Comparison of Visual Outcomes for Myopia after Refractive Surgery using Femtosecond Laser-assisted and Epipolis LASIK

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Abstract

Purpose This study was to clinically evaluate the visual outcomes after refractive surgery for myopia using femtosecond laser-assisted in situ keratomileusis (femto-LASIK) and epipolis LASIK (flap-off epi-LASIK). Methods Forty eyes of 27 patients were divided into 2 groups in a retrospective study. Uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), manifest refraction (MR),corneal asphericity (Q-value) and corneal higher-order aberrations (HOAs) were assessed pre- and postoperatively. Results The pre- and postoperative changes in flattest keratometry reading(K1), steepest keratometry reading(K2), central corneal thickness(CCT), and only Q-value of the anterior surface was statistically significant for both groups (femto-LASIK: P=0.014, P=0.03, P<0.001, P=0.001, respectively; epi-LASIK: all P<0.001). The postoperative corneal thickness spatial profile (CTSP) were statistically significant thinner than preoperative CTSP in both procedures (all P<0.05), and the epi-LASIK was significant thinner than femto-LASIK at 6 mm ring of CTSP (P=0.039). The improvement in LogMAR UDVA after refractive surgery was statistically significant for both groups (P<0.001 for all groups); it was significantly improved for femto-LASIK on day 1 and at 1 week postoperatively (P<0.001, P=0.019, respectively). In analysis of corneal HOAs, there were significant reduction of vertical coma aberration and horizontal secondary astigmatism aberration, and induction of spherical aberration in the front corneal HOAs after femto-LASIK (P=0.021, P=0.001, P=0.001, respectively); in the total corneal HOAs changes were the same pattern as the front corneal HOAs (P=0.007, P=0.004, P<0.001, respectively), but in the back corneal HOAs changes, a few significant induction of vertical coma aberration, and reduction of oblique trefoil aberration and oblique tetrafoil aberration (all P<0.05). In flap-off epi-LASIK, there were only significant induction of SA in the front and total corneal HOAs after surgery (all P<0.05); in the back corneal HOAs, a few significant induced horizontal secondary astigmatism aberration and reduced SA aberration (P=0.027, P=0.011, respectively), however, the back corneal HOAs changes were not significant effect on the total corneal HOAs changes. Conclusion Femto-LASIK showed better early visual outcomes than that noted by epi-LASIK, but there was no significant difference between the outcomes of the 2 procedures 1 week postoperatively.

Background

The refractive power of the eyes changes during growth and maturation. Myopia, a condition in which the cornea focuses light in front of the retina and not directly on it, has become the most common medical condition in younger patients. Conventionally, orthokeratology (ortho-k) has been used to correct corneal shape and to slow axial elongation of the eye during childhood.[1,2] However, refractive surgery may be more effective than ortho-k lens application for cases of moderate or severe myopia in patients older than 20 years.[3]

In the early 1990s, photorefractive keratectomy (PRK) was first introduced for the surgical correction of myopia, the laser ablation refractive surgery were well used in anterior segment operation. With the advancement in the techniques used for epithelium removal, femto-LASIK and epi-LASIK have emerged in the field of refractive surgery.

Numerous studies have compared the visual outcomes of femtosecond laser-assisted LASIK (femto-LASIK) and epipolis LASIK (epi-LASIK) were comparing anterior surface refractive errors.[4-8] To compare the forward straylight in the early stage after refractive surgery, there was slightly increased in femto-LASIK procedure than other refractive surgery techniques, and was significantly increased throughout the follow-up period after epi-LASIK surgery.[9]

Depending on with or without flap, the epi-LASIK divided into flap-on epi-LASIK and flap-off epi-LASIK. Ang RE et al.[10] and Zhang Y et al.[11] were reported that flap-off epi-LASIK with MMC has less pain, corneal haze and faster visual recovery, while visual results, refractive outcomes, contrast sensitivity (CS), and higher-order aberrations (HOAs) were comparable with flap-on epi-LASIK. Wen D and associates[12] published a network meta-analysis to comparative evaluation the visual outcomes and visual quality, the report shows that there were no statistically significant difference in either visual outcomes (efficacy and safety) or visual quality (HOAs and CS), but femto-LASIK behaved better in predictability than any other type of surgeries. Additionally, the thinner corneas, higher intraocular pressure (IOP), and higher myopia requiring greater laser ablation are more predisposed to the anterior shift of the cornea.[13]

In principle, Pentacam is using scheimpflug camera to determinate corneal tomography and topography to provide more detail corneal informations.[14-16] The aim of this study was to compare the visual outcomes, refractive errors changes about anterior and posterior surface and effectiveness of femto-LASIK and epipolis LASIK (flap-off).

Methods

Patients: LASIK was performed in 40 eyes of 27 patients between April 2014 and February 2016 in the Department of Ophthalmology, Catholic University, St. Mary's Hospital, Seoul, South Korea. The study protocol followed the guidelines of the Declaration of Helsinki and was approved by the Institutional Review Board of St. Mary's Hospital, Seoul, South Korea. Written informed consent was obtained from all the patients included in this study.

Patients included in the study received refractive surgery to correct myopia, and had normal preoperative topography. All patients demonstrated at least 1 year of stable refraction before undergoing refractive surgery. Exclusion criteria included ocular pathology; retinal disorders; previous ocular surgery; co-morbidities such as diabetes, autoimmune pathologies, and endocrine pathologies; dry eye symptoms; and insufficient follow-up. We also excluded patients with corneal instability, haze or other complications, and retreatment cases. Patients had to discontinue the use of soft contact lenses for at least 2 weeks and rigid gas permeable (RGP) lenses for at least 4 weeks prior to surgery.

Preoperative assessment: All patients underwent a standard ophthalmologic examination preoperatively on day 1, at week 1, and at 1, 3, and 6 months postoperatively. The investigation included a manifest refraction (MR), cycloplegic refraction, slit-lamp examination, ultrasound pachymetry, dilated funduscopy, and IOP measurement using a Goldmann applanation tonometer. Uncorrected distance visual acuity and corrected distance visual acuity (CDVA) were assessed using Snellen charts. The CDVA was always assessed using trial frames and not contact lenses.

Corneal asphericity (Q-value), corneal HOAs and keratometry were evaluated using Pentacam (OCULUS Optikgerate GmbH, Wetzlar, Germany). Corneal topography and HOAs were measured using videokeratoscopy (Keratron Scout topographer, Optikon 2000 SpA, Rome, Italy) under photopic conditions (1500 lux), similar to those under an operating microscope for deciding surgery plan.

Surgical procedure: All surgeries targeted emmetropia and the treatment plan followed the Custom Ablation Manager protocol. Ablations were performed using the AMARIS 750S excimer laser (SCHWIND Eye-Tech Solutions, Kleinostheim, Germany). The aberration-free mode was used, in which ablation was performed with an optimized aspheric profile. All surgeries were performed by a single experienced surgeon (CKJ). Topical anesthetic eye drops containing proparacaine (Alcaine, Alcon-Couvreur, Puur, Belgium) were administered. Femtosecond laser-assisted LASIK flaps were cut using the iFS Advanced Femtosecond Laser (Abbott Medical Optics, Inc., Irvine, CA, USA) with superior hinges, 100 µm flap thickness, and 8.4 or 8.5 mm flap diameters. Flap-off epi-LASIK was performed using the Epi-K^{TM} epikeratome (Moria SA, Antony, France). After lifting the flap, ablation was performed on a 6.5 mm optical zone. The planned refractive correction (6.7-9.0 mm) of the ablation zone was carried out automatically in a variable transition zone size. Mitomycin C (0.02%) was placed on the residual bed, after which the stromal surface was irrigated with balanced salt solution, and a bandage contact lens (Senofilcon A, Acuvue Oasys; Johnson & Johnson, Jacksonville, FL, USA) was placed over the surgical site.

The patients were administered topical antibiotic eye drops 4 times/week, topical corticosteroid eye drops 4 times/day (tapered off over 1 week), and topical lubricants.

Postoperative evaluation: Patients were reviewed on day 1, at 1 week, and at 1, 3, and 6 months postoperatively. All postoperative follow-up visits included the assessment of UDVA, CDVA, MR, and the recording of manual keratometry readings. Pentacam was used to evaluate central corneal thickness (CCT), corneal thickness spatial profile (CTSP), corneal asphericity (Q-value) and corneal HOAs.

Statistical analysis: Data were entered into an Excel spreadsheet database (Microsoft, Redmond, Washington, USA) and statistical analysis was performed using SPSS for Windows, version 18.0 (SPSS, Inc., Chicago, IL, USA). Normality was tested using the Shapiro-Wilk test. The Wilcoxon rank sum test and Mann-Whitney test were used for nonparametric analysis. P-values of < 0.05 were considered significant.

Results

The study population included 27 patients who were divided into 2 groups based on whether a flap was created during surgery (epi-LASIK) or not (femto-LASIK). The aberration-free treatment mode of the laser procedure was used for all patients. The characteristics of the 2 groups are summarized in Table 1. There were no significant differences between the baseline ophthalmic characteristic of the 2 groups.

Table 2 shows the comparative evaluation of the pre- and postoperative changes between the 2 groups. Keratometry measurement was performed using a manual keratometer. There were no significant differences between the 2 groups for the flattest keratometry reading (K_1), steepest keratometry reading (K_2), CCT, or Q-vaule (Ant. and Post.). The pre- and postoperative changes in K_1, K_2, CCT, and Q-value (Ant.) were significant for both the groups ($P = 0.014$, $P = 0.03$, and $P < 0.001$, $P = 0.001$, respectively, in femto-LASIK; all $P < 0.001$, in epi-LASIK).

The changes of corneal thickness spatial profile (CTSP) are shown in Table 3. There were no statistically significant difference in preoperative and postoperative between two groups at 0 mm, 2 mm, 4 mm and 8 mm ring of corneal (all $P > 0.05$), but was significant thinner after epi-LASIK than femto-LASIK at 6 mm ring ($P = 0.039$). Further details can be found in Table 3.

The changes in UDVA are shown in Figure 1. The mean changes in LogMAR UDVA (improvement) were significant for both groups postoperatively (all $P < 0.001$). The improvement was more significant for femto-LASIK on day 1 and at 1 week postoperatively ($P < 0.001$ and $P = 0.019$, respectively).

The mean preoperative manifest refraction spherical equivalent (MRSE) was -5.94 ± 2.23 and -5.94 ± 1.62 D for femto-LASIK and epi-LASIK groups, respectively ($P = 0.904$).The postoperative refraction were statistically significant myopic refraction errors after one day and one week in epi-LASIK than femto-LASIK ($P < 0.001$, $P = 0.009$, respectively), and there were statistically significant improvement of refraction errors in both groups from one day after refractive surgery (all $P < 0.001$) (Figure 2).

Figure 3 shows the changes HOAs of the front, back and total cornea between femto-LASIK and epi-LASIK. There were significant reduction of vertical coma ($Z_{3,-1}$) aberration from -0.086 ± 0.251 to -0.393 ± 0.335 and horizontal secondary astigmatism ($Z_{4,2}$) aberration from 0.013 ± 0.051 to -0.113 ± 0.113, and induction ofprimary spherical aberration (SA) ($Z_{4,0}$) from 0.271 ± 0.132 to 0.479 ± 0.139 in the front corneal HOAs after femto-LASIK ($P = 0.021$, $P = 0.001$, $P = 0.001$, respectively); in the total corneal HOAs changes, there were significant reduction of vertical coma ($Z_{3,-1}$) aberration from -0.128 ± 0.215 to -0.368 ± 0.328 and horizontal secondary astigmatism ($Z_{4,2}$) aberration from -0.007 ± 0.055 to -0.122 ± 0.117, and induction of primary SA ($Z_{4,0}$) aberration from 0.168 ± 0.061 to 0.430 ± 0.137 after femto-LASIK ($P = 0.007$, $P = 0.004$, $P < 0.001$, respectively). However, in the back corneal HOAs changes, there were significant induction of vertical coma ($Z_{3,-1}$) aberration from 0.013± 0.025 to 0.027 ± 0.027, and reduction of oblique trefoil ($Z_{3,-3}$) aberration from -0.026 ± 0.042 to -0.055 ± 0.037 and oblique tetrafoil ($Z_{4,-4}$) aberration from 0.006 ± 0.030 to -0.008 ± 0.029 ($P = 0.015$, $P = 0.046$, $P = 0.049$, respectively). In flap-off epi-LASIK, there were only significant induction of SA from 0.250 ± 0.128 to 0.626 ± 0.232 and -0.156 ± 0.033 to 0.556 ± 0.227 in the front and total corneal HOAs after surgery (all $P < 0.001$); in the back corneal HOAs, there were significant induction of horizontal secondary astigmatism ($Z_{4,2}$) aberration from -0.001 ± 0.016 to 0.007 ± 0.018 and reduction of SA ($Z_{4,0}$) aberration from -0.156 ± 0.033 to -0.163 ± 0.037 ($P = 0.027$ and $P = 0.011$).

To comparative evaluation the corneal HOAs changes between two groups after surgery, the increment of primary spherical aberrations ($Z_{4,0}$) in the flap-off epi-LASIK than femto-LASIK. It was 0.479 ± 0.139 and 0.626 ± 0.232 in the front cornea; 0.430 ± 0.137 and 0.556 ± 0.227 in the total cornea, respectively (P = 0.016 and P = 0.017). Whenever, analysis of the back corneal HOAs, there were significant difference in vertical coma ($Z_{3,-1}$) aberration 0.027 ± 0.027 (femto-LASIK) and 0.001 ± 0.034 (flap-off epi-LASIK);horizontal secondary astigmatism ($Z_{4,2}$) aberration -0.008 ± 0.012 (femto-LASIK) and 0.007 ± 0.018 (flap-off epi-LASIK); oblique tetrafoil ($Z_{4,-4}$) aberration -0.008 ± 0.029 (femto-LASIK) and 0.015 ± 0.026 (flap-off epi-LASIK), respectively (P = 0.018, P = 0.007, P = 0.022, respectively).

Discussion

Many studies have been conducted to determine whether flap creation using a femtosecond laser is more effective than flap creation using a microkeratome. In previous studies, Kalyvianaki MI et al.[17] reported that there were equal visual and refractive results between epi-LASIK and off-flap epi-LASIK for the treatment of low and moderate myopia. Another study, Na KS et al.[18] found that off-flap epi-LASIK has superior visual recovery and corneal re-epithelialization than epi-LASIK surgery in early postoperative period. In addition, femto-LASIK surgery despite the accurate, safety, and predictable in flap creation, occasionally occur complications either intraoperatively or postoperatively.[19] Hence, in the current study, we clinically evaluated the visual and refractive outcomes between femto-LASIK and off-flap epi-LASIK surgery in myopia or myopic astigmatism, however, there were no statistically significant difference in refractive and visual outcomes between femto-LASIK and off-flap epi-LASIK surgery.

In generally, the surface ablation techniques (such as photorefractive keratectomy (PRK), transepithelial photorefractive keratectomy (T-PRK), laser epithelial keratomileusis (LASEK), and epipolis laser in situ keratomileusis (epi-LASIK)) has less painful and offer faster visual rehabilitation than stromal ablation methods (such as laser in situ keratomileusiswith the flap created with either a mechanical microkeratome or femtosecond-based microkeratome (femto-LASIK)). Meanwhile, corneal haze with decreased corneal transparency is typically determined by corneal backward light scattering. It has been reported that the ablation volume may increase the degree of backscattering,[20] and cases of severe myopia that require more ablation may require a higher dose of mitomycin C during the refractive procedure.[21,22] Sia RK et al.[23] and Chen J et al.[24] reported that mitomycin C was beneficial for reduction of corneal haze without delaying epithelialization. According to this study of our data, it was a little difference. There were statistically significant improvement of visual acuity and refractive errors after on day 1 and 1 week in femto-LASIK than off-flap epi-LASIK, however there were similar outcomes between two different surgical technique during the remaining follow-up period.

Until now, there have been numerous disagreements concerning which guided ablation technique is most accurate: topography-guided, wavefront-guided, or wavefront-optimized ablation profile.[25-27] In principle, topography-guided ablation is centered on the corneal vertex and corrects corneal shape for HOAs; wavefront-guided ablation is centered on the pupil center and corrects corneal shape for whole-eye HOAs; wavefront-optimized ablation is designed to minimize and prevent induced SA.

There have been no perfect planning methods for refractive surgery still now. Due to this lack, it is not possible to measure the shape of the lens, the refractive indices, or the retinal radius with accuracy. Although all examination devices (aberrometers and auto-refractors) are based on the non-accommodative state, they are designed to prevent accommodation by maintaining a fixed distance from the target or by fogging the eye before measurement.[28] With the development of biometry reading devices, it is possible to measure the individual eye to provide a treatment plan. In the current study, the epi-LASIK treatment spherical equivalent was significantly lower than the femto-LASIK equivalent ($P = 0.02$; data not shown).

The principle of refractive surgery is to induce positive SA shifts for myopic correction and negative shifts for hyperopic correction.[29,30] The effect of SA on the depth of focus has been investigated using adaptive optics systems.[31] The depth of focus, by definition, is relatively insensitive to focal length and subject distance for a fixed f-number; typically, myopia is a condition of the eye in which light focuses in front of the retina instead of on it. Myopic or hyperopic refractive surgery aims to correct the corneal shape by changing the keratometric power.[32,10]

Huang J et al.[33] and Jain R et al.[34] confirmed the highly repeatable results after LASIK using a Scheimpflug camera, and with no significant difference in keratometry readings compared to those provided by manual keratometry.[35] In this study, we also used the Scheimpflug camera to evaluate the outcomes after refractive surgery. We found both procedures showed a statistically significant decrease in CCT and reduced the keratometry readings. We also found the changes of keratometry were due to ablation of the keratometry axis. This ablation technique was achieved by balancing the negative and positive cylinder ablations to create a more spherical optical zone.[36]

The induced changes in corneal asphericity (Q) and SA after laser ablation are key factors when selecting candidates for refractive surgery. Scheimpflug imaging gave reliable measurements consistent with those in the literature; there was a positive change in the Q value of the anterior surface after myopic ablation and a negative change after hyperopic ablation.[37] Total corneal refractive power is negative posterior refractive power compensated with positive anterior refractive power. The steepening of the anterior corneal surface increases positive refractive power; when both surfaces bulge similarly, the anterior surface exerts far greater absolute refractive changes than the posterior surface.

However, Shih P et al.[38] demonstrated that the Bowman's membrane and Descemet's membrane, as a pair of forces, provided approximately 20% of the rigidity against bending, despite their extremely small thickness. While after refractive surgery, the disruption of Bowman's or Descemet's layer had been associated with corneal ectasia. Moreover, corneal posterior surface elevation can be used to diagnose keratoconus and forme fruste keratoconus (FFKC). In addition, research has focused on the biomechinical simulation of stress concentration after refractive surgery,[38] and they supposed that both surface and stromal ablation techniques were obliquely downwards stress direction after surgery. This study revealed that the posterior surface was more oblate changes after surgery, and there were no accidents of keratectasia after refractive surgery. Dai ML and associates[39] investigated the anterior chamber depth were shallower in the LASIK patients than non-operated myopic eyes. However, in our study results, there also have significant changes in anterior chamber depth after surgery.

Cornea is an elastic and pellucid connective tissue. After refractive surgery, corneal curvature and opacity make influence in postoperative visual outcomes. The concept of corneal thickness spatial profiles were first introduced by Ambrosioet al.[40] Buhren J et al.[41] discriminant analysis subclinical keratoconus and normal eyes by using corneal anterior and posterior surface aberrations and thickness spatial profiles. They found that the posterior aberrations and thickness spatial profile data did not markedly improve discriminative ability over that of anterior wavefront data alone. In our study, we using corneal thickness spatial profiles (CTSP) to evaluated the corneal thickness changes with different corneal diameters. We interestingly found that CTSP changes were significant thinner in epi-LASIK than femto-LASIK at 6 mm ring of cornea, and the CTSP changes of central was much more than mid periphery. Zernike polynomial can be used for characterization of wavefront aberrations of the human eye and for complex corneal shapes. In this study, the corneal HOAs at 6.5 mm diameter were statistically significant difference in front and total HOAs of primary SA, and a few significant difference in posterior HOAs of vertical coma aberration, oblique trefoil aberration and oblique tetrafoil aberration. We postulated these changes of CTSP make influence of changes of corneal HOAs and also effect on the Q-value (8 mm) changes after LASIK. The principle of Sheimpflug imaging analysis system is examining slit images of the anterior segment of the eyes light scattering,[42] the different surgical technique made different effect of corneal elasticity and backward light scattering after refractive surgery.

Aberrations include lower order and higher-order components. Corneal aberrations are usually positive; aberrations of the lens are usually negative. Li YJ et al.[43] reported that total spherical aberration (SA) changed more than other HOAs with accommodation. Moreover, Ocular wavefront aberrations are primarily created in the cornea and lens and are strongly affected by various factors, including the accommodative state,[44] pupil diameter,[45] tear film,[46] age,[47] and pupil entrance decentration.[48] Based on our results, the statistically significant difference in postoperative SA between two difference surgical technique, but have no clinical significant difference.

Furthermore, the corneal epithelium is formed using surperficial, wing, and basal cells. Epi-LASIK with flap-off was separated using an Epi-K^{TM} epikeratome, and the absence of the epithelium was a factor in corneal repairing. It has been verified that the epithelial flap acts as a barrier; it protects the eye from inflammatory mediators and infectious bacteria, and stabilizes the tear film. In addition, the most common complication reported after LASIK is dry eye, or LASIK-induced neurotrophic epitheliopathy. The 2007 Dry Eye Workshop by the Tear Film & Ocular Surface Society listed “visual disturbance” as one of the major symptoms of dry eye. So far, the diagnostic methods and treatments for dry eye have been limited. Moreover, dry eye syndrome increased corneal HOAs and was caused by tear film instability or corneal surface irregularity. In further study, we need to evaluate the visual quality by using contrast sensitivity or symptomatic questionnaire. Finally, we involved small sample size of patients, therefore the large population of patients the results should be more dependable.[49]

Conclusions

Refractive surgery has been regarded as an excellent surgical options whom considered without contact lenses or glasses. Nevertheless, the flap related complications after refractive surgery is still existed. Femto-LASIK and off-flap epi-LASIK have no statistically significant difference in outcomes after 6 months postoperatively, but the femto-LASIK has the superior visual outcomes than epi-LASIK in early stage. Our study results indicated that both femto-LASIK and off-flap epi-LASIK was safe, effective, and predictable refractive surgeries. Moreover, the epithelial layer played an important role in visual outcomes in case of myopia with low astigmatism, and off-flap epi-LASIK was an effective surgical technique for patients without accidents of corneal ectasia after refractive surgery.

Abbreviations

Femto-LASIK = femtosecond laser-assisted in situ keratomileusis, Epi-LASIK = epipolis LAISK, UDVA = uncorrected distance visual acuity, CDVA = corrected distance visual acuity, MR = manifest refraction, CS = contrast sensitivity, HOAs = higher-order aberrations, K_1 = flattest keratometry reading, K_2 = steepest keratometry reading, CCT = central corneal thickness, CTSP = corneal thickness spatial profile, Q-vale = corneal asphericity, AD = ablation depth, ACD = anterior chamber depth, RBT = preoperative predict residual bed thickness.

Declarations

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Availability of data and materials

The datasets obtained and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

Conceived and designed the experiments: W-JW C-KJ.

Performed the experiments: C-KJ.

Analyzed the data: JP W-JW Y-SY.

Contributed regents/materials/analysis tools: JP W-JW Y-SY C-KJ.

Wrote the paper: JP.

All authors have read and approved the manuscript.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Seoul St. Mary's Hospital (Korea) and requirement for individual consent was waived (IRB Registry Number KC14RISI0570).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1. Preoperative Parameters between Femo-LASIK and Epi-LASIK

Parameter	Mean ± Standard Deviation		P-value
	Femto-LASIK	Epi-LASIK	
SE (D)	-5.94 ± 2.23	-5.94 ± 1.92	0.783
K1 (D)	42.35 ± 2.06	42.50 ± 2.13	0.829
K2 (D)	43.53 ± 1.31	43.79 ± 2.20	0.989
AD (µm)	100.15 ± 34.13	90.31 ± 27.57	0.813
ACD (mm)	3.12 ± 0.26	3.25 ± 0.30	0.331
RBT (µm)[a]	365.00 ± 43.28	331.95 ± 40.03	0.777
CCT (µm)	597.15 ± 27.69	552.15 ± 28.76	0.597

SE = spherical equivalent; K1 = flat keratometry; K2 = steep keratometry; AD = ablation depth; ACD = anterior chamber depth; RBT = preoperative predict residual bed thickness; CCT = central corneal thickness.

Table 2. Comparison of preoperative and postoperative changes between femto-LASIK and epi-LASIK patients

Parameter	Mean ± Standard Deviation		P-value
	Femto-LASIK	Epi-LASIK	
K1 (D)			
Pre-op	42.35 ± 1.06	42.50 ± 2.13	0.989
Post-op	37.80 ± 2.58	37.76 ± 2.33	0.945
P-value*	0.001	<0.001	
K2 (D)			
Pre-op	43.53 ± 1.31	43.79 ± 2.20	0.841
Post-op	38.59 ± 2.80	38.61 ± 2.40	0.978
P-value*	0.001	<0.001	
CCT (µm)			
Pre-op	597.15 ± 27.69	552.15 ± 28.76	0.597
Post-op	475.27 ± 28.89	454.89 ± 43.54	0.086
P-value*	<0.001	<0.001	
ACD (mm)			
Pre-op	3.12 ± 0.26	3.25 ± 0.30	0.331
Post-op	2.99 ± 0.21	3.19 ± 0.28	0.256
P-value*	<0.001	0.031	
Q-value (Ant.)			
Pre-op	-0.29 ± 0.11	-0.22 ± 0.21	0.099
Post-op	1.09 ± 0.83	1.04 ± 0.38	0.890
P-value*	<0.001	0.031	
Q-value (Post.)			
Pre-op	-0.03 ± 0.11	0.06 ± 0.15	0.621
Post-op	-0.05 ± 0.15	0.12 ± 0.16	0.007
P-value*	0.288	0.003	

K1 = flattest keratometry reading; K2 = steepest keratometry reading; CCT = central corneal thickness; Ant. = anterior surface; Post. = posterior surface; Pre-op = preoperative; Post-op = postoperative; Q-value = corneal asphericity.

Table 3. Comparison of preoperative and postoperative changes of CTSP between two groups

Parameter	Mean ± Standard Deviation		*P* Value
	Femto-LASIK	Epi-LASIK	
0 mm			
Pre-op	574.45 ± 28.45	547.45 ± 28.34	0.381
Post-op	473.53 ± 28.38	452.47 ± 43.15	0.074
P Value	< 0.001	< 0.001	
2 mm			
Pre-op	584.30 ± 28.15	557.20 ± 27.87	0.418
Post-op	490.67 ± 26.29	469.95 ± 42.37	0.068
P Value	< 0.001	< 0.001	
4 mm			
Pre-op	614.90 ± 28.67	587.30 ± 26.73	0.431
Post-op	546.53 ± 20.97	524.84 ± 40.12	0.066
P Value	< 0.001	< 0.001	
6 mm			
Pre-op	668.95 ± 30.15	639.90 ± 27.30	0.531
Post-op	634.93 ± 20.40	605.47 ± 49.14	0.039
P Value	< 0.001	< 0.001	
8 mm			
Pre-op	752.40 ± 31.73	722.95 ± 31.84	0.889
Post-op	731.20 ± 27.52	709.42 ± 41.02	0.074
P Value	0.007	0.001	

CTSP = corneal thickness spatial profile; Pre-op = preoperative; Post-op = postoperative.

Figures

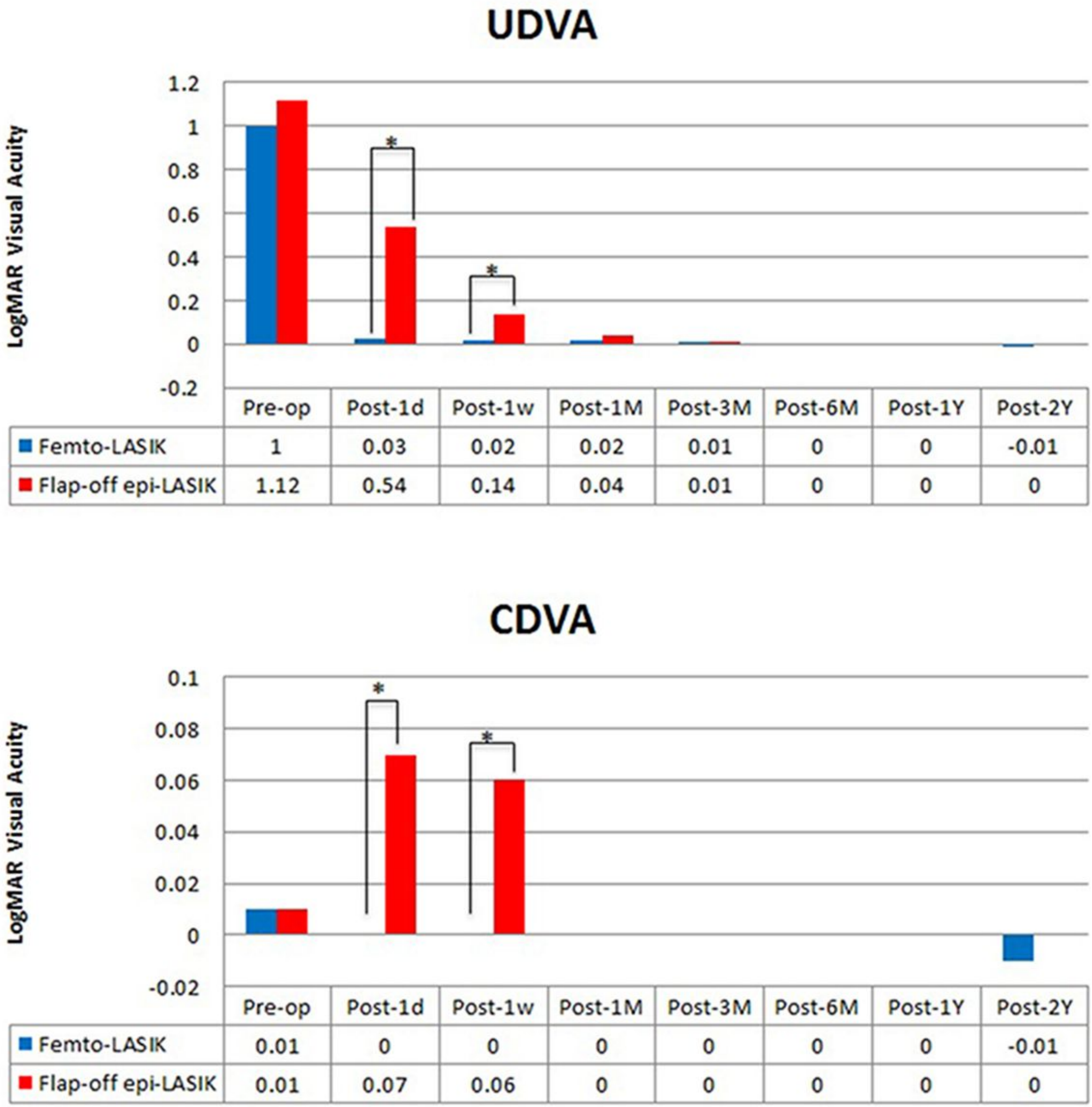

Figure 1

UDVA before and after femto-LASIK and epi-LASIK treatments (UDVA = Uncorrected distance visual acuity; femto-LASIK = femtosecond laser-assisted in situ keratomileusis;epi-LASIK = epipolis LASIK).

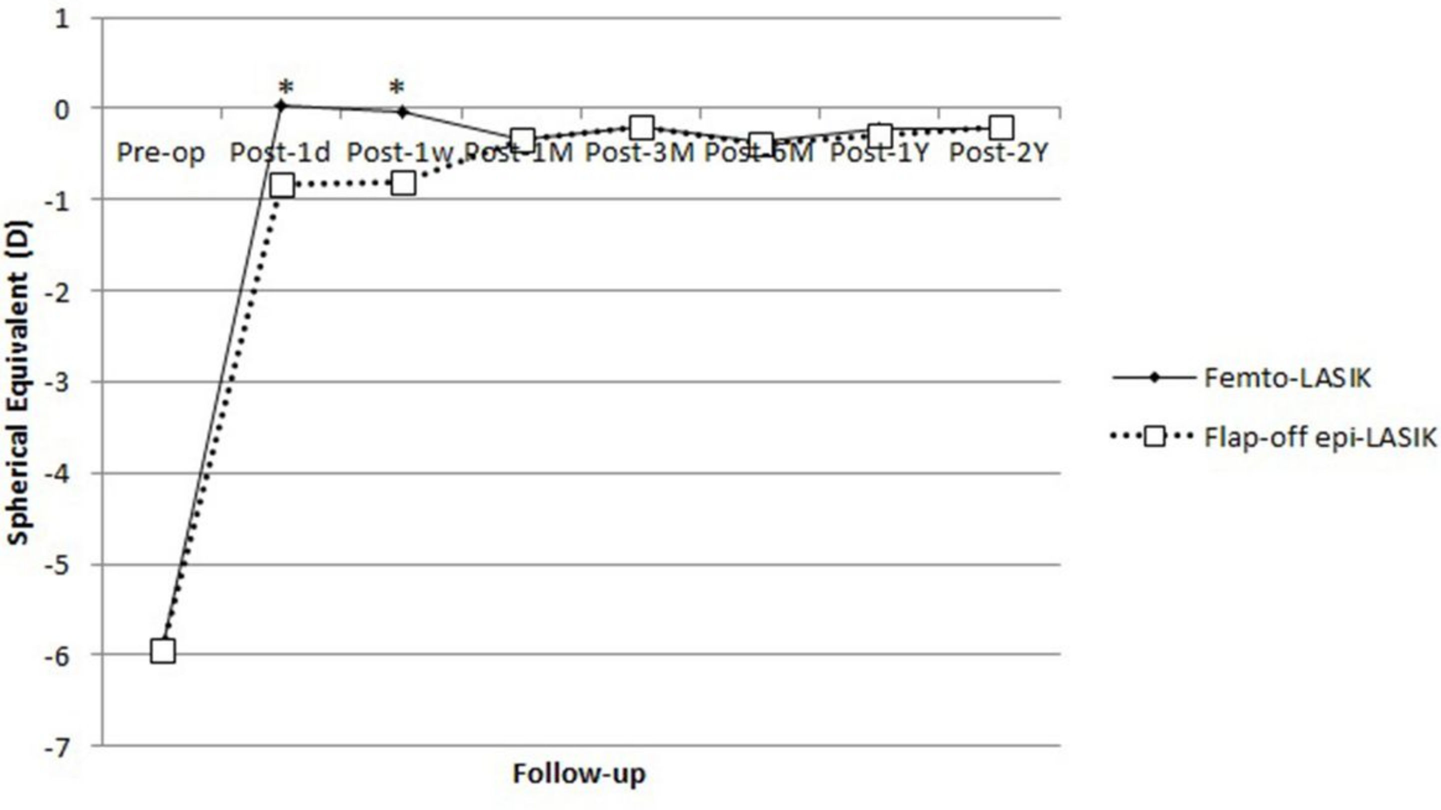

Figure 2

Spherical equivalent refraction measured preoperatively (Pre-op) and at 1 day (d), 1 week (w), 1, 3, 6 months (M) after femto-LASIK and epi-LASIK(D = diopters).

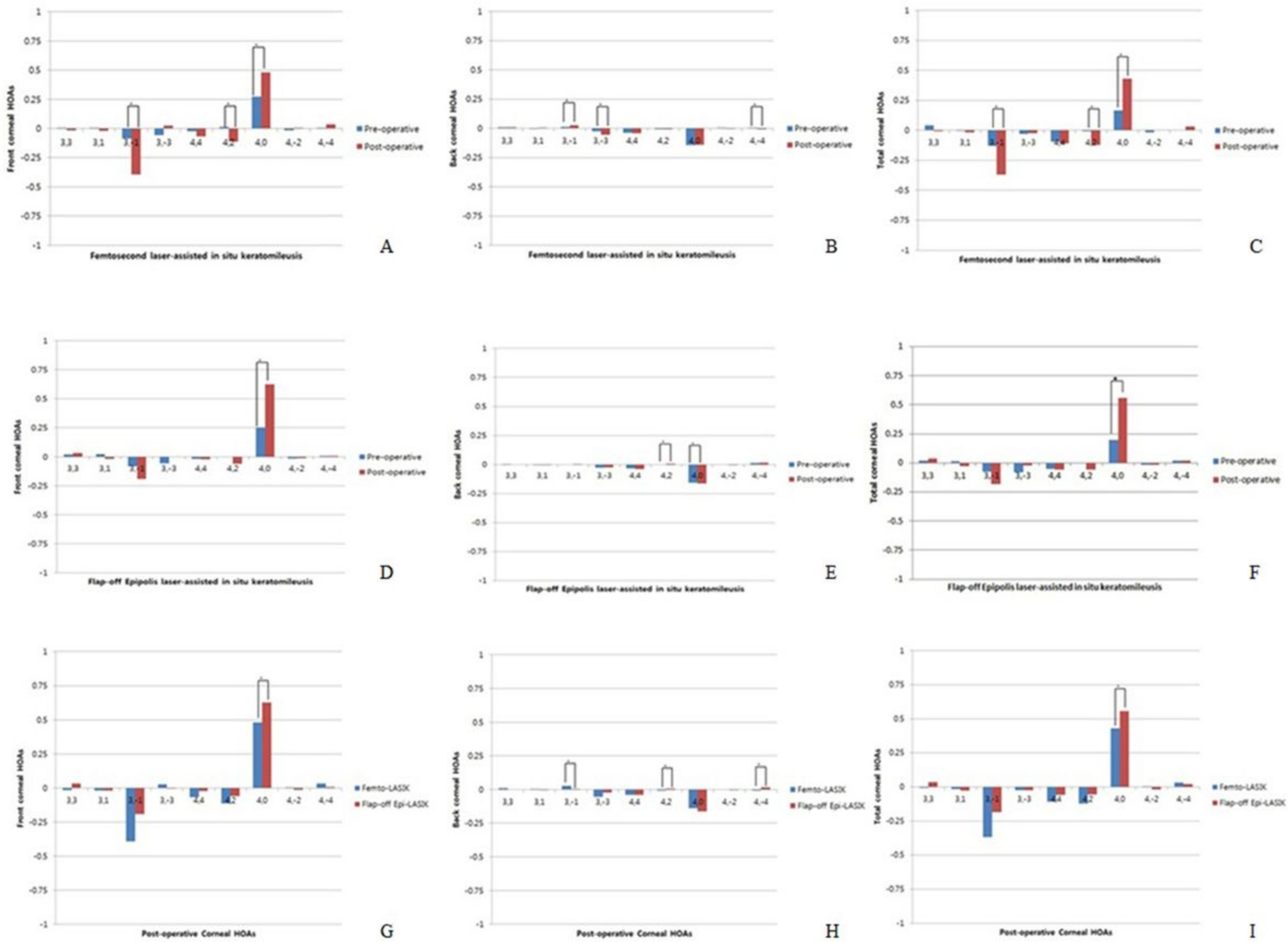

Figure 3

Comparison of the corneal higher-order aberrations (HOAs) changes betweenfemto-LASIK and flap-off epi-LASIK (A.The front corneal HOAs changes between pre- and postoperative in femto-LASIK; B. The back corneal HOAs changes between pre- and postoperative in femto-LASIK; C. The total corneal HOAs changes between pre- and postoperative in femto-LASIK; D. The front corneal HOAs changes between pre- and postoperative in flap-off epi-LASIK; E.The back corneal HOAs changes between pre- and postoperative in flap-off epi-LASIK; F. The total corneal HOAs changes between pre- and postoperative in flap-off epi-LASIK; G. The front corneal HOAs).