

Photorefractive keratectomy in the correction of astigmatism using Schwind Amaris 750s laser

Okkes Baz¹, Necip Kara², Ercument Bozkurt¹, Engin Bilge Ozgurhan¹, Alper Agca¹, Kemal Yuksel¹, Yavuz Ozpinar¹, Ahmet Demirok¹

¹Department of Ophthalmology, Beyoglu Eye Research and Education Hospital, Istanbul, Turkey

²Department of Ophthalmology, Kanuni Sultan Suleyman Education and Research Hospital, Istanbul, Turkey

Correspondence to: Necip Kara, Kartaltepe Mh. Akin Sk. Akin Apt. No:8/14 Bakirkoy/Istanbul, Turkey. dr.necipkara@gmail.com

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Abstract

• **AIM:** To evaluate the results of three photorefractive keratectomy (PRK) procedures in the treatment of astigmatism.

• **METHODS:** In this retrospective comparative case series, 89 eyes of 50 patients who underwent PRK treatment for astigmatism were enrolled. The patients were divided into 3 groups based on the PRK procedure: Group 1: PRK without mitomycin-C (MMC) application, Group 2: PRK with MMC application, and Group 3: Trans-Photorefractive Keratectomy (T-PRK). The efficacy, safety, predictability, and complications of treatment were assessed at 1, 3 and 6 months after the treatment.

• **RESULTS:** At postoperative 6 months, the percentage of postoperative uncorrected visual acuity (UCVA) of 20/20 or better was 55.6% (20 eyes) in group 1, 75% (15 eyes) in group 2, and 75.8% (25 eyes) in group 3 ($P=0.144$). The percentage of postoperative best corrected visual acuity (BCVA) of unchanged or gained ≥ 1 lines was 80.6% (29 eyes) in group 1, 70% (14 eyes) in group 2, and 90.9% (30 eyes) in group 3 ($P=0.151$). The percentage of postoperative BCVA of lost ≥ 2 lines was 11.1% (4 eyes) in group 1, 20% (4 eyes) in group 2, and 6.1% (2 eyes) in group 3. The mean manifest refractive spherical equivalent (MRSE) and mean cylindrical refraction were not significantly different among the each groups ($P>0.05$). At postoperative 6 months, the percentage of MRSE of within ± 0.50 D was 100% (36 eyes) in Group 1, 100% (20 eyes) in Group 2, and 93.9% (31 eyes) in Group 3. At the each follow-up period, there was no significant difference in number of eyes with haze and mean haze score ($P>0.05$).

• **CONCLUSION:** The study showed that PRK without MMC, PRK with MMC and T-PRK appears to have similar

effectiveness, safety and predictability in the treatment of astigmatism. The incidence of haze was also similar between the three groups.

• **KEYWORDS:** photorefractive keratectomy; mitomycin-C; trans-photorefractive keratectomy; astigmatism

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INTRODUCTION

Since the approval of the excimer laser for use in corneal refractive surgery, significant developments for treatment refractive diseases including myopia, hyperopia, and astigmatism have been achieved^[1]. Even though laser *in situ* keratomileusis (LASIK) has become the procedure of choice for patients and refractive surgeons because of less pain and rapid visual rehabilitation, photorefractive keratectomy (PRK) still remains an useful surgical option in certain cases, such as eyes with thin corneas or large pupils and excessively flat or steep cornea^[2-8].

Although PRK is generally considered to have excellent safety profile, the complications in the post-operative period include pain, irregular epithelial healing, and corneal haze^[9]. Many techniques such as laser-assisted subepithelial keratectomy (alcohol assisted) or epithelial laser *in situ* keratomileusis (epikeratome assisted) were developed to decrease these complications. Previous studies indicated that these techniques were not showed superiority to conventional PRK^[10-13]. In the late 1990s, a laser-assisted method for epithelial debridement, termed transepithelial PRK (T-PRK), was introduced as an alternative option to conventional PRK^[14].

Many surgical procedures have been advocated for the correction of astigmatism. Photorefractive keratectomy has been reported to be an efficient and relatively safe procedure for the correction of astigmatism. The purpose of this study was to evaluate safety, efficacy, and predictability in the treatment of astigmatism with three PRK procedures using the Schwind Amaris 750s Laser.

SUBJECTS AND METHODS

Subjects A retrospective study was performed in 89 consecutive eyes of 50 patients who underwent PRK treatment for astigmatism in the Beyoglu Eye Research and Education Hospital. The study adhered to the tenets of the Declaration of Helsinki and was approved by the Local Ethics Committee. All patients were informed about the details and risks of treatment procedures, and a written informed consent was discussed and obtained.

Patients with astigmatism were considered eligible for the study if they were at least 21 years old and free of ocular disease, and they had no previous ocular surgery with at least 1 year of refractive stability. Patients wearing contact lenses were asked to discontinue their use for at least a month before surgery.

Exclusion criteria were corneal pachymetry below 450 μ m, ophthalmic disease with visual impairment, eyes with previous surgery, and autoimmune diseases. Patients who had a calculated postoperative residual corneal stromal thickness 250 μ m after ablation, had any prior ocular surgery, or had abnormal corneal topography were excluded from the study.

The patients were divided into 3 groups based on surgical procedure as stated below: Group 1: PRK without MMC application; Group 2: PRK with MMC application; Group 3: T-PRK.

Methods

Clinical examination Preoperative and postoperative data were collected retrospectively from the patient records. All patients were given a complete ophthalmic examination including visual acuity, manifest refractions, slit-lamp biomicroscopy, applanation tonometry, and dilated fundus examinations. The preoperative assessment also included keratometry, corneal topography (Orbscan IIz, Bausch & Lomb), and ultrasonic pachymetry. The uncorrected visual acuity (UCVA) and best corrected visual acuity (BCVA) were recorded using logMAR and Snellen charts.

Surgical procedure All surgeries were performed using the Schwind Amaris 750s (Schwind Eye-tech-solutions GmbH, Germany). This laser works with a 750Hz flying/scanning spot, a video eye-tracker with 1050Hz repetition rate, and a 0.54mm Gaussian-like beam profile.

Preoperatively, each eye received one drop of proparacaine (Alcaine[®]). In group 1 and 2, the corneal epithelium was removed using the Amoils brush (Innovative Excimer Solutions Inc, Toronto, Canada). For group 2 patients, a MMC (0.02mg/cc) was applied for 1 minute, applied with a weck cell sponge and thoroughly irrigated with balanced salt solution. In Group 3, the epithelium and stroma were ablated in a single step using the transepithelial PRK nomogram of the Amaris laser. The laser treatment was delivered using the ablation profile of the laser's software.

Postoperative care and follow-up Patients received a bandage contact lens, which was removed after 4 days. Postoperatively, all patients were instructed to instill topical dexamethasone, moxifloxacin, and artificial tears for 1 week. Follow-up examinations were done at 1, 3, and 6 months. Main outcomes measures were efficacy, safety, and predictability of treatment. Postoperative complications and presence of haze were also recorded at each follow up. Postoperative corneal haze was graded according to a scale of 0 to 4^[15].

Statistical Analysis All statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) version 16. The normality of the data was confirmed using the Shapiro-Wilk Test ($P>0.05$). An ANOVA test was used to compare more than two means. When statistical significance was found, the differences between each postoperative period were further compared using the Tukey test for pairwise comparisons. The Chi-square test was used to determine the differences of percentage of patients between the groups. Differences with a value of $P<0.05$ were considered statistically significant.

RESULTS

Demographic Profile Eighty-nine eyes of 50 patients who underwent PRK treatment for astigmatism were enrolled in this retrospective study. The demographic and clinical characteristics of the groups of subjects are shown in Table 1. No statistically significant differences were observed among the groups in terms of age and gender distribution, baseline central corneal thickness and keratometry values ($P>0.05$).

Efficacy Table 2 shows the results of UCVA for three groups. There was no significant differences in UCVA among the three groups at each postoperative follow up ($P>0.05$). Figure 1 shows the distribution of UCVA at 6 months for each PRK procedures. The percentage of postoperative UCVA of 20/20 or better was 55.6% (20 eyes) in group 1, 75% (15 eyes) in group 2, and 75.8% (25 eyes) in group 3. The percentage of postoperative UCVA of 20/20 or better was significantly different between the groups (pearson Chi-square test, $P=0.144$).

Safety Table 3 shows the results of BCVA for three groups. There was no significant differences in UCVA among the three groups at each postoperative visits ($P>0.05$). Figure 2 shows the distribution of BCVA at 6 months for each groups. The percentage of postoperative BCVA of unchanged or gained ≥ 1 lines was 80.6% (29 eyes) in group 1, 70% (14 eyes) in group 2, and 90.9% (30 eyes) in group 3. The rate of postoperative BCVA of unchanged or gained ≥ 1 lines was not significantly different between the groups ($P=0.151$). The percentage of postoperative BCVA of lost ≥ 2 lines was 11.1% (4 eyes) in group 1, 20% (4 eyes) in group 2, and 6.1% (2 eyes) in group 3. There was no significant differences in the percentage of postoperative BCVA of lost

Table 1 Demographics and clinical characteristics of patients $\bar{x} \pm s$ (range)

Parameters	PRK	PRK+MMC	T-PRK	<i>P</i>
Number of eyes/patients	36/18	20/13	33/19	
Female/Male	10/8	8/5	11/8	¹ 0.946
Age (a)	30.9±7.9(18-49)	29.5±5.6(18-36)	31.4±8.4(20-51)	² 0.658
Baseline keratometry (D)				
K1	42.6±1.7(39.3-46.5)	43.1±1.6(40.3-45.9)	42.6±1.5(40-46)	² 0.558
K2	44.6±1.4(42.0-47.7)	44.9±1.7(42-48)	44.1±1.5(41.7-47.0)	² 0.186
Baseline CCT (µm)	527±35(452-595)	521±37(451-613)	522±34(473-606)	² 0.792

PRK: Photorefractive keratectomy; MMC: Mitomycin-C; T-PRK: Trans-photorefractive keratectomy; SD: Standard deviation; D: Diopter; CCT: Central corneal thickness; ¹Anova-test (a post hoc test); ²Pearson Chi-square test.

Table 2 Preoperative and postoperative visual acuities in logMAR units [$\bar{x} \pm s$ (range)]

Follow-up	PRK	PRK+MMC	T-PRK	¹ <i>P</i>
UCVA				
Preop	0.69±0.33(0.15~1.30)	1.01±0.25(0.30~1.30)	0.72±0.36(0.30~1.30)	0.002
Postop 1 month	0.06±0.11(-0.08~0.52)	0.05±0.12(-0.08~0.52)	0.05±0.36(-0.08~0.52)	0.894
Postop 3 months	0.02±0.06(-0.08~0.22)	0.04±0.12(0.0~0.52)	0.05±0.10(0.0~0.52)	0.344
Postop 6 months	0.03±0.07(-0.08~0.30)	0.01±0.10(-0.08~0.30)	0.02±0.07(-0.08~0.30)	0.837
BCVA				
Preop	0.04±0.08(-0.08~0.30)	0.02±0.13(-0.08~0.52)	0.02±0.06(-0.08~0.30)	0.591
Postop 1 month	0.04±0.07(-0.08~0.30)	0.04±0.12(-0.08~0.52)	0.03±0.06(-0.08~0.22)	0.970
Postop 3 months	0.01±0.06(-0.08~0.15)	0.04±0.12(0.0~0.52)	0.01±0.07(-0.08~0.30)	0.312
Postop 6 months	0.03±0.07(-0.08~0.30)	0.01±0.10(-0.08~0.30)	0.01±0.06(-0.08~0.30)	0.991

PRK: Photorefractive Keratectomy, MMC: Mitomycin-C, T-PRK: Trans-Photorefractive Keratectomy, UCVA: Uncorrected visual acuity, BCVA: Best corrected visual acuity; ¹Anova-test (a post hoc test).

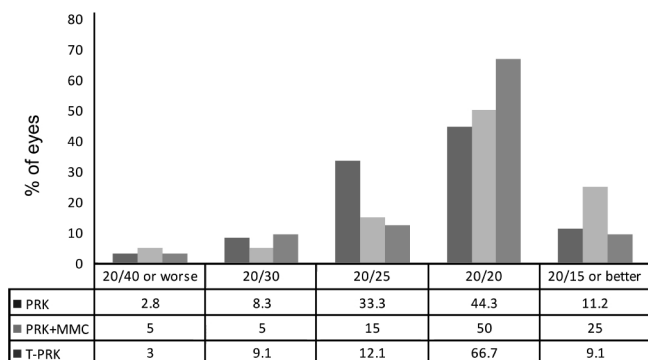


Figure 1 Distribution of UCVA at the postoperative 6 months

UCVA: Uncorrected visual acuity; PRK: Photorefractive Keratectomy; MMC: Mitomycin-C; T-PRK: Trans-photorefractive keratectomy.

≥2 lines among the three groups at each postoperative visits (*P*=0.297).

Predictability Table 3 shows the refraction at 1, 3 and 6 months after surgery for each group. At postoperative 6 months, mean manifest spherical equivalent refraction (MRSE) and mean cylindrical refraction were not significantly different among the each groups (*P*>0.05). Figure 3A shows the predictability of MRSE refraction at the postoperative 6 months. At postoperative 6 months, the percentage of MRSE of within ±0.50D was 100% (36 eyes) in Group 1, 100% (20 eyes) in Group 2, and 93.9% (31 eyes) in Group 3. The rate of MRSE of within ±0.50D was not

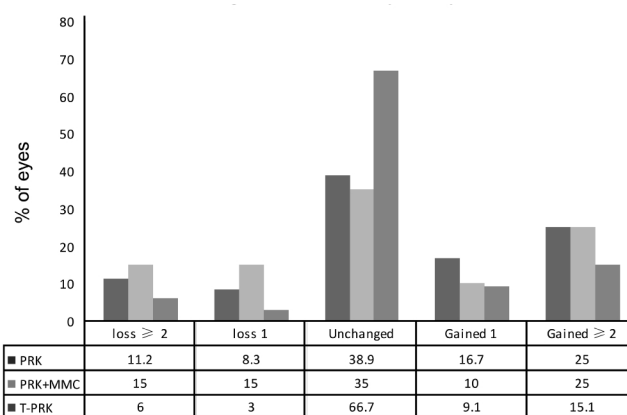


Figure 2 Distribution of changes in lines of BCVA at the postoperative 6 months

BCVA: Best-corrected visual acuity; PRK: Photorefractive keratectomy; MMC: Mitomycin C; T-PRK: Trans-photorefractive keratectomy.

significantly different between the groups (*P*=0.176). Figure 3B shows the predictability of cylindrical refraction at the postoperative 6 months. The percentage of cylindrical refraction of within ±0.50D was 97.2% (35 eyes) in Group 1, 100% (20 eyes) in Group 2, and 100% (33 eyes) in Group 3. There was no statistically significant difference in the percentage of eyes within ±0.50D of the cylindrical refraction between the groups (*P*=0.475). Mean reduction in astigmatism was 96.8% (1.93D to 0.06D) in group 1, 100% (1.61D to 0.0D) in group 2, and 99.4% (1.70D to 0.01D) in group 3.

Table 3 Preoperative and postoperative spherical equivalent refraction and cylindrical refraction $\bar{x} \pm s$ (range)

Parameters	PRK	PRK+MMC	T-PRK	¹ P
Spherical equivalent (D)				
Preop.	-1.69±0.90(-4.0~-0.38)	-3.0±1.2(-5.0~-1.50)	-1.76±1.46(-5.50~0.50)	<0.001
Postop. 1 month	-0.08±0.30(-0.75~1.00)	-0.11±0.36(-1.50~0.0)	-0.05±0.21(-1.0~0.25)	0.792
Postop. 3 months	-0.00±0.16(-0.50~0.75)	0.0±0.0(0~0)	-0.07±0.35(-1.25~0.75)	0.436
Postop. 6 months	-0.01±0.12(-0.38~0.50)	0.0±0.0(0~0)	-0.06±0.25(-1.25~0.00)	0.361
Cylinder (D)				
Preop.	-1.93±0.98(-4.0~-0.50)	-1.61±1.3(-5.0~-0.50)	-1.70±0.91(-5.0~-0.50)	0.476
Postop. 1 month	-0.11±0.31(-1.50~0.00)	-0.03±0.16(-0.75~0.0)	-0.00±0.04(-0.25~0.0)	0.133
Postop. 3 months	-0.02±0.12(-0.75~0.00)	0.0±0.0(0~0)	-0.12±0.35(-1.50~0.0)	0.076
Postop. 6 months	-0.06±0.18(-0.75~0.00)	0.0±0.0(0~0)	-0.01±0.08(-0.50~0.00)	0.152

PRK: Photorefractive keratectomy; MMC: Mitomycin C; T-PRK: Trans-photorefractive keratectomy; SD: Standard deviation; D: Diopter; ¹Anova-test (a post hoc test).

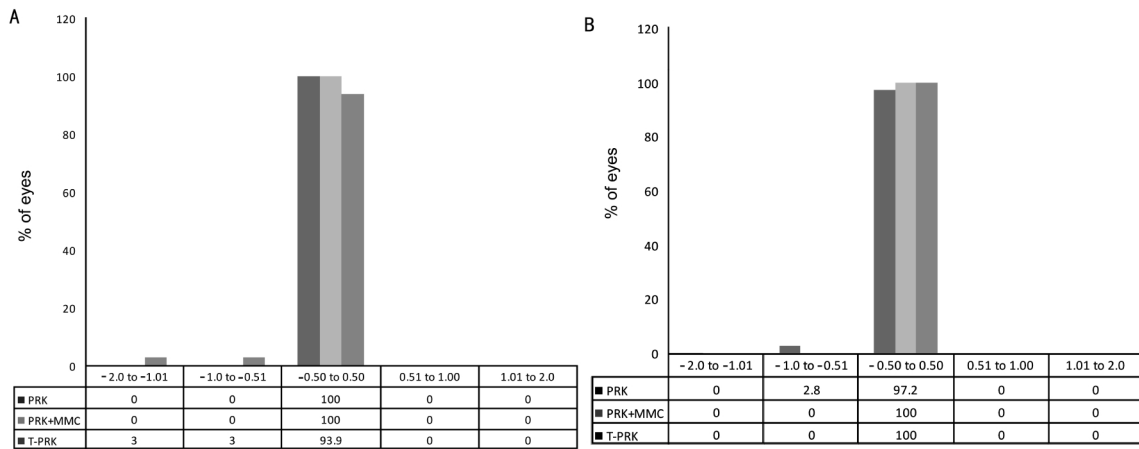


Figure 3 Predictability of SE (A) and cylindrical (B) refraction at the postoperative 6 months SE: Spherical equivalent; PRK: Photorefractive keratectomy; MMC: Mitomycin-C; T-PRK: Trans-photorefractive keratectomy.

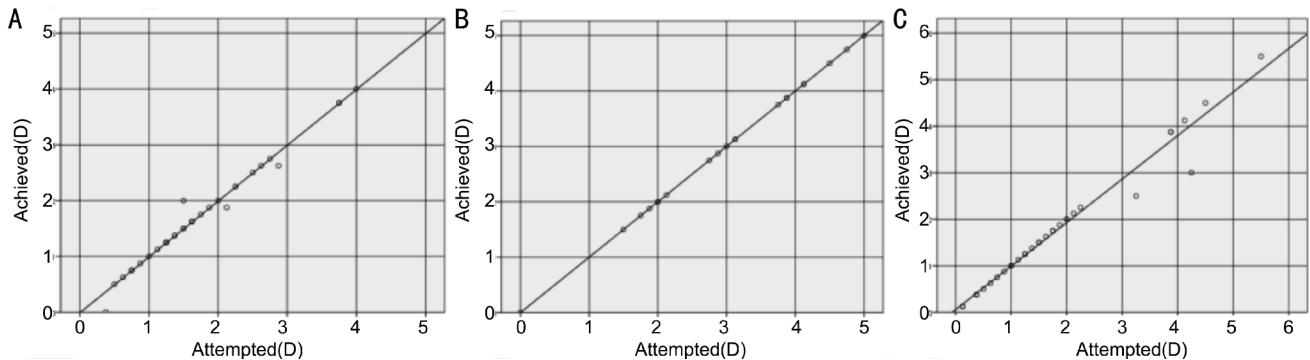


Figure 4 Scatterplot of the attempted versus achieved spherical equivalent refraction A: After PRK without MMC application for astigmatism; B: After PRK with MMC application for astigmatism; C: After T-PRK without MMC application for astigmatism PRK: Photorefractive Keratectomy, MMC: Mitomycin-C.

Scatterplot of the attempted versus achieved MRSE after each PRK procedure for astigmatism are shown in Figure 4A-C.

Haze Grading and Complications Postoperative haze was assessed at each time point. Subepithelial haze was grade 2 or below in all patients at all follow-up visits. At the each follow-up period, there was no significant difference in number of eyes with haze and mean haze score ($P>0.05$). There were no other remarkable complications throughout the study period (Table 4).

DISCUSSION

Even though LASIK has been adopted worldwide as a safe and effective means of correcting myopia, hyperopia, and astigmatism, PRK remains a useful tool in the refractive surgeons [4,16]. PRK treatment is applied by different methods for the correction of astigmatism. Each method has certain advantages and drawbacks[17].

This study evaluated the safety, predictability, and efficacy of three different PRK procedures in the treatment of astigmatism using Schwind Amaris 750S laser. Results after

Table 4 Rate of haze rate and haze score after PRK treatment

Follow-up	PRK	PRK+MMC	T-PRK	P
Postop. 1 month				
n (%)	15 (41.7)	6 (30)	6 (18.2)	¹ 0.106
Mean Haze score	0.78±0.57	0.83±0.68	0.81±0.65	² 0.982
Postop. 3 months				
n (%)	15 (41.7)	6 (30)	9 (27.2)	¹ 0.495
Mean Haze score	0.70±0.56	0.85±0.62	0.70±0.53	² 0.817
Postop. 6 months				
n (%)	9 (25)	4 (20)	6 (18.2)	¹ 0.768
Mean haze score	0.59±0.66	0.78±0.63	0.50±0.54	² 0.640

PRK: Photorefractive keratectomy; MMC: Mitomycin C; T-PRK: Trans-photorefractive keratectomy; SD: Standard deviation; ¹Pearson Chi-square test; ²Anova-test (a post hoc test).

a follow-up of 6 months showed an improvement of the mean UCVA in all treated eyes, without a statistically significant difference between the three groups. The percentage of postoperative UCVA of 20/20 or better was 55.6% (20 eyes) in group 1, 75% (15 eyes) in group 2, and 75.8% (25 eyes) in group 3, without a significant differences between the groups ($P=0.144$). Stojanovic *et al*^[18] studied the results of PRK without MMC application using the 200Hz flying-spot technology of the LaserSight LSX excimer laser in the treatment of myopic astigmatism. They found that 78% of the eyes achieved an uncorrected visual acuity of 20/20 or better^[18]. Sedghipour *et al*^[19] compared the efficacy of wavefront-guided and cross-cylinder PRK with MMC application in moderate- to-high astigmatism. After 6 months, 80% of the eyes in the wavefront-guided group had UCVA of 20/20 or better compared to 40% in the cross-cylinder group^[19]. Haw *et al*^[20] evaluated the results of PRK without MMC application for the treatment of primary compound myopic astigmatism. The authors noted that 56% of the eyes had an UCVA of 20/20 or greater^[20]. Fadlallah *et al*^[9] assessed the outcomes of T-PRK using the Amaris laser. They found that T-PRK for mild to moderate myopia with or without astigmatism was safe and easier to perform than conventional PRK, and patients had less pain, less postoperative haze, and a faster healing time. The visual outcomes with the 2 techniques were comparable^[9].

At postoperative 6 months, our study showed an improvement of the mean BCVA in each group, without a statistically significant difference between the three groups. The percentage of postoperative BCVA of unchanged or gained ≥ 1 lines was 80.6% (29 eyes) in group 1, 70% (14 eyes) in group 2, and 90.9% (30 eyes) in group 3, without a statistically significant difference between the three groups ($P=0.151$). Sedghipour *et al*^[19] compared the results of wavefront-guided and cross-cylinder PRK in moderate-to-high astigmatism. They reported that the percentage of eyes with no change in BCVA was 54% and 58.3% in the wavefront and crosscylinder groups, respectively. No treated

eyes in either group lost more than two lines of BCVA^[19]. Roszkowska *et al*^[21] reported that no eye lost lines of BCVA after PRK in compound myopic astigmatism^[21].

Regarding safety, we found that mean MRSE and mean cylindrical refraction were not significantly different among the each group at postoperative 6 months. At postoperative 6 months, the percentage of MRSE of within $\pm 0.50D$ was 100% (36 eyes) in Group 1, 100% (20 eyes) in Group 2, and 93.9% (31 eyes) in Group 3, without a statistically significant difference between the three groups ($P=0.176$). There was no statistically significant difference in the percentage of eyes within $\pm 0.50D$ of the cylindrical refraction among the each groups ($P>0.05$). Mean reduction in astigmatism was 96.8% (1.93D to 0.06D) in group 1, 100% (1.61D to 0.0D) in group 2, and 99.4%(1.70D to 0.01D) in group 3. Stojanovic *et al*^[18] reported that 77% of the eyes were within $\pm 0.50D$ of the desired SE refraction in the treatment of myopic astigmatism with PRK using the 200 Hz flying-spot technology of the LaserSight LSX excimer laser^[18]. A 61% decrease (0.54D) in astigmatism reported by Fraunfelder *et al*^[22] and a 70% (mean, 0.98D) decrease in astigmatism reported by Haw *et al*^[20] after PRK treatment^[20,22]. Haw *et al*^[20] also reported that SE refraction was within $\pm 0.50D$ in 55% of eyes.

Postoperative corneal haze is a concern after PRK. Although several studies have clearly shown that MMC inhibits haze formation, the application of MMC is not without risk^[23-25]. Many studies report the significance of corneal haze after PRK treatment for high myopia^[23,24]. Thomas *et al*^[25] demonstrated a significant association between postoperative corneal haze and preoperative astigmatism treated with conventional PRK without MMC application^[25]. Haw *et al*^[20] found that a corneal haze was apparent in 13.5% of eyes that underwent PRK without MMC for the treatment of primary compound myopic astigmatism^[20]. Fadlallah *et al*^[9] compared the haze formation between the T-PRK and conventional PRK with alcohol epithelial removal for myopic eyes with or without astigmatism. They found that at the postoperative 3-months, grade 1 or more haze persisted in 5 eyes (10%) in the T-PRK group and in 13 eyes (26%) in the conventional PRK group^[9]. These results were associated with longer epithelial remodeling in the T-PRK and the improved ablation profile of the Amaris laser by authors^[9]. Our results do not agree with results of this study. Our study showed no significant difference between the three PRK procedures in rate of haze at each follow up point. The role of laser-assisted epithelial ablation on corneal haze formation is controversial. A study indicates that laser-assisted epithelial ablation induces less keratocyte apoptosis, leading to less haze, some studies found a more intense inflammatory response and a greater increase in backscattering of light associated with increased keratocyte activation and myofibroblast transformation after laser-epithelial ablation^[26,27].

This study was limited by the small number of patients in each group, short follow-up period, and by its retrospective study design. However, the study is important in terms of comparison of efficacy, safety and predictability of three PRK procedures for astigmatism.

In summary, the study suggests that PRK with the Schwind Amaris 750S excimer laser system is safe, effective, and predictable for treating astigmatism. Based on the results of our current study, PRK without MMC, PRK with MMC and T-PRK have similar safety, effectivity, and predictability. The rate of haze and mean haze score were comparable between the groups.

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