Available online at www.sciencedirect.com

ScienceDirect

Journal of Current Ophthalmology 30 (2018) 48–53
http://www.journals.elsevier.com/journal-of-current-ophthalmology

Original research

Two-year results of femtosecond assisted LASIK versus PRK for different severity of astigmatism

Mohammad Miraftab [a], Hassan Hashemi [b], Soheila Asgari [c,*]

[a] Noor Ophthalmology Research Center, Noor Eye Hospital, Tehran, Iran
[b] Noor Research Center for Ophthalmic Epidemiology, Noor Eye Hospital, Tehran, Iran
[c] Department of Epidemiology and Biostatistics, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran

Received 1 January 2017; revised 23 August 2017; accepted 16 September 2017
Available online 9 October 2017

Abstract

Purpose: To compare two-year results of femtosecond laser assisted LASIK (femto-LASIK) and photorefractive keratectomy (PRK) in terms of astigmatism correction in patients with less than 2.0 diopters (D) of spherical error and more than 2.0 D of cylinder error.
Methods: In this retrospective study, data were extracted from 100 patient charts. The two study groups were matched by age, gender, and baseline uncorrected distance visual acuity (UDVA) and refractive astigmatism (RA). Preoperative astigmatism was categorized as mild: 2.00 to <3.00 D, moderate: 3.00 to <4.00 D, and severe: ≥4.00 D.
Results: Mean RA in the femto-LASIK and PRK groups was respectively −3.15 ± 0.94 D (−7.00 to −2.00 D) and −3.29 ± 0.95 D (−6.25 to −2.00 D) at baseline ($P = 0.284$), and −0.61 ± 0.40 D and −0.62 ± 0.60 D one year after surgery ($P = 0.674$), but significantly lower in the femto-LASIK group (−0.61 ± 0.39 vs. −0.83 ± 0.56 D, $P = 0.021$) at 2 years when the rate of residual astigmatism more than 1.0 D was 6.3% in the femto-LASIK and 19.6% in the PRK group ($P = 0.046$). Mean UDVA in the femto-LASIK group (0.02 ± 0.05 logMAR) was better than the PRK group (0.06 ± 0.10 logMAR) ($P = 0.025$). Mean corrected distance visual acuity (CDVA) was not significantly different between groups (0.01 ± 0.03 vs. 0.01 ± 0.04 logMAR, $P = 0.714$). Both groups had 1–4 Snellen lines CDVA improvement. The three subgroups of baseline astigmatism did not differ significantly in terms of residual astigmatism (all $P > 0.05$). However, in subgroups with ≥4.00 D cylinder, there was less astigmatic regression at 1 year in the femto-LASIK group (0.28 ± 0.43 D) than the PRK group (0.54 ± 0.68 D) ($P = 0.007$).
Conclusions: Our results pointed to better two-year results with femto-LASIK in the treatment of different degrees of astigmatism. UDVA improvement was superior with femto-LASIK, but the two methods did not significantly differ in terms of CDVA improvement.

Keywords: Femtosecond assisted LASIK; PRK-MMC; High astigmatism

Introduction

The prevalence of refractive astigmatism (RA) defined as a cylinder refractive error more than 1.0 diopter (D) is between 14.9% and 34.4% globally[1,2] and 11.1%[3] in Iran. Population-based studies in Iran have also shown considerable frequency distributions of corneal astigmatism greater than 1.0 D.[4] Moderate to high astigmatism has always been a challenge in refractive surgery for various reasons, including difficulties in determining the amount and axis of astigmatism, proper centration of the surgical ablation profile, incorporating astigmatism in surgical nomograms,[5–7] and more chance of postoperative haze formation after photorefractive keratectomy (PRK) compared to laser-assisted in situ keratomileusis (LASIK), which may lead to regression of astigmatism in the long-term.

Declaration of interest: All authors have no financial or proprietary interest in a product, method, or material described herein.

* Corresponding author.
E-mail address: soheilaasgari@gmail.com (S. Asgari).

Peer review under responsibility of the Iranian Society of Ophthalmology.

https://doi.org/10.1016/j.joco.2017.09.003

Several studies have shown the safety and efficacy of different types of refractive surgeries such as LASIK and PRK in the correction of myopia or hyperopia with low to moderate astigmatism.[8–10] Katz et al.[11] have compared the 6-month results of LASIK and PRK for the correction of astigmatism greater than 3.0 D and concluded that both procedures have similar safety (1.01 ± 0.17 vs. 1.10 ± 0.26), efficacy (0.74 ± 0.19 vs. 0.76 ± 0.32), and predictability (67% vs. 65% within ±0.5 D), respectively. In the present study, 2-year results of femtosecond laser assisted LASIK (femto-LASIK) and PRK in the correction of astigmatism greater than 2.0 D are compared in cases with low spherical error. Patients with minimum spherical error were selected for the study to minimize the influence of spherical correction on astigmatic correction and allow for better evaluation of the results with astigmatic correction. In other words, this study aims to answer two main questions: 1) Do two-year results with femto-LASIK and PRK procedures differ in terms of residual astigmatism? and 2) How does the amount of baseline astigmatism affect the difference between the two procedures in terms of residual astigmatism?

Methods

This study was done retrospectively by reviewing the charts of different severity of astigmatism who underwent femto-LASIK or PRK at Noor Eye Hospital. The Noor Review Board approved this study, and anonymous data were extracted from the medical records.

Inclusion criteria for this study were a minimum age of 20 years, spherical component less than 2.00 D, and cylindrical component more than 2.00 D. Patients with a history of ocular pathology or any ocular surgery were excluded from the study. The two groups were matched by age, gender, uncorrected distance visual acuity (UDVA), and RA.

From each chart, we extracted the preoperative and the 1- and 2-year postoperative vision and refraction data. Visual acuity was tested using the Snellen chart, and recorded variables included UDVA and corrected distance visual acuity (CDVA). Refraction was first determined using the Topcon KR-8800 auto-refractometer (Topcon, Tokyo, Japan) and then refined through retinoscopy (HEINE BETA 200, Germany).

In the PRK group, the epithelium of the anesthetized (proparacaine hydrochloride 0.5%) cornea was scraped mechanically without the use of alcohol. Ablation was performed using the WaveLight Allegretto EX500 (Alcon, TX, US) excimer laser with a 6.5 mm ablation zone and 1.25 mm blend zone. Mitomycin C (MMC) was used in all cases. A sponge soaked in MMC 0.02% was applied to the ablated cornea for 10 s per diopter correction. After rinsing with 30 cc sterile solution balanced salt solution, a bandage contact lens (Air Optix, Ciba vision) was placed over the treated cornea. The postoperative prescription included betamethasone 0.1% four times a day, levofloxacin eye drops 5 mg/ml four times daily, and artificial tears (Hypromellose, preservative free) as needed. Daily examinations continued until complete epithelial healing was observed. After reepithelialization, the lens is removed, and levofloxacin was discontinued, but betamethasone and artificial tear drops continued for another two weeks. Afterwards, fluorometholone 0.1% drop was prescribed to be tapered over a course of 3 months.

In the femto-LASIK group, after applying topical anesthesia as in the procedure above, a 110 μm superior hinged flap was created using the Femto LDV (Ziemer Ophthalmic Systems AG, Port, Switzerland) femtosecond laser platform. The flap diameter was 9–10 mm depending on keratometry. After lifting the flap, ablation was performed using the WaveLight Allegretto EX500 (Alcon, TX, USA). The selected optical zone was 6.5 mm with a blend zone of 1.25 mm. The postoperative regimen included chloramphenicol 0.5% every 6 h for 3 days and betamethasone 0.1% every 6 h for 7 days.

Analyses were done in two parts. First, we compared mean residual astigmatism, UDVA, CDVA, frequency of residual astigmatism greater than 0.5 D and 1.0 D, UDVA ≥ 20/25, and CDVA ≥ 20/25 between the two treatment groups. Then we categorized astigmatism into three subgroups of mild: 2.00 to <3.00 D, moderate: 3.00 to <4.00 D, and severe: ≥4.00 D and repeated the comparisons in each subgroup.

Statistical analyses were performed using independent sample *t*-test and the chi-square test. In subgroups, the changes of astigmatism from first to second year were compared between groups by repeated measures analysis of variance. The level of significance was set at 0.05.

Results

One hundred patients were enrolled in each group. The preoperative spherical and cylindrical errors were −0.25 ± 1.07 (−2.00 to 2.00) D and −3.22 ± 0.94 (−7.00 to −2.00) D. The mean age of the patients in the two groups of femto-LASIK and PRK was 27.52 ± 6.23 and 26.19 ± 5.89 years, respectively ($P = 0.514$), and the mean preoperative cylinder error was −3.15 ± 0.94 D (−7.00 to −2.00 D) and −3.29 ± 0.95 D (−6.25 to −2.00 D), respectively ($P = 0.284$). By the end of the two-year follow-up, no case of ectasia had been observed.

In the femto-LASIK and PRK groups, the mean amounts of preoperative cylinder error were −2.39 ± 0.30 D and −2.43 ± 0.26 D ($P = 0.630$) in the mild astigmatism group, −3.25 ± 0.21 D and −3.34 ± 0.23 D ($P = 0.221$) in the moderate group, and −5.29 ± 1.10 D and −4.41 ± 0.42 D ($P = 0.109$) in the severe astigmatism group, respectively.

Comparison between femto-LASIK and PRK

At one year after surgery, mean cylinder error in the femto-LASIK and PRK groups was −0.61 ± 0.40 D and −0.62 ± 0.60 D, respectively, and the difference between the two groups was not statistically significant ($P = 0.674$). At 2 years after surgery, mean cylindrical error in the femto-LASIK group (−0.61 ± 0.39 D) was significantly lower than the PRK group (−0.83 ± 0.56 D) ($P = 0.021$). At 2 years, the prevalence of cases with residual astigmatism greater than 0.5 D was significantly higher in the PRK group (58.8%) than the femto-LASIK group (39.6%) ($P = 0.043$). Also, the percentage of cases with residual astigmatism greater than 1.0 D was significantly higher in the PRK group (19.6%) than the femto-LASIK group (6.3%) ($P = 0.046$).

Changes of UDVA and CDVA are presented in Table 1. At one year after surgery, mean UDVA was 0.06 ± 0.09 logMAR and 0.03 ± 0.06 logMAR in the femto-LASIK and PRK groups, respectively ($P = 0.119$). But at 2 years, UDVA results were better in the femto-LASIK group than the PRK group (0.02 ± 0.05 logMAR vs. 0.06 ± 0.10 logMAR, $P = 0.025$).

Table 1
Comparison of uncorrected distance visual acuity (UDVA) and corrected distance visual acuity (CDVA) between femtosecond laser assisted LASIK (femto-LASIK) and photorefractive keratectomy (PRK) in astigmatism > 2.00 D.

		Preoperative	At 1 year	At 2 years
UDVA (logMAR)	Femto-LASIK	0.48 ± 0.23	0.06 ± 0.09	0.05 ± 0.01
	PRK	0.48 ± 0.24	0.03 ± 0.06	0.10 ± 0.01
CDVA (logMAR)	Femto-LASIK	0.03 ± 0.08	0.03 ± 0.07	0.01 ± 0.03
	PRK	0.03 ± 0.07	0.01 ± 0.03	0.01 ± 0.04

UDVA: Uncorrected distance visual acuity, CDVA: Corrected distance visual acuity, Femto-LASIK: Femtosecond laser assisted LASIK, PRK: Photorefractive keratectomy.

At 1 year, mean CDVA was 0.03 ± 0.07 logMAR and 0.01 ± 0.03 logMAR in the femto-LASIK and PRK groups, respectively ($P = 0.093$). At 2 years, mean CDVA in the femto-LASIK group (0.01 ± 0.03 logMAR) was similar to PRK group (0.01 ± 0.04 logMAR) ($P = 0.714$).

In the second year, 95.8% in the femto-LASIK group versus 80.4% in the PRK group had a UDVA of 20/25 or better ($P = 0.019$). Also, 97.9% in the femto-LASIK group versus 94.1% in the PRK group had 20/25 or better CDVA ($P = 0.618$) (Fig. 1). Improved CDVA was observed in 25.5% in the femto-LASIK group and 19.8% in the PRK groups, while the percentage of patients with decreased CVDA was 1.0% versus 5.3% in these two groups, respectively ($P = 0.125$).

Comparison based on level of baseline astigmatism

As presented in Table 2, there were no significant differences between the two groups in terms of mean residual astigmatism in the first and second years after surgery at different levels of baseline astigmatism (all $P > 0.05$). However, in subgroups with ≥4.00 D cylinder, there was less astigmatic regression at 1 year in the femto-LASIK group

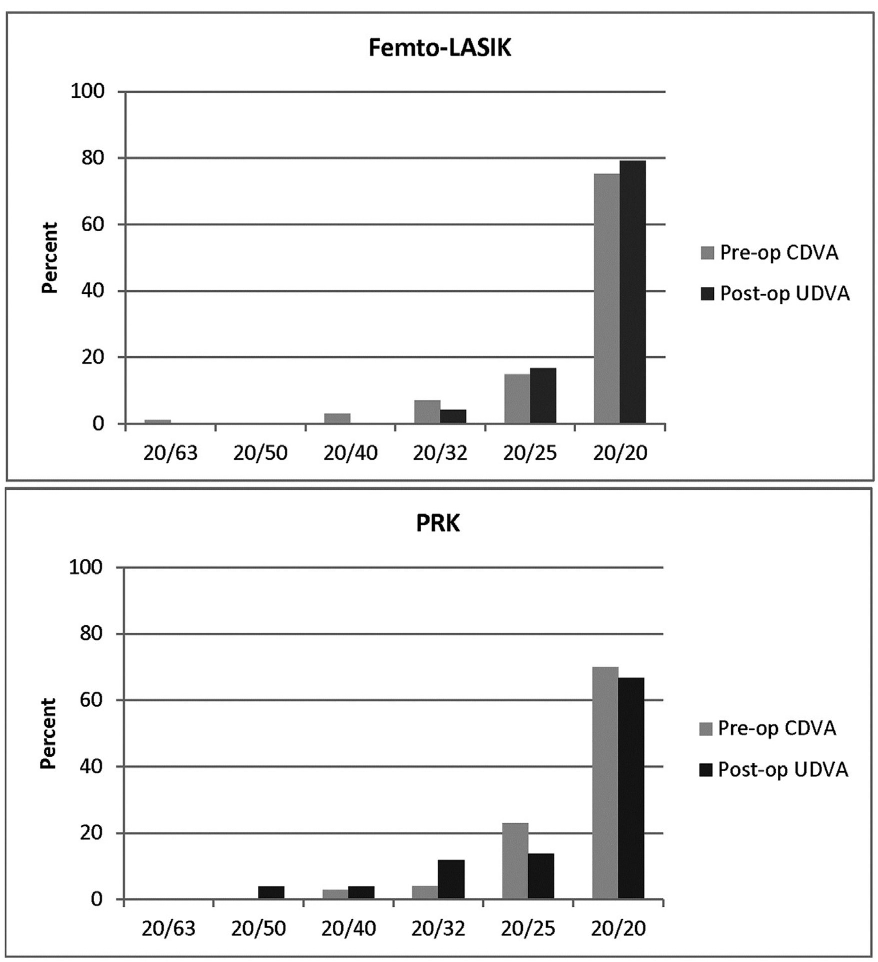

Fig. 1. Two-year efficacy with the femtosecond laser assisted LASIK (femto-LASIK) (top) and photorefractive keratectomy-Mitomycin C (PRK-MMC) (bottom) groups in the treatment of cases with high astigmatism.

Table 2
Comparison of one-year and two-year results between the two methods of femtosecond laser assisted LASIK (femto-LASIK) and photorefractive keratectomy (PRK) in terms of astigmatism correction at different levels of baseline astigmatism.

	Baseline astigmatism (diopter)	Refractive astigmatism		*P*-value
		Femto-LASIK group	PRK-MMC group	
At 1 year	2.00 to <3.00	−0.43 ± 0.27	−0.44 ± 0.41	0.976
	3.00 to <4.00	−0.67 ± 0.45	−0.82 ± 0.77	0.476
	≥4.00	−0.80 ± 0.40	−0.78 ± 0.65	0.943
	Total	−0.61 ± 0.40	−0.62 ± 0.60	0.674
At 2 years	2.00 to <3.00	−0.46 ± 0.33	−0.62 ± 0.41	0.176
	3.00 to <4.00	−0.68 ± 0.24	−0.75 ± 0.44	0.592
	≥4.00	−1.08 ± 0.52	−1.32 ± 0.71	0.488
	Total	−0.61 ± 0.39	−0.83 ± 0.56	0.021

Femto-LASIK: Femtosecond laser assisted LASIK, PRK: Photorefractive keratectomy.

(0.28 ± 0.43 D) than the PRK group (0.54 ± 0.68 D) ($P = 0.007$).

In the femto-LASIK group, mean residual astigmatism in those with mild astigmatism was lower than those with severe astigmatism with marginal significance ($P = 0.066$) at one year after surgery. This difference was not significant in the PRK group ($P = 0.099$). In the second year after surgery, mean residual astigmatism showed an increase at higher levels of baseline astigmatism in femto-LASIK patients (all $P < 0.05$). In PRK patients, mean residual astigmatism in those with severe astigmatism was greater than the moderate group ($P = 0.011$) and the mild astigmatic group ($P = 0.004$) (Table 2).

As illustrated in Fig. 2, in the mild astigmatic group, 100% of femto-LASIK patients versus 80% of PRK patients had 20/25 or better UDVA ($P = 0.040$) at 2 years after surgery; the inter-group difference was not significant in other levels of astigmatism (all $P > 0.05$). The rate of 20/25 or better CVDA did not differ between the two methods of surgery at the three levels of the astigmatism (all $P > 0.05$).

Discussion

Studies have compared results of LASIK and PRK in the treatment of astigmatism less than 2.00 D, and they have shown that although femto-LASIK is preferable based on

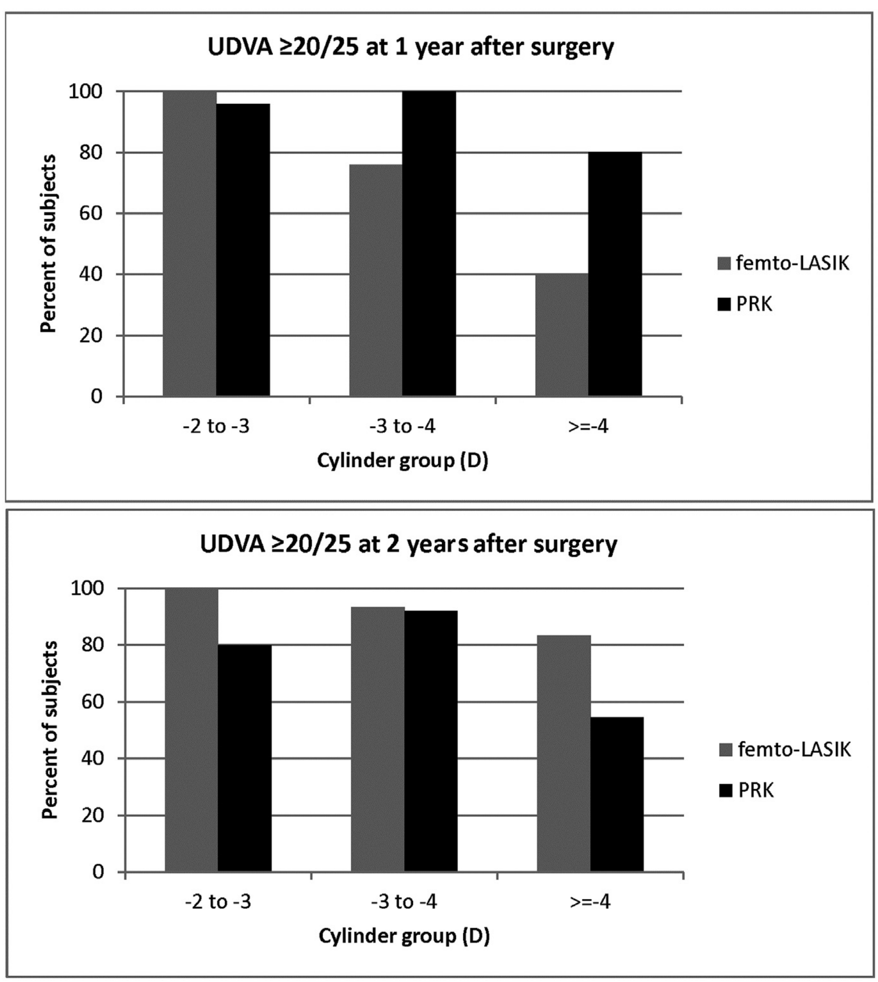

Fig. 2. Frequency distribution of uncorrected distance visual acuity (UDVA) in different levels of baseline astigmatism at 1 year (top) and two years (bottom) after femtosecond laser assisted LASIK (femto-LASIK) and photorefractive keratectomy-Mitomycin C (PRK-MMC) for the treatment of cases with high astigmatism.

short-term outcomes, the two methods have comparable safety and efficacy in the long-term.[8,12,13] Nonetheless, high astigmatic cases which are quite a challenge in refractive surgery have been studied less. In a 6-month study of non-wavefront-guided LASIK results, Arbelaez et al.[14] reported desirable efficacy for this method in the correction of 2.00–4.75 D astigmatism. Katz et al.[11] compared six-month results with conventional LASIK and PRK for the correction of 3.25–5.75 D astigmatism and showed that the methods have similar efficacy. In the present matched comparative study, the 2-year results of femto-LASIK and PRK were compared in the treatment of cases with moderate to high astigmatism (2.00–7.00 D). Results of the two surgical methods were also compared at different levels of baseline astigmatism.

The results of present study showed that although there were no differences between the two procedures in terms of mean residual astigmatism at one year after surgery, femto-LASIK had better results compared to PRK by the second year when the rate of residual astigmatism >1.0 D was 6.3% with femto-LASIK and 19.6% in the PRK group. Our one-year results with femto-LASIK were quite close to the studies by Igarashi et al.[15] and Hasegawa et al.[16] who reported favorable one-year results with LASIK in cases of moderate to high astigmatism. Katz et al.[11] reported similar predictability rates for femto-LASIK and PRK in their 6-month study of cases with astigmatism greater than 3.0 D. We found no inter-method difference in residual astigmatism at one year, but due to regression in PRK, second year results were in favor of femto-LASIK. This could be attributed to epithelial hyperplasia which occur in a meridional pattern and is more common after PRK than femto-LASIK.

Our study also showed that residual astigmatism increases at higher levels of baseline astigmatism with both femto-LASIK and PRK. The inter-group difference at different levels of baseline astigmatism was not statistically significant which could be due to the small sample size of the subgroup with high levels of astigmatism. From a clinical point of view, however, it should be noted that among cases with severe astigmatism, mean astigmatism in the femto-LASIK group was 0.88 D higher than the PRK group at baseline and 0.24 D less than the PRK group at 2 years, and thus, the amount of astigmatism correction was greater in patients treated with femto-LASIK. In other words, in cases with 4.0 D or more astigmatism, femto-LASIK was associated with better results and can be the preferred modality compared to PRK.

Overall, in the present study, UDVA in the PRK group had better results compared to femto-LASIK at one year when 92.0% in this groups achieved 20/25 or better UDVA versus 78.2% in the femto-LASIK group. These results were better compared to the 6-month study by Katz et al.[11] who reported a UDVA of 20/40 or better in 77.2% of their PRK cases versus 91.2% with LASIK. However, results changed over the second year after surgery and were eventually better with femto-LASIK than PRK. This may be due to astigmatism stability in the femto-LASIK group and regression in the PRK group. In other words, while residual astigmatism remained unchanged during the second postoperative year in the femto-LASIK group (0.61 D vs. 0.61 D), this rate increased in the PRK group (0.62 D vs. 0.83 D). As a limitation of this study, its retrospective nature might have lead to increased selection bias because only those with complete follow-up exams were included.

In terms of CDVA, no difference was observed between the two surgical groups. Analysis in different levels of baseline astigmatism showed that CDVA is not influenced by this variable. Despite a different follow-up time, Katz et al.[11] reported a similar safety index with us.

In conclusion, in the treatment of astigmatism, although there is more residual astigmatism at higher levels of correction, femto-LASIK offers better efficacy than PRK in the mid-term. Femto-LASIK is also the preferred method in terms of improving UDVA.

References

1. Pärssinen O, Kauppinen M, Viljanen A. Astigmatism among myopics and its changes from childhood to adult age: a 23-year follow-up study. *Acta Ophthalmol*. 2015;93(3):276–283.
2. Williams KM, Verhoeven VJM, Cumberland P, et al. Prevalence of refractive error in Europe: the European eye Epidemiology (E3) Consortium. *Eur J Epidemiol*. 2015;30(4):305–315.
3. Hashemi H, Hatef E, Fotouhi A, Mohammad K. Astigmatism and its determinants in the Tehran population: the Tehran eye study. *Ophthalmic Epidemiol*. 2005;6(12):373–381.
4. Asgari S, Hashemi H, Mehravaran S, et al. Corneal refractive power and eccentricity in the 40- to 64-year-old population of Shahroud, Iran. *Cornea*. 2013;32(1):25–29.
5. Khalifa M, El-Kateb M, Shaheen MS. Iris registration in wavefront-guided LASIK to correct mixed astigmatism. *J Cataract Refract Surg*. 2009;35(3):433–437.
6. Shen EP, Chen WL, Hu FR. Manual limbal markings versus iris-registration software for correction of myopic astigmatism by laser in situ keratomileusis. *J Cataract Refract Surg*. 2010;36(3):431–436.
7. Schallhorn SC, Venter JA, Hannan SJ, Hettinger KA. Clinical outcomes of wavefront-guided laser in situ keratomileusis to treat moderate-to-high astigmatism. *Clin Ophthalmol*. 2015;9:1291–1298.
8. Hatch BB, Moshirfar M, Ollerton AJ, Sikder S, Mifflin MD. A prospective, contralateral comparison of photorefractive keratectomy (PRK) versus thin-flap LASIK: assessment of visual function. *Clin Ophthalmol*. 2011;5:451–457.
9. Slade SG, Durrie DS, Binder PS. A prospective, contralateral eye study comparing thin-flap LASIK (sub-Bowman keratomileusis) with photorefractive keratectomy. *Ophthalmology*. 2009;116(6):1075–1082.
10. Habibollahi A, Hashemi H, Seyedian MA, et al. One year outcomes of photorefractive keratectomy with the application of mitomycin-C in the treatment of mild to moderate hyperopia. *Middle East Afr J Ophthalmol*. 2015;22(4):484–488.
11. Katz T, Wagenfeld L, Galambos P, Darrelmann BG, Richard G, Linke SJ. LASIK versus photorefractive keratectomy for high myopic (>3 diopter) astigmatism. *J Refract Surg*. 2013;29(12):824–831.
12. Christiansen SM, Mifflin MD, Edmonds JN, Simpson RG, Moshirfar M. Astigmatism induced by conventional spherical ablation after PRK and LASIK in myopia with astigmatism <1.00 D. *Clin Ophthalmol*. 2012;6:2109–2117.
13. Fraunfelder FW, Wilson SE. Laser in situ keratomileusis versus photorefractive keratectomy in the correction of myopic astigmatism. *Cornea*. 2001;20(4):385–387.
14. Arbelaez MC, Vidal C, Arba-Mosquera S. Excimer laser correction of moderate to high astigmatism with a non-wavefront-guided aberration-

free ablation profile: six-month results. *J Cataract Refract Surg*. 2009; 35(10):1789–1798.
15. Igarashi A, Kamiya K, Shimizu K, Komatsu M. Time course of refractive and corneal astigmatism after laser in situ keratomileusis for moderate to high astigmatism. *J Cataract Refract Surg*. 2012;38(8):1408–1413.
16. Hasegawa A, Kojima T, Isogai N, Tamaoki A, Nakamura T, Ichikawa K. Astigmatism correction: laser in situ keratomileusis versus posterior chamber collagen copolymer toric phakic intraocular lens implantation. *J Cataract Refract Surg*. 2012;38(4):574–581.