.26±0.21	
Median (Range)	-1.75(-2.50 to -1.00)	-0.25(-0.75-0.00)	
Mean diff±SD		-1.53±0.45	
Moderate			
Mean±SD	-3.27±0.49	-0.37±0.37	**<0.001**
Median (Range)	-3.25(-4.00 to -2.75)	-0.25(-1.00-0.00)	
Mean diff±SD		-2.89±0.51	
Severe			
Mean±SD	-5.00±0.57	-0.70±0.45	**<0.001**
Median (Range)	-5.00(-6.00 to -4.25)	-0.75(-1.50-0.00)	
Mean diff±SD		-4.29±0.68	
Ker. Ast. (D)			
Mild			**<0.001**
Mean±SD	1.84±0.55	0.8±0.35	

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Median (Range)	1.94(0.75-2.50)	0.81(0.12-1.38)	
Mean diff±SD		1.03±0.53	
Moderate			
Mean±SD	3.25±0.44	0.95±0.36	**<0.001**
Median (Range)	3.25(2.64-4.00)	0.88(0.37-2.00)	
Mean diff±SD		2.30±0.45	
Severe			
Mean±SD	4.79±0.73	1.56±0.78	**<0.001**
Median (Range)	4.50(4.12-6.13)	1.75(0.25-2.50)	
Mean diff±SD		3.23±0.95	

Ref: Refractive; Ast: Astigmatism; Ker: Keratometric; D: Diopter; SD: Standard Deviation; diff: difference; K: Keratometry; PRK: Photo Refractive Keratectomy.

According to Table 2, PRK significantly decreased astigmatism in all three types of mild, moderate, and severe keratometric astigmatism (P <0.001)

In keratometric astigmatism, 18 eyes (39.1%) had mild astigmatism. PRK has significantly decreased the mean of mild keratometric astigmatism (Table 2), though it was significant only until 3 months after the surgery (P=0.002).

In keratometric astigmatism, 22 eyes (47.8%) had moderate astigmatism. PRK has also significantly decreased the mean of keratometric astigmatism, though it was significant only until 1 month after the surgery (P <0.001).

Six eyes (13%) had severe keratometric astigmatism. Also, PRK has significantly decreased the mean of severe keratometric astigmatism, it was significant only until 1 month after the surgery (P <0.001). six months after the surgery, there was a significant increase in the mean of severe keratometric astigmatism compared to that of 3 months after the surgery (P = 0.008).

Table 3 shows the comparison of the effect of PRK on different severities of astigmatism. Also, the mean decrease of preoperative refractive astigmatism compared to the 12 month after the surgery in mild, moderate and severe astigmatism is -1.53±0.45, -2.89±0.5, and -4.29±0.68, respectively, indicating a significant postoperative astigmatism reduction in all 3 groups (P <0.001). Despite the significant effect of PRK on reducing all types of astigmatism, the effect of PRK on reducing severe astigmatism was greater than on the moderate (P <0.001) and mild types (P <0.001). Also, the effect of PRK on reducing moderate astigmatism was greater than on the mild type (P <0.001).

Table 3: Comparison of PRK outcome between different severities of astigmatism

Astigmatism (D)	**Preoperative M±SD**	**post operative**			**P**	
		M±SD	**Mean diff±SD**	**M±SD**		
Refractive						<0.001

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Mild VS Moderate	-1.79±0.42 -3.27±0.49	-0.26±0.21 -037±0.37	-1.53±0.45 -2.89±0.51	1.36±0.18	<0.001	
Mild VS Severe	-1.79±0.42 -5.00±0.57	-0.26±0.21 -0.70±0.45	-1.53±0.45 -4.29±0.68	2.75±0.18	<0.001	
Moderate VS Severe	-3.27±0.49 -5.00±0.57	-0.37±0.37 -0.70±0.45	-2.89±0.51 -4.29±0.68	1.39±0.21	<0.001	
Keratometric						0.002
Mild VS Moderate	1.84±0.55 3.25±0.44	0.80±0.35 0.95±0.36	1.03±0.53 2.30±0.45	-1.26±0.17	<0.001	
Mild VS Severe	1.84±0.55 4.79±0.73	0.80±0.35 1.56±0.78	1.03±0.53 3.23±0.95	-2.19±0.26	<0.001	
Moderate VS Severe	3.25±0.44 4.79±0.73	0.95±0.36 1.56±0.78	2.30±0.45 3.23±0.95	0.93±3.23	0.002	

M: Mean; SD: Standard Deviation; D: Diopter.

Despite the significant effect of PRK on reducing keratometric astigmatism, the effect of PRK on reducing severe astigmatism was greater than on the moderate (P <0.002) and mild types (P <0.001). Also, the effect of PRK on reducing moderate astigmatism was greater than on the mild type (P <0.001).

In the present study, 37 (80.4%), 5 (10.9%), and 4 (8.7%) eyes had with the rule, against the rule, and oblique refractive astigmatism, respectively. Also, PRK significantly reduced the three types of astigmatism with P <0.001, P=0.01, and P=0.01, indicating no significant difference between the three types (P = 0.29). however, since the frequency distribution of the three groups is not identical, the result is not reliable and may not be generalized.

In keratometric astigmatism, 39 (84.8%), 3 (6.5%), and 4 (8.7%) eyes were with the rule, against the rule, and blique astigmatism, respectively. Also, PRK significantly decreased keratometric astigmatism of with the rule, against the rule and oblique with p<0.001, p=0.07, and p=0.07, respectively.

It can be concluded that the type of keratometric astigmatism is not an obstacle to the effect of PRK on the correction of keratometric astigmatism. However, since the frequency distribution of the three groups was not identical, the result is not reliable and may not be generalized.

In the study of refractive astigmatism, 16 (34.8%), 19 (41.3%), and 11 (23.9) eyes were among the age group of 18-25, 26-35, over 35 years, respectively.

The mean decrease of preoperative refractive astigmatism compared to the 12 month after the surgery in the age group of 18-25, 26-35, and over 35 years was -2.78±1.25, -2.57±1.30, and -2.40±2.30, respectively. Although PRK significantly decreased the mean astigmatism of all age groups (P <0.001), there was no significant difference between the three age groups (P = 0.75).

In keratometric astigmatism, 16 (34.8%), 19 (40.6%) and 11 (21.3%) eyes were in the age group of 18-25, 26-35, and over 35 years, respectively. Also, the mean decrease of preoperative refractive astigmatism compared to

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the 12 month after the surgery in the age group of 18-25, 26-35, and over 35 years was 2.25±0.92, 1.75±1.06, and 1.73±0.73, respectively. Although PRK significantly decreased the mean astigmatism of all age groups (P <0.001), there was no significant difference between the three age groups (P = 0.23). It can be also concluded that the age is not an obstacle to the effect of PRK on correction of keratometric and refractive astigmatisms.

Corneal opacity was observed in 7 eyes (5 patients) after PRK. Five (71.42%) and 2 eyes (28.57%) had severe and moderate refractive astigmatism, respectively. In these patients, the mean of refractive astigmatism was -4.64, which was higher than the mean of the refractive astigmatism in all patients (- 3.01). Also, corneal opacity averagely occurred at 6 months after the surgery, with the mean severity of 1.07 degrees. Given that 5 out of 12 eyes with severe astigmatism (41.66%) and 2 out of 12 eyes with moderate astigmatism (16.66%) had corneal opacity, and none of the 22 eyes with mild astigmatism had corneal opacity, the prevalence of corneal opacity in severe astigmatism was significantly higher than in mild astigmatism (P = 0.001) and considerably (but not significantly) higher than in moderate astigmatism (P = 0.06). Also, the prevalence of opacity in moderate astigmatism was non significantly higher than in mild type. (P=0.16)

Table 4 shows the results of patients vector analysis. When the CI (ratio of SIA to TIA) is 1, >1, and <1, the surgery is quite successful, there is overcorrection, and undercorrection, respectively. In the present study, the mean CI was ≤1 (0.96±0.12), indicating the success of surgery. Also, IOS (ratio of DV to TIA) is zero if the surgery is successful, which is ≥0 in the present study (0.14 ± 0.08).

Table 4: Vector Analysis of Patients

Parameter	**Mean±SD**	**Median (Range)**
TIA(D)	3.25±1.63	**2.81(1.00-6.66)**
SIA(D)	3.11±1.52	**2.72(1.00-7.00)**
Difference Vector(D)	0.43±0.34	**0.24(0.11-1.53)**
Correction index	0.96±0.12	**0.96(0.68-1.24)**
Index of Success	0.14±0.08	**0.12(0.02-0.33)**
Angle of error(degrees)	-1.84±3.22	**-1.94(-9.71 to 6.99)**
Magnitude of error(degrees)	-0.13±0.46	**-0.11(-1.81 to 0.67)**
Flattening effect (D)	3.07±1.52	**2.66(0.97-6.98)**
Flattening Index	0.95±0.12	**0.95(0.68-1.24)**

SD: Standard Deviation; TIA: Target Induced Astigmatism; D: Diopter; SIA: Surgically Induced Astigmatism.

According to figure 5, there is a direct linear relationship between the TIA and SIA, indicating the success of the surgery.

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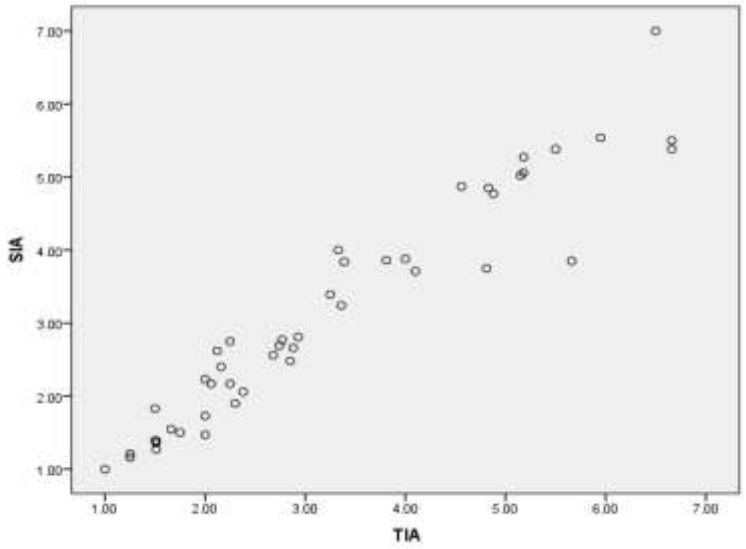

Figure 5: Correction of Astigmatism

As shown in figure 6, AE in 28 eyes (60.86%) was negative, indicating a clockwise rotation, in 11 eyes (23.91%) were equal to zero, and in 7 eyes (15.21%) were positive, indicating a counterclockwise rotation.

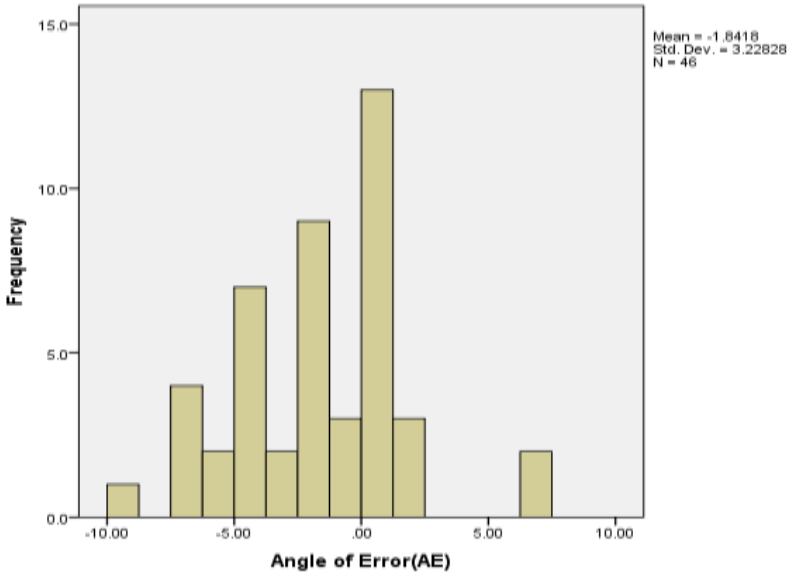

Figure 6: Mean angle of error at 12 months after PRK

According to figure 7, the angle of error is around the zero. If the value is negative, there is undercorrection, and if the value is positive, there is overcorrection. In 30 (65.21%), 2 (4.34%), and 14 (30.43%) eyes, the angle of error was <0, 0, and >0, respectively. Most eyes had a near-zero angle of error, indicating the success of the surgery.

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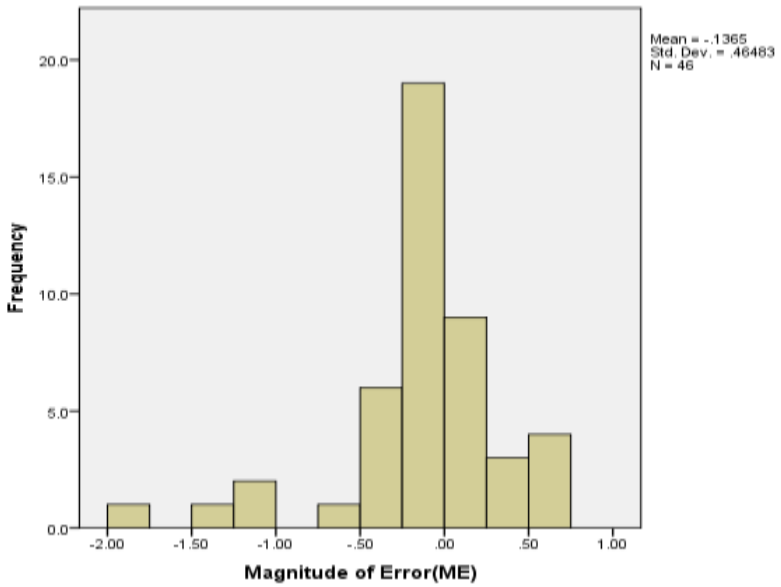

Figure 7: Mean Magnitude of error at 12 months after PRK

IV. DİSCUSSİON

In the present study, we evaluated the effect of Photorefractive Keratectomy (PRK) on the correction of astigmatism in 46 eyes from 25 patients with astigmatism of 1-6 diopters, who referred to Ardabil Noor Surgery Center. The mean of refractive and keratometric astigmatism before the surgery was -3.01±1.42 and 2.9±1.11, respectively. Also, The mean of refractive and keratometric astigmatism 12 months after the surgery was 0.40±0.37 and 0.98±0.51, respectively, which was statistically significant (P <0.001).

In 2013, Okkes Baz et al. examined 89 eyses from 50 patients with astigmatism who underwent PRK. (4) They divided patients into 3 groups of PRK-treated, PRK-treated with mitomycin, and T_PRK-treated. Mean SE before surgery in these groups was -1.93±0.98, -1.61±1.3, and -1.70±0.91, respectively. Also, 6 months after the surgery, the mean of astigmatism was -0.06±0.18, 0.0. ±0.0, and 0.01±0.08, respectively. The reduction of astigmatism in these groups was 96.8%, 100%, and 99.4%, respectively, indicating the effectiveness of PRK in reducing astigmatism.

In a study by Ikhyun Jun et al. (10), 89 eyes from 89 patients treated with T_PRK were examined. The mean of sphere and astigmatism before the surgery was-3.77±1.57 and -2.84±0.35, respectively. At follow-up after 6 months, astigmatism was decreased by 89% in these patients. Weldon et al. (2000) performed a study on 93 eyes from 56 patients of astigmatism with myopia (11). The mean of sphere and astigmatism before the surgery was -3.64±1.82 and 2.35±0.99, respectively. After 24 months of follow-up, patients' astigmatism decreased by 64% (astigmatism at 24 months after the surgery was 0.89±0.58). in other studies conducted in Iran, including Sedghipour et al (12), Taheri et al (13) Peyman et al. (14) and Razmjoo et al. (3) PRK was effective in reducing astigmatism, which is consistent with the results of the present study.

In the present study, the effectiveness of PRK in reducing severe refractive and keratometric astigmatism was greater than the mild and moderate types. Also the effectiveness of PRK in reducing moderate refractive and keratometric astigmatism was higher than mild type.

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In a study by Sedghipour et al. (12), the effectiveness of PRK was examined in two groups of wavefront-guided (50 eyes from 25 patients with astigmatism) and cross cylinder (48 eyes from 24 patients with astigmatism). After 6 months of follow-up, it was found that the effect of PRK correction on severe and moderate astigmatism is greater than the mild type, and the results were consistent with the results of the present study. Miraftab et al. (15) examined 100 patients with astigmatism and followed the patients for 2 years. They concluded that at the first year after treatment, the severity of astigmatism had no effect on treatment. However, at the second year after treatment, the amount of residual astigmatism in severe type was higher than moderate (P = 0.01) and mild (P = 0.004) types (16). The results of mentioned study were inconsistent with the results of the present study. In other studies, there was no difference between mild, moderate, and severe astigmatism correction, indicating the effectiveness of PRK in all three cases of astigmatism.

In the present study, the stability of refraction in refractive and keratometric astigmatisms occurred at 3 months and 1 month after the surgery, respectively. Ashwag et al. (16) examined 159 eyes from 80 patients with astigmatism who underwent PRK in 2017. In this study, the stability of the refraction occurred 1 year after the surgery, which was inconsistent with the results of our study. Weldon et al. (11) conducted a study on 93 eyes from 56 patients of astigmatism with myopia who were treated with PRK after 2 years of follow-up. In this study, the stability of refraction was established at 1 month after the surgery. The results was consistent with the results of our study. In a study by Aleksander et al (17), conducted on 87 eyes with myopia and astigmatism which were treated with PRK, it was found that after 12 months of follow-up, refraction stability was established at 3 months after the surgery. The results was consistent with the results of our study. It seems that differences in postoperative refraction stability can be due to difference in the type of laser device used and probable difference in tissue repair.

In the present study, PRK was effective in correcting all three types of refractive stigmatism (WTR, ATR, and oblique) ($P < 0.05$). However, in keratometric astigmatism, PRK was effective only in WTR group ($P < 0.001$). Also, in ATR and oblique groups, despite the marked effect of PRK on the reduction of astigmatism, the effect was not significant (P=0.07). The difference in the effect of PRK on the correction of three types of astigmatism was not significant either in the refractive stigmatism (P = 0.29) or in the keratometric astigmatism (P = 0.08). also, in keratometric astigmatism, difference in mean of astigmatism correction in with the rule group had a near marked significant relationship with oblique astigmatism (P=0.06). It can be said that type of astigmatism was not an obstacle to the effectiveness of PRK in correcting astigmatism. Also, in all three types of stigmatism, we can observe the effect of PRK. However, since the frequency distribution of all 3 types of astigmatism in the present study was not identical, the results are not reliable and may not be generalized.

In this study, the effect of PRK on the correction of refractive (P = 0.75) and keratometric (P = 0.23) astigmatism was identical in all age groups. Other studies have not suggested the effect of age on astigmatism correction.

In the present study, the opacity occurred in 7 eyes (15.21%) with mean refractive astigmatism of -4.64 six months after the surgery and 71.42% and 28.57% of eyes with opacity had severe and moderate astigmatism, respectively. The mean severity of opacity in these patients was 1.07 degrees with a range of 0.5-2 degrees. In the study of Okkes Baz et al (4), opacity with a severity of ≤ 2 was observed in all patients and all visits. There was also no relationship between the opacity and amount of refractive error,, which was inconsistent with the results of the present study. Okkes Baz et al (4) suggested that the laser decreases the keratocytes apoptosis thus leading to

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opacity. In a study by Aleksander et al. (17), opacity occurred 3 months after the surgery. The severity of opacity ranged from 0.5 to 1.5, and 3% of them was more severe than trace (these eyes had a SE ranging from -6.12 to -10. The results of this study were consistent with our study. In a study by Weldon et al., 13.5% of patients had opacity(11), ranging from trace to mild. The opacity occurred at 12 months after the surgery. In this study, the mean severity of opacity decreased by 47% from 12 months to 24 months after the surgery. According to previous studies, with an increase in refractive error correction, the prevalence of corneal opacity increases. The result of these studies were consistent with the present study. (18)

In the present study, PRK had a good effect on visual acuity. Also, there was a significant relationship between preoperative UCVA and BCVA with postoperative UCVA and BCVA (P <0.001). In this study, the patients with ≥20/40 UCVA were 21.74% (10 eyes) and 100% (46 eyes) before and 12 months after the surgery, respectively. 36 eyes (78.26%) and zero eye had pre and post-op (12 months) UCVA of <20/40 respectively. Also, patients with ≥20/40 BCVA were 93.47% (43 eyes) and 100% (46 eyes) before and 12 months after the surgery, respectively. patients with ≤20/40 UCVA were 6.53% (3 eyes) and (zero eye) 0.00% postoperative (12 months), respectively.

In the present study, none of the patients at the 12-month postoperative period had a decrease of snellen line with glasses compared to preoperative period. In other studies, visual acuity improved after the surgery and it was consistent with the results of the present study. In a study by Okkes et al. (4), despite PRK improved visual acuity, in the patients treated with PRK, PRK and mitomycin, and T_PRK, 11.11%, 20% and 6.1% had a decreased BCVA of >2 lines of Snellen chart. Decreased BCVA in the mitomycin-treated PRK group was higher than other groups, perhaps because of the high degree of opacity in this group. In a study by Weldone et al. (11), 1 eye lost 1 line of vision with glasses after the surgery, and in 25% of cases, the mean SE after the surgery was more than 1 diopter, which led to undercorrection and decreased visual acuity. In a study by Sedghipour et al (12), in the cross cylinder method, 1 eye lost 1 line of BCVA. The wave front guided method performed better than the cross cylinder method in correcting UCVA. In the present study, fortunately, there was no decrease in vision either without or with glasses compared to before the surgery.

In the present study, the mean reduction of preoperative sphere after surgery was not significant (P = 0.11) because we limited the sephere betwenn -1 and +1. Thus, the reason for the lower number of patients in this study compared to other studies is limiting the sphere betwenn -1 and +1 to further evaluation of the astigmatism.

In the present study, the spherical equivalent at 12 months after the surgery had a significant decrease compared to preoperative SE (P <0.001), which was consistent with the result of other studies, including Fredrick et al. (19), Weldone et al (11), Aleksander et al (17), Ikhyun jun et al (10, 20) and Sadghipour et al (12).

In the present study, the mean of preoperative refractive astigmatism was -3.01±1.42 and 0.40±0.37 before and 12 months after the surgery. At 12 months after the surgery, 12 (26.8%), 22 (47.8%), 5 (10.9%) 6 (13%), and 1 eye had an astigmatism of 0, ≤0.50, 0.75, 1.00, and >1.00D respectively.

In our study, the mean angle of error (ME) was -0.13±0.46. Also, the angle of error in 2 (4.35%), 14 (30.43%), and 30 (65.22%) eyes was zero, positive (overcorrection), and negative (undercorrection), respectively. 28 (60.87%) and 40 (86.95%) eyes had -0.25 ≤ME≤ 0.25 and 0.50 ≤ME≤ 0.50, respectively. In a study by Weldon et

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al. (11), the mean ME was -0.62±1.42, and in the study of Ikhyun jun et al. (10) was -0.11±0.31, which showed an undercorrection. The results of these studies were consistent with the results of the present study.

In a study by Ikhyun jun et al. (20) conducted on 196 eyes with high astigmatism in two groups of T_PRK after 6 months of follow-up, it was found that the mean ME was 0.06±0.28 and 0.05±0.31, indicating the overcorrection. In the study of Sedghipour et al (12), the ME of cross cylinder and wave front guided groups was 0.20±0.99 and -0.29±0.53, respectively. Due to near zero ME and AE in most of the above studies, the presented undercorrection and overcorrections are negligible.

In this study, the mean SIA was lower than the mean of TIA, indicating an undercorrection. In 14 eyes (30.43%), the mean SIA was higher than the TIA. In a study by Weldon et al, only 5 eyes (8.5%) had a mean SIA higher than the TIA, which was consistent with the present study. In a study by Ikhyun Jun et al. (10) and SedghiPour et al (12), the mean SIA was lower than TIA, indicating the undercorrection of astigmatism. These studies were consistent with the results of the present study. In a study by Ikhyun jun et al. (20), the mean SIA was higher than TIA, indicating an overcorrection of astigmatism.

In the current study, the mean angle of error (AE) was -1.84±3.22 (range: -9.71-6.99) and angle of error in 28 eyes (60.86%) was negative, indicating a clockwise rotation, in 11 eyes (23.91%) were equal to zero, and in 7 eyes (15.21%) were positive, indicating a counterclockwise rotation. Also, 100% of the eyes (46 eyes) had an angle of error between +10 and -10 degrees. In the study of Weldon et al. (11), the mean angle of error was 0.31±21.8; also 72.2% and 88.1%, of the eyes had an angle of error between +10 and -10 and between -20 and +20 degrees, respectively and the range of angle of error was between -78 and 80 degrees. 30.5% of the eyes had a positive angle of error, though the negative degree was prefered.

In the study of Sedghipour et al (12), the degree of angle of error was -0.71±1.08 and -1.26 ± 4.44 in the wavefront guided and cross cylinder groups. In a study by Ikhyun Jun et al. (10), the mean angle of error in T_PRK was -0.86±2.44 (-12.00 to 5.00). In another study by Ikhyun Jun et al. (20), the mean AE was -0.44±3.32 (-8 to 14 degees). In the study of Aleksander et al. (17), the mean AE was 1.3±12.5 (-40 to 42.5).

In the present study, the mean index of success (IOS) was 0.14±0.08. In Weldon et al.'s (11) study, the IOS was 0.39. also, in Ikhyun jun et al.'s (20) study was 0.11±0.99. In another study by Ikhyun jun et al. (10) and also by Sedghipour et al., in wave front guided and cross cylinder group was 0.14±0.11, 0.12 ±0.09., and 0.39±0.28, repectively. In all of the above studies, there was near zero IOS, indicating the success of PRK surgery in reducing patients astigmatism.

V. CONCLUSİON

PRK surgery with Allegretto Wave Light Eye-Q 400 has been a successful surgery in correcting and reducing all types of astigmatism (mild, moderate and severe) and its effect on severe astigmatism (4.25-6.00 D) is higher than mild and moderate astigmatism. .

Limitations

Given that sphere in this study was considered between +1 and -1, it was a good examination in terms of astigmatism. Among the limitations of the present study is the low number of patients of ATR and oblique astigmatism that due to the higher prevalence of WTR astigmatism than other types of astigmatism in society, this

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makes it impossible to statically compare the effect of PRK on the three types of astigmatism (WTR, ATR, and oblique)

Recommendations

It is suggested that in future studies a relatively equal number of all three types of astigmatism will be investigated. In that case, In that case it is possible to provide a more accurate statistical comparison between the types of astigmatism and the effect of laser on them.

Disclosure

The authors report no conflicts of interest in this work.

REFERENCES

1. Ojaghi H, Moghaddar R, Ahari SS, Bahadoram M, Amani F. Amblyopia prevention screening program in Northwest Iran (Ardabil). International journal of preventive medicine. 2016;7.
2. Najafi A, Ojaghi H, Zahirian moghadam T, Sharghi A. prevalence of types of corneal astigmatism before cataract surgery .International Journal of Pharmaceutical Research. 2020;12(2):311-03.
3. Razmjoo H, safarian a, akbari M. Evaluation of photorefractive keratectomy results using solitary technique for correction of refractive errors in patients with astigmatism more than two diopters. Isfahan Medical School. 2014;31(238):6.
4. Baz O, Kara N, Bozkurt E, Ozgurhan EB, Agca A, Yuksel K, et al. Photorefractive keratectomy in the correction of astigmatism using Schwind Amaris 750s laser. International journal of ophthalmology. 2013;6(3):356.
5. Serrao S, Lombardo G, Ducoli P, Lombardo M. Long-term corneal wavefront aberration variations after photorefractive keratectomy for myopia and myopic astigmatism. Journal of Cataract & Refractive Surgery. 2011;37(9):1655-66.
6. Hashemian MN, Ojaghi H, Mohammadpour M, Jabbarvand M, Rahimi F, Abtahi M-A, et al. Femtosecond laser arcuate keratotomy for the correction of postkeratoplasty high astigmatism in keratoconus. Journal of research in medical sciences: the official journal of Isfahan University of Medical Sciences. 2017;22.
7. Fantes FE, Hanna KD, Waring GO, Pouliquen Y, Thompson KP, Savoldelli M. Wound healing after excimer laser keratomileusis (photorefractive keratectomy) in monkeys. Archives of Ophthalmology. 1990;108(5):665-75.
8. Alpins NA, Goggin M. Practical astigmatism analysis for refractive outcomes in cataract and refractive surgery. Survey of ophthalmology. 2004;49(1):109-22.
9. Alpins NA. A new method of analyzing vectors for changes in astigmatism. Journal of Cataract & Refractive Surgery. 1993;19(4):524-33.
10. Jun I, Kang DSY, Reinstein DZ, Arba-Mosquera S, Archer TJ, Seo KY, et al. Clinical outcomes of SMILE with a triple centration technique and corneal wavefront-guided transepithelial PRK in high astigmatism. Journal of Refractive Surgery. 2018;34(3):156-63.
11. Haw WW, Manche EE. Photorefractive keratectomy for compound myopic astigmatism. American journal of ophthalmology. 2000;130(1):12-9.
12. Sedghipour M, Sorkhabi R, Mostafaei A. Wavefront-guided versus cross-cylinder photorefractive keratectomy in moderate-to-high astigmatism: a cohort of two consecutive clinical trials. Clinical ophthalmology (Auckland, NZ). 2012;6:199.
13. TAHERI H, RAMIN S. Successful Surgical Correction of Astigmatism using Customized Ablation Photorefractive Keratectomy. Medical hypothesis, discovery and innovation in ophthalmology. 2016;5(2):53.
14. Peyman A, Dastborhan Z, Peyman M. Astigmatic treatment with photorefractive keratectomy: Investigations of non-keratometric ocular astigmatism. Journal of current ophthalmology. 2017;29(2):98-102.
15. Miraftabb M HH, Asgari S. Towe-year result of femtosecond assisted LASIK versus PRK for different severty of Astigmatism. Journal of Current Ophthalmology. Journal of Current Ophthalmology. 2018;30(30):48-53.
16. Almosa AA, Fawzy SM. Effect of mitomycin C on myopic versus astigmatic photorefractive keratectomy. Journal of ophthalmology. 2017;5.
17. Stojanovic A, Nitter TA. 200 Hz flying-spot technology of the LaserSight LSX excimer laser in the treatment of myopic astigmatism: six and 12 month outcomes of laser in situ keratomileusis and photorefractive keratectomy. Journal of Cataract & Refractive Surgery. 2001;27(8):1263-77.

DOI: 10.37200/IJPR/V24I5/PR2020783
Received: 23 Apr 2020 | Revised: 30 Apr 2020 | Accepted: 24 May 2020

18. Liesegang TJ, Skuta GL, Cantor LB. Basic and clinical science course. American Academy of Ophthalmology. 2005:2005-6.
19. Fraunfelder FW, Wilson SE. Laser in situ keratomileusis versus photorefractive keratectomy in the correction of myopic astigmatism. Cornea. 2001;20(4):385-7.
20. Jun I, Kang DSY, Arba-Mosquera S, Choi JY, Lee HK, Kim EK, et al. Comparison between Wavefront-optimized and corneal Wavefront-guided Transepithelial photorefractive keratectomy in moderate to high astigmatism. BMC ophthalmology. 2018;18(1):154.

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