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Comparison of high order aberration after conventional and customized ablation in myopic LASIK in different eyes of the same patient

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Abstract: Purpose: To verify whether there exists any difference in higher order aberrations after undergoing myopic LASIK (laser in situ keratomileusis) with conventional ablation and customized ablation in different eyes of the same patient. Methods: This was a prospective randomized study of 54 myopic eyes (27 patients) that underwent LASIK using the Nidek EC-5000 excimer laser system (Nidek, Gamagori, Japan). Topography-guided customized aspheric treatment zone (CATz) was used in the first eye of the patient (study group) and the other eye of the same patient was operated on with conventional ablation (control group). Higher order aberrations [root-mean-square (RMS) in the 5-mm zone] of both groups were observed with the Nidek OPD-Scan aberrometer before and 3 months after LASIK. Preoperative mean refractive error was similar between two eyes of the same patient ($t=-0.577$, $P>0.05$). Results: Preoperatively, higher order aberrations (RMS in the 5-mm zone) in the CATz ablation and conventional groups were (0.3600±0.0341) μm and (0.2680±0.1421) μm, respectively. This difference was not statistically significant ($t=1.292$, $P>0.05$). Three months after LASIK, higher order aberrations (RMS in 5-mm zone) in the CATz ablation and conventional groups were (0.3627±0.1510) μm and (0.3991±0.1582) μm, respectively. No statistically significant difference was noted between pre- and postoperative higher order aberrations in the CATz group ($t=-0.047$, $P>0.05$). However, a statistically significant increase in higher order aberrations was observed after conventional ablation ($t=-5.261$, $P<0.05$). A statistically significant difference was noted in the increase of higher order aberrations after LASIK between groups ($t=-2.050$, $P=0.045$). Conclusion: LASIK with conventional ablation and topography-guided CATz ablation resulted in the same BSCVA (best spectacle-corrected visual acuity) 3 month after LASIK. Higher order aberrations were increased, but the increase of higher order aberrations after customized ablation treatment was less than that after conventional ablation.

Key words: Myopic LASIK (laser in situ keratomileusis), Higher order aberrations, Customized ablation
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INTRODUCTION

The concept of customized ablation in excimer corneal refractive surgery was introduced recently (Mrochen *et al*., 2000). This new technique tended to facilitate better visual outcome by reducing or eliminating existing ocular aberrations. The worldwide application of conventional ablation in LASIK (laser in situ keratomileusis) aroused general concern on whether there are differences in visual outcome and high order aberration when comparing conventional ablation LASIK with customized ablation. However, each of these studies was limited by the small number of eyes studied (Mrochen *et al*., 2001a; Nuijts *et al*., 2002; Phusitphoykai *et al*., 2003).

This prospective randomized study aimed at analyzing the higher order aberrations before and after myopic LASIK and to verify whether any difference in induced higher order aberrations occurs with conventional ablation compared to customized aspheric treatment zone (CATz) ablations in eyes of the same patient.

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PATIENTS AND METHODS

Fifty-four eyes of 27 consecutive patients who underwent LASIK for myopia at the Zheyi Eye Center from Nov. 2004 to Dec. 2004 were studied. Mean patient age was 23.965 years (ranging from 18 to 42 years). The preoperative spherical equivalent refractions in the entire series ranged from −2.62 to −10.00 Diopters (D). All patients completed 3-month follow-up. The study was approved by the Ethical Committee of Zheyi Eye Center, the First Affiliated Hospital, School of Medicine, Zhejiang University. Informed consent was obtained from all patients after a thorough explanation of the procedure and its potential benefits and risks.

Preoperatively, all patients had a complete ophthalmic examination including uncorrected visual acuity (UCVA) and best spectacle-corrected visual acuity (BSCVA) using the Snellen visual chart. Manifest and cycloplegic refraction, corneal topography (Orbscan, Orbtek Inc., Salt Lake City, Utah), applanation tonometry, slit-lamp examination of the anterior segment, and direct or indirect ophthalmoscopy were performed. Corneal thickness was measured by ultrasonic pachymetry KSX 1000 (OTI Medical Services Inc.). No eye had ocular abnormalities other than a refractive error. Preoperatively, BSCVA was ≥20/25 in each eye, and no eye had previous ocular surgery.

The higher order root-mean-square (RMS) wavefront aberrations for combined third to sixth Zernike aberration orders at 5-mm zone of both groups were measured by the Nidek OPD-Scan (Nidek, Gamagori, Japan) aberrometer before and 3 months after surgery.

Customized aspheric treatment zone ablation was performed randomizedly in the first eye of each patient (study group). Conventional ablation was performed in the other eye of the same patient (control group).

Three or more consecutive OPD-Scan measurements were taken without pupil dilation in all eyes, the best OPD map of the study group eye was chosen to put into Final Fit software designing the CATz treatment profile. The treatment profile was placed into the Nidek EC-5000 CXII excimer laser system. All examinations were performed by the same person using the same procedure.

A 9.5-mm diameter flap with mean thickness of 130 μm was created with a superior hinge with a Moria M2 110 microkeratome (Moria, Antony, France). The ablation was performed using the 193 nm conventional scanning-silt laser system in conventional eye and Super Flex Scan laser system with a combined scanning slit and 2.0-mm flying spot in the CATz group. The 200 Hz eye tracking system was used in both eyes and with a combined torsion error detector in the CATz group during laser ablation.

All patients were treated by the same surgeon at the Zheyi Eye Center. No flap complications (e.g., epithelial defects or microstriae) were observed in any eye. No eye developed epithelial ingrowth or sterile interface inflammation or steroid glaucoma.

SPSS for Windows V 10.0 (SPSS, Chicago, Ill) was used for statistical analysis. Result of HOA (high order aberrations) was expressed as mean±standard deviation. Result of uncorrected visual acuity (UCVA) was expressed as percent.

RESULTS

Refractive outcomes

Table 1 shows the UCVA distribution in the two groups at 3 months after LASIK. *UCVA*≥20/20 was achieved in 70.37% of eyes in both groups. *UCVA*≥20/25 was achieved in 92.59% of eyes in the CATz group and 88.89% of eyes in the conventional group. Their difference was not statistically significant (x^2=0.011, P=0.917).

Table 1 Uncorrected visual acuity (UCVA) of Snellen after 3 months LASIK

UCVA	Number of eyes (%)	
	Study group	Control group
≥20/15	4 (14.81)	5 (18.52)
≥20/20	19 (70.37)	19 (70.37)
≥20/25	25 (92.59)	24 (88.89)
≥20/30	27 (100)	27 (100)

x^2= 0.011, P=0.917

The mean preoperative and 3-month postoperative spherical equivalents of the subjective manifest refraction in CATz and conventional groups are shown in Table 2. Mean refractive error was similar between both eyes of the same patient before and after surgery.

Table 2 Spherical equivalent refraction outcomes (mean±standard deviation, D)

Group	Preoperative	Postoperative
Study	−5.43±2.13	−0.05±0.36
Control	−5.33±1.98	0.03±0.43
t	−0.577	1.321
P	0.569	0.345

Changes in higher order aberrations

The mean preoperative and 3-month postoperative higher order RMS wavefront aberrations for combined third to sixth Zernike aberration orders at 5-mm zone in the CATz and conventional groups are shown in Table 3. No statistically significant difference was noted in preoperative higher order aberrations between groups (t=1.292, P>0.05). The data showed that higher order RMS wavefront aberration was increased after LASIK in both groups. This difference was larger than that of the study group and was statistically significant in the control group (t=−5.216, P=0.000), but was not statistically significant in the study group (t=−0.047, P=0.963). A statistically significant difference was noted in the increase of higher order aberrations between the two groups (t=−2.050, P=0.045), with the control group showing larger increase in higher order RMS from pre- to postoperatively.

Higher order aberrations were recorded and analyzed separately as T. Coma, T. Trefoil and Spherical aberration (Table 3). No significant difference was noted in each HOA between groups preoperatively (P>0.05). T. Coma and T. Trefoil were increased after LASIK in both groups. These increases were statistically significant in the control group (P<0.01), but not in the study group (P>0.05). Spherical aberration was increased significantly after LASIK in both groups. A statistically significant difference was noted in the increase of T. Coma aberrations after LASIK between groups (t=−2.011, P=0.049), but not in T. Trefoil and Spherical aberration (t=−1.394, P=0.169; t=0.020, P=0.842, respectively).

DISCUSSION

Many studies showed that conventional LASIK is an effective and safe surgery for correction of myopia. However, conventional treatments can only correct lower order aberrations and frequently increase high order aberration of the cornea and change the relative contributions of coma and spherical aberration (Oshika *et al*., 1999). It is well known that up to 30% of patients experience night vision problems after LASIK such as glare and halo, decreased contrast sensitivity, and poor subjective vision despite excellent objective uncorrected visual acuity (UCVA). It is believed that these complaints are caused by an increase in postoperative higher order aberrations (Mrochen *et al*., 2001b; Moreno-Barriuso *et al*., 2001). Factors that may cause an increase of optical aberrations postoperatively are variables in the LASIK procedure including creation of the corneal flap, corneal lamellar ablation resulting in asymmetric anterior surface flattening, mild decentration of the laser ablation, and wound healing effects such as epithelial hyperplasia and forward shifting of the posterior cornea. Other factors may include accommodation, aging, and pupil size (Wilson *et al*., 2001; Seitz *et al*., 2001; Baek *et al*., 2001).

Customized LASIK may have several advantages over conventional LASIK techniques. The greatest benefit is the potential for reducing post-LASIK night-vision problems, which are frequently caused by an increase in aberrations postoperatively. Customized LASIK may decrease the amount of induced aberration and has the potential to reduce pre-existing aberrations. Mrochen *et al*.(2001a) reported super vision (*BSCVA*>20/10) after wavefront-guided LASIK in 16% of eyes. Other studies did not reach the same conclusion: Phusitphoykai *et al*.(2003) and Vongthongsri *et al*.(2002) reported that LASIK with conventional ablation and wavefront-guided customized ablation resulted in the same BSCVA 1 month after LASIK, and that high order aberrations were not statistically different following

Table 3 Higher order aberrations (RMS in 5-mm zone) (mean±standard deviation, μm)

Group	HOA		T. Coma		T. Trefoil		Spherical aberration	
	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
Study	0.3600±0.0341	0.3627±0.1510	0.1139±0.0713	0.1310±0.0864	0.2357±0.1740	0.2560±0.1558	0.0527±0.0465	0.0969±0.0600**
Control	0.2680±0.1421	0.3991±0.1582**	0.1023±0.0495	0.1764±0.0874**	0.2029±0.1490	0.2973±0.1381**	0.0463±0.0329	0.0870±0.0437**

** Pair t test P<0.01

LASIK between the two ablation types. Our clinical study showed that the BSCVA is not significantly different and that higher order aberrations are increased after LASIK whether the treatment was conventional or customized, but the increase of higher order aberrations after customized ablation was less than that after conventional ablation. A statistically significant difference was noted in the increase of T. Coma aberrations after LASIK between groups, but not in T. Trefoil and Spherical aberration. Difference in corneal flap could affect aberration pattern (Vongthongsri *et al*., 2000) different pupil size and ablation zone; different aberrometry, corneal epithelial changes after LASIK, or even nomogram or software changes may produce changes in wavefront aberration (Schweigerling *et al*., 2002; Miller *et al*., 2002).

Studies comparing standard LASIK in control eyes versus customized LASIK within the same patient are more likely to accurately detect differences as opposed to studies in which standard and customized treatments are performed and compared among two different groups of patients. Three-month data reported should incorporate wound-healing effects. Our main purpose was to control the healing process variable and other individual factors by comparing ablation types in the same patient. The result of this study does not allow us to conclude that LASIK with topography-guided customized aspheric treatment zone (CATz) improves visual outcome, but we did find that customized ablation induces less increase of higher order than conventional aberrations ablation. It will be interesting to compare CATz ablation with conventional ablation with different optical and transition zones or analysis diameter. Further studies are needed to evaluate quality of vision, pupil size and wavefront aberrations

References

Baek, T., Lee, K., Kagaya, F., Tomiokoro, A., Amano, S., Oshika, T., 2001. Factors affecting the forward shift of posterior corneal surface after laser in situ keratomileusis. *Ophthalmology*, **108**(2):317-320. [doi:10.1016/S0161-6420(00)00502-9]

Miller, J.M., Anwaruddin, R., Strub, J., Schwiegerling, J., 2002. Higher order aberrations in normal, dilated, intraocular lens, and laser in situ keratomileusis corneas. *J. Refract Surg.*, **18**(5 Suppl.):S579-S583.

Moreno-Barriuso, E., Lloves, J.M., Marcos, S., Navarro, R., Llorente, L., Barbero, S., 2001. Ocular aberrations before and after myopic corneal refractive surgery: LASIK-induced changes measured with laser ray tracing. *Invest. Ophthalmol. Vis. Sci.*, **42**(6):1396-1403.

Mrochen, M., Kaemmerer, M., Seiler, T., 2000. Wavefront-guided laser in situ keratomileusis: early results in three eyes. *J. Refract Surg.*, **16**(2):116-121.

Mrochen, M., Kaemmerer, M., Seiler, T., 2001a. Clinical results of wavefront-guided laser in situ keratomileusis 3 months after surgery. *J. Cataract Refract. Surg.*, **27**(2): 201-207. [doi:10.1016/S0886-3350(00)00827-0]

Mrochen, M., Kaemmerer, M., Mierdel, P., Seiler, T., 2001b. Increased higher-order optical aberrations after laser refractive surgery: a problem of subclinical decentration. *J. Cataract Refract. Surg.*, **27**(3):362-369. [doi:10.1016/S0886-3350(00)00806-3]

Nuijts, R.M., Nabar, V., Hament, W.J., Eggink, F.A., 2002. Wavefront-guided versus standard laser in situ keratomileusis to correct low to moderate myopia. *J. Cataract Refract. Surg.*, **28**(11):1907-1913. [doi:10.1016/S0886-3350(02)01511-0]

Oshika, T., Klyce, S.D., Applegate, R.A., Howland, H.C., El Danasoury, M.A., 1999. Comparison of corneal wavefront aberrations after photorefractive keratectomy and laser in situ keratomileusis. *Am. J. Ophthalmol.*, **127**(1): 1-7. [doi:10.1016/S0002-9394(98)00288-8]

Phusitphoykai, N., Tungsiripat, T., Siriboonkoom, J., Vongthongsri, A., 2003. Comparison of conventional versus wavefront-guided laser in situ keratomileusis in the same patient. *J. Refract Surg.*, **19**(2 Suppl.):S217-S220.

Schweigerling, J., Snyder, R.W., Lee, J.H., 2002. Wavefront and topography: kerato-induced corneal changes demonstrate that both are needed for customized ablation. *J. Refract Surg.*, **18**(5 Suppl.):S584-S588.

Seitz, B., Torres, F., Langenbucher, A., Behrens, A., Suarez, E., 2001. Posterior corneal curvature changes after myopic laser in situ keratomileusis. *Ophthalmology*, **108**(4): 666-672. [doi:10.1016/S0161-6420(00)00581-9]

Vongthongsri, A., Srivannaboon, S., Horatanaruang, O., Nariptaphan, P., 2000. Laser in situ keratomieusis corneal flap creation with the Nidek MK-2000 and the Carriazo Barraquer microkeratomes. *J. Refract Surg.*, **16**(2 Suppl.): S272-S275.

Vongthongsri, A., Phusitphoykai, N., Naripthapan, P., 2002. Comparison of wavefront-guided customized ablation vs conventional ablation in laser in situ keratomileusis. *J. Refract Surg.*, **18**(3 Suppl.):S332-S335.

Wilson, S.E., Mohan, R.R., Hong, J.W., Lee, J.S., Choi, R., Mohan, R.R., 2001. The wound healing response after laser in situ keratomileusis and photorefractive keratectomy: elusive control of biological variability and effect on custom laser vision correction. *Arch. Ophthalmol.*, **119**(6):889-896.