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ORIGINAL ARTICLE

Comparison of Femtosecond-Assisted Laser *in Situ* Keratomileusis and Wavefront-Guided Femtosecond-Assisted Laser *in Situ* Keratomileusis Procedures in Terms of High-Order Aberrations

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Abstract

Introduction: To compare the results of femtosecond-assisted laser *in situ* keratomileusis (FS-LASIK) and wavefront-guided FS-LASIK (WFG FS-LASIK) procedures in terms of high-order aberrations (HOAs).

Methods: One hundred and twenty-eight eyes of 64 patients with myopia and/or myopic astigmatism who had undergone FS-LASIK procedure comprised Group I. Their mean age was 27.87±5.49 (19–41) years. Thirty-two of them were male (50%) and 32 (50%) were female. One hundred and twenty-eight eyes of 64 patients with myopia and/or myopic astigmatism who had undergone WFG FS-LASIK procedure comprised Group II. Their mean age was 28.56±6.01 (19–42) years. Thirty-two of them were male (50%) and 32 (50%) were female. Two groups are compared with each other in terms of HOAs.

Results: In respect to age and sex, there was no significant difference between FS-LASIK and WFG FS-LASIK groups (p>0.050). Regarding pre-operative and post-operative spherical, cylindrical, and spherical equivalent values, uncorrected distance visual acuity, and corrected distance visual acuity, there was no significant difference between two groups (p>0.050). FS-LASIK induced more spherical aberration, coma, and trefoil than WFG FS-LASIK (p=0.000).

Discussion and Conclusion: In conclusion, both FS-LASIK and WFG FS-LASIK are effective and safe procedures in the treatment of myopia and myopic astigmatism. FS-LASIK induces more spherical aberration, coma, and trefoil than WFG FS-LASIK procedure, meaning it causes more HOAs.

Keywords: Aberration; coma; femtosecond-assisted laser *in situ* keratomileusis; spherical aberration; trefoil; wavefront-guided femtosecond-assisted laser *in situ* keratomileusis.

Assisted laser *in situ* keratomileusis (LASIK) is an effective and safe surgery for correction of myopia and myopic astigmatism. However, conventional excimer laser ablation can treat only lower order aberrations such as myopia, hyperopia, and astigmatism and frequently increases higher-order aberrations (HOAs) of cornea which may cause loss of contrast sensitivity, monocular diplopia, halos and glare in night vision, and decreased vision quality[1-5]. These HOAs degrade retinal image. Post-operative increased HOAs are caused by corneal flap creation, corneal

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lameller ablation resulting in asymmetric anterior surface flattening, mild decentration of the laser ablation, wound healing effects like epithelial hyperplasia, and forward shifting of the posterior cornea. Accommodation, aging, and pupil size are also influential[6-8].

Wavefront-guided LASIK (WFG LASIK) with iris registration may improve visual performance by reducing or eliminating both induced and pre-existing HOAs. Wavefront-optimized lasers have changed the ablation profile of conventional treatments by adding more prolate peripheral ablation, thereby reducing spherical aberration, however, they have no effect on other HOAs. Wavefront-guided ablation appears to have clear-cut benefit compared with wavefront-optimized ablation only for patients with significant pre-operative HOAs[9,10].

In this study, retrospectively femtosecond-assisted LASIK (FS-LASIK) procedure is compared with WFG FS-LASIK in terms of HOAs.

Materials and Methods

The study protocol was approved by the local ethics committee (Karatay University, Faculty of Medicine Ethics Committee, 29.11.2018-2018/006, Konya, Turkey). An informed written consent was obtained from the patients before the surgery. The study was carried out according to the tenets of the Declaration of Helsinki.

One hundred and twenty-eight eyes of 64 patients with myopia and/or myopic astigmatism who had undergone FS-LASIK procedure between February 2017 and June 2017 comprised Group I. One hundred and twenty-eight eyes of 64 patients with myopia and/or myopic astigmatism who had undergone WFG FS-LASIK procedure between February 2017 and June 2017 comprised Group II. All of the surgeries were performed by a single surgeon (SC). Patients included in the study did not have diabetes mellitus, connective tissue diseases, or any ocular diseases that might affect the vision. Patients wearing soft contact lenses were instructed to stop wearing them at least 1 week before the surgery. This duration was 4 weeks for hard contact lens wearers.

FS-LASIK procedures were performed by the Visumax femtosecond laser system (Carl Zeiss, Meditec AG, Jena, Germany) with a repetition rate of 500 KHz and a pulse energy of 150 nj, for flap creation. The ablation was performed with Wavelight EX500 (Alcon) laser system.

WFG FS-LASIK procedures were performed by the Visumax femtosecond laser system (Carl Zeiss, Meditec AG, Jena, Germany) with a repetition rate of 500 KHz and a pulse energy of 150 nj, for flap creation. Refraction and wavefront information gathered by Wavelight Oculyzer II (Alcon, GmbH-Am, Wolsfmatel S-91058 Ertagen, Germany) and Wavelight Allegro Topolyzer-VARIO (Alcon, GmbH-Am, Wolsfmatel S-91058 Ertagen, Germany) was transferred to Wavelight EX500 (Alcon) laser system. The ablation was performed, an eye tracker was used to perform accurate ablation on the center of pupil. After irrigation, the flap was repositioned.

After the surgical procedures, patients used topical antibiotic (Moxifloxacin 0.5%, Vigamox, Alcon, USA) 4 times a day for a week, topical steroid (dexamethasone Na phosphate 0.1%, Dexa-sine, Liba, USA) 4 times a day for 2 weeks, and a preservative-free topical lubricating drop (Na Hyaluronate 0.15%, Eyestil, SIFI, Italy) 4 times a day for 3 months.

Full ophthalmological examinations including uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), intraocular pressure measurement, fundus examination, and topographic measurements were performed preoperatively and 1st day, 1st week, 1st month, 3rd month, and 6th month after the operation. Corneal HOAs were measured by Wavelight Oculyzer II device and calculated using the Zernike polynomials, presented as root mean square (RMS, in μm) preoperatively, and 1st month and 6th month postoperatively.

For statistical analysis, SPSS version 22 program was used. For comparison of data, Chi-square test and t test were used. $P<0.05$ value was accepted as statistically significant.

Results

The mean age of Group I was 27.87±5.49 (SD) (19–41) years. Thirty-two of them were male (50%) and 32 (50%) were female. The mean age of Group II was 28.56±6.01 (SD) (19–42) years. Thirty-two of them were male (50%) and 32 (50%) were female. In respect to age, sex, pre-operative spherical, cylindrical, and spherical equivalent (SE) values, UDVA, CDVA, K values, central corneal thickness (CCT) values, flap diameter and thickness, optic zone diameter, ablation depth, and residual stromal bed thickness, there was no significant difference between the first (FS-LASIK) and second (WFG FS-LASIK) groups. The pre-operative and intraoperative patient characteristics are shown in Table 1.

In respect to post-operative spherical, cylindrical, and SE values, UDVA, and CDVA, there was no significant difference between the first (FS-LASIK) and second (WFG FS-LASIK) groups. Post-operative findings of the patients are shown in Table 2.

Table 1. The pre-operative and intraoperative patient characteristics

Parameters	FS-LASIK n=128	WFG FS-LASIK n=128	p
Age (years)	27.87±5.49 (SD) (19–41)	28.56±6.01 (SD) (19–42)	0.256
Sex (male/female)	28/27 (50%/50%)	27/28 (50%/50%)	0.885
Sphere (D)	−5.53±2.74 (−10.00–0.00)	−5.76±2.83 (−10.00–0.00)	0.224
Cylinder (D)	−1.43±1.34 (−5.00–0.00)	−1.51±1.29 (−5.00–0.00)	0.453
SE (D)	−6.04±2.01 (−10.00–−2.00)	−6.12±2.15 (−10.00–2.00)	0.199
UDVA (logMAR)	1.58±0.22 (1.00–2.00)	1.53±0.25 (1.00–2.00)	0.334
CDVA (logMAR)	0.03±0.03 (0.00–0.10)	0.02±0.02 (0.00–0.10)	0.976
K (D)	44.15±1.41 (40.9–46.7)	44.23±1.53 (40.6–46.9)	0.727
CCT (μm)	533.63±26.84 (501–603)	524.77±27.02 (504–609)	0.286
Flap diameter (mm)	8.9±0.35 (8–9)	8.80±0.33 (8–9)	0.865
Flap thickness (μm)	109.54±3.46 (110-110)	109.62±3.33 (100–110)	0.901
Optic zone diameter (mm)	6.46±0.30 (6–7)	6.54±0.34 (6–7)	0.871
Ablation depth (μm)	80.51±26.24 (32–159)	79.93±28.42 (28–161)	0.814
Residual stromal bed thickness (μm)	321.34±21.51 (299–404)	327.13±22.11 (298–403)	0.422

FS-LASIK: Femtosecond-assisted laser in situ keratomileusis; WFG FS-LASIK: Wavefront-guided femtosecond-assisted laser in situ keratomileusis; D: Diopter; SE: Spherical equivalent; UDVA: Uncorrected distance visual acuity; CDVA: Corrected distance visual acuity; K: Keratometry; CCT: Central corneal thickness; SD: Standard deviation; P-value; calculated using t-test and for comparison of percentages calculated using Chi-square test.

In respect to pre-operative HOAs, there was no significant difference between the first (FS-LASIK) and second (WFG FS-LASIK) groups. However, post-operative HOAs of the first (FS-LASIK) group were significantly greater than those of the second (WFG FS-LASIK) group (p=0.000). The pre-operative and post-operative corneal HOAs are shown in Table 3.

Discussion

Wavefront aberration is highly dependent on pupil size, with increased HOAs apparent as the pupil dilates. HOAs also increase with age. Especially spherical aberration and coma may increase after conventional surface ablation or LASIK for myopia. This is correlated with the degree of pre-operative myopia. After standard hyperopic laser vision correction, HOAs increase in the opposite direction[11,12].

HOAs have become an important issue in refractive surgery field, because HOAs can affect post-operative visual quality. Decreased contrast sensitivity, diplopia, glare, and halos in night vision may occur due to HOAs generated after corneal ablation[13].

There are two main methods of using wavefront measurements in laser eye surgery. The first is the wavefront-optimized ablations in which the adjustments are done on average population data and the ablation profile is based on an ideal model without evaluating the patient's own aberrometry. Its aim is to optimize the asphericity of cornea to precompansate for the expected HOAs in the average eye. The second is the wavefront-customized ablations, also known as wavefront-guided ablations, in which the patient's own aberration profile is taken into consideration to correct both induced and preexisting HOAs[14].

In this study, visual outcomes and corneal aberrations in eyes undergone FS-LASIK and WFG FS-LASIK procedures are evaluated. In respect to visual outcomes, there were no significant differences between two groups. However, FS-LASIK induced more spherical aberration, coma, and trefoil than WFG FS-LASIK procedure.

Wang et al.[15] observed that after FS-LASIK changes in corneal aberration occurred mainly on the anterior surface, which may have a significant effect on visual quality. Lee et al.[16] found that the changes of posterior corneal surface forward shift showed no difference among LASIK, LASEK, and WFG LASEK in moderate myopia. HOAs were significantly increased after LASIK and LASEK. The changes of HOAs were significantly smaller in WFG LASEK than LASIK or LASEK. Toda et al.[17] reported that both customized ablation systems used in LASIK achieved excellent results in predictability and visual function. The wavefront-guided ablation system may have some advantages in quality of vision. Vongthongsri[18] found that LASIK with both conventional ablation and wavefront-guided customized ablation resulted in the same BSCVA 1 month after LASIK. Pre-operative and 1-month post-operative HOAs were not statistically different following LASIK between ablation types. Caste et al.[19] reported that custom cornea WFG LASIK surgery appears safe and effective and provides clinical benefits that appear to exceed those of conventional surgery. Fares et al.[20] reported that meta-analysis showed no clear

Table 2. Post-operative findings of the patients

Parameters	FS-LASIK n=128	WFG FS-LASIK n=128	p
1-month post-operative spherical value (D)	−0.02±0.22 (SD) (−1.00–0.75)	−0.06±0.24 (SD) (−1.00–0.75)	0.221
6-month post-operative spherical value (D)	−0.04±0.17 (−1.00–0.50)	−0.03±0.19 (−1.00–0.50)	0.313
1-month post-operative cylindrical value (D)	−0.12±0.23 (−1.00–0.00)	−0.10±0.22 (−0.75–0.00)	0.466
6-month post-operative cylindrical value (D)	−0.05±0.14 (−1.00–0.00)	−0.04±0.13 (−0.50–0.00)	0.542
1-month post-operative SE value (D)	−0.06±0.25 (−1.00–0.75)	−0.10±0.35 (−1.25–0.75)	0.347
6-month post-operative SE value (D)	−0.06±0.15 (−1.00–0.00)	−0.05±0.19 (−1.00–0.50)	0.556
1-month post-operative UDVA (logMAR)	0.03±0.04 (0.00–0.30)	0.04±0.05 (0.00–0.20)	0.876
6-month post-operative UDVA (logMAR)	−0.04±0.06 (−0.10–0.20)	−0.04±0.08 (−0.10–0.20)	0.689
1-month post-operative CDVA (logMAR)	0.006±0.03 (0.00–0.10)	0.006±0.03 (0.00–0.10)	0.792
6-month post-operative CDVA (logMAR)	−0.05±0.05 (−0.10–0.10)	−0.06±0.06 (−0.10–0.10)	0.529

FS-LASIK: Femtosecond-assisted laser in situ keratomileusis; WFG FS-LASIK: Wavefront-guided femtosecond-assisted laser in situ keratomileusis; D: Diopter; SE: Spherical equivalent; UDVA: Uncorrected distance visual acuity; CDVA: Corrected distance visual acuity; SD: Standard deviation, P-value; calculated using t-test.

Table 3. The pre-operative and post-operative corneal HOAs

Parameters	FS-LASIK n=128	WFG FS-LASIK n=128	p
Pre-operative total HOA (μm)	0.19±0.09 (SD) (0.05–0.50)	0.19±0.09 (SD) (0.03–0.47)	0.873
1-month post-operative total HOA (μm)	0.37±0.10 (0.10–0.59)	0.23±0.10 (0.10–0.48)	0.000
6-month post-operative total HOA (μm)	0.35±0.11 (0.10–0.57)	0.21±0.11 (0.10–0.48)	0.000
Pre-operative SA (μm)	0.17±0.04 (0.03–0.30)	0.18±0.05 (0.05–0.35)	0.543
1-month post-operative SA (μm)	0.31±0.03 (0.10–0.46)	0.21±0.05 (0.10–0.37)	0.000
6-month post-operative SA (μm)	0.30±0.06 (0.20–0.45)	0.19±0.06 (0.20–0.36)	0.000
Pre-operative coma (μm)	0.07±0.01 (0.01–0.18)	0.07±0.01 (0.01–0.18)	0.883
1-month post-operative coma (μm)	0.17±0.02 (0.04–0.25)	0.11±0.02 (0.05–0.18)	0.000
6-month post-operative coma (μm)	0.17±0.03 (0.05–0.23)	0.11±0.03 (0.07–0.21)	0.000
Pre-operative trefoil (μm)	0.06±0.03 (0.03–0.19)	0.06±0.03 (0.02–0.18)	0.725
1-month post-operative trefoil (μm)	0.16±0.01 (0.10–0.26)	0.11±0.01 (0.10–0.20)	0.000
6-month post-operative trefoil (μm)	0.16±0.02 (0.13–0.25)	0.11±0.01 (0.10–0.22)	0.000

FS-LASIK: Femtosecond-assisted laser in situ keratomileusis; WFG FS-LASIK: Wavefront-guided femtosecond-assisted laser in situ keratomileusis; HOA: High-order aberration; SA: Spherical aberration; SD: Standard deviation, P-value; calculated using t-test.

evidence of a benefit of wavefront-guided over non-wavefront-guided ablations. However, there was a lack of standardized reporting of UDVA better than 20/20, which might mark an advantage in wavefront-guided treatment. With high preexisting HOAs, wavefront-guided has advantages over non-wavefront-guided treatment. Kung et al.[21] reported that the wavefront-guided preference was more pronounced in patients with lower baseline HOAs. Keir et al.[22] observed that despite an increase in HOAs, WFG LASIK yields excellent visual acuity and contrast sensitivity. Spherical aberration, which increases the most following non-WFG LASIK, showed no significant change. Manche et al.[23] reported that WFG LASIK remains a well-tolerated and effective keratorefractive procedure, with a trend toward superiority. Chen et al.[24] reported that WFG LASIK not only afforded clinically measurable improvements in vision but also significant improvements in subjective functional vision and vision-related quality of life 1 year after surgery. Agarwal et al.[25] reported that LASIK performed using the WaveLight® EX500 excimer and WaveLight® FS200 laser platform provided improved contrast sensitivity and visual acuity with minimal introduction of HOAs, making it a suitable platform for low myopic astigmatic patients.

Conclusion

Both FS-LASIK and WFG FS-LASIK are effective and safe procedures in the treatment of myopia and myopic astigmatism. FS-LASIK induces more spherical aberration, coma and trefoil than WFG FS-LASIK procedure.

Ethics Committee Approval: Karatay University, Faculty of Medicine Ethics Committee, 29.11.2018-2018/006, Konya, Turkey.

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