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Topography-guided treatment of decentered laser ablation using LaserSight's excimer laser

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PURPOSE. *To assess the efficacy of topography-guided laser ablation for correction of previously decentered laser ablation using LaserSight's excimer laser.*
METHODS. *Re-treatment was performed to correct decentered ablation using LaserSight's excimer laser for 18 patients who previously underwent LASIK surgery for myopia correction in both eyes. For each patient, only the decentered eye was re-treated while the other asymptomatic eye forms a control group for this study. Measurements were conducted on ablation center, best spectacle-corrected visual acuity (BSCVA), contrast sensitivity and corneal aberrations pre- and post-operatively.*
RESULTS. *For the retreated 18 eyes, the mean decentration was significantly reduced from 1.32±0.28mm to 0.61±0.23mm post-operatively (t=16.24, p<0.001), and with a significant improvement in mean BSCVA from 0.08±0.09 logMAR to 0.01±0.11 logMAR (t=4.58, p<0.001). The post-operative contrast sensitivity at the spatial frequencies (SF) of 1.00 and 0.70 was significantly improved (p<0.05 for both SFs). Corneal higher-order aberrations (HOAs), including the coma-like aberrations and spherical aberration, were decreased. In comparing the measurements for the retreated group to those for the control group, no significant difference was found either in decentration or in BSCVA, but the contrast sensitivity at 0.70 was lower and the level of corneal aberrations was higher.*
CONCLUSIONS. *Topography-guided ablation with LaserSight excimer laser is effective to correct decentered ablation. However, the re-treated eye is still inferior to the eye with originally centered ablation in corneal optical quality or visual performance. (Eur J Ophthalmol 2008; 18: 708-15)*

KEY WORDS. *LASIK, Topography-guided, Decentration, Aberrations*

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INTRODUCTION

In daily practice of refractive surgery, decentered ablation has been reported for a small proportion of patients who received photorefractive keratectomy (PRK) or laser in situ keratomileusis (LASIK). Decentration of the ablation can be recognized from decentered pattern of corneal power map in corneal topography test (1), and further diagnosed with typical symptoms, including severe visual distortion, astigmatism, glare, halos, monocular diplopia, and even loss of best spectacle-corrected visual acuity (BSCVA). Several techniques have been developed in clinical practices to treat the decentration of ablation, such as rigid gas permeable contact lenses (RGP CL) and further re-treatment of laser surgery. However, the RGP CL may not work for many patients who are hypersensitive and have

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discomfort with the CL (2). On the other hand, some surgical techniques such as laser ablations using various masking techniques (3, 4), selected zonal laser ablation (5), and diametric laser ablation (6) were used with only limited success and predictability. The treatment of decentration is one of the most difficult complications of corneal refractive surgery (7).

Since the decentration of ablation can be easily demonstrated with corneal topography, it is reasonable to retreat it with topography-guided laser ablation technique. During the last few years, the development of topography-guided laser ablation enables surgeons to perform precise treatment, including the previously difficult correction of decentration. Recently, several studies with topography-guided ablation techniques have been reported with significant improvement in visual qualities for the retreated eyes (8-10). However, evaluation of the topography-guided ablation techniques in previous studies was focused only on the change in optical quality or visual performance after the retreatment, without comparing the turnouts of retreatment to those of the ablations which were succeed at the first time. In this study, a retrospective evaluation of the topography-guided ablation technique in correcting decentration of ablation was made by comparing visual quality and corneal aberration between retreated eyes and the eyes with originally centered ablation.

METHODS

Patients

Eighteen eyes with decentration of ablation from 18 patients (10 male and 8 female) were retreated with the LaserSight topography-guided laser system (LaserSight Technologies, Inc., Winter Park, FL). While the 18 retreated eyes had apparently decentered ablation pattern in corneal map and also with various decentration symptoms such as halos, ghost images, and/or glare, the other 18 eyes were successfully ablated in previous surgeries, with or without mild decentration. The 18 retreated eyes, therefore, formed an experimental group while the other 18 eyes made a control group. The 18 patients underwent myopic LASIK treatment in both eyes between February 2004 and July 2005 in the Shanghai Peace Eye Hospital (Shanghai, China). The initial spherical equivalent (before first LASIK) was –7.92±2.47 D (range from –3.25 to –14.0 D) in the experimental group versus –7.90±2.40 D (range from –4.5 to –13.75 D) in the control group. The mean age was 27.7±9.4 years old (with a range of 20 to 45 years) at the time of retreatment. The period between the original LASIK surgery and the retreatment ranged from 6 to 26 months. The average follow-up time was 6±2.4 months. In every case, informed consent of the patient was obtained before surgery. All surgeries were performed by the same surgeon (L.W.) at Shanghai Peace Eye Hospital (Shanghai, China).

Clinical examination

Preoperative examinations included tests for visual acuity (uncorrected VA [UCVA] and BSCVA), refraction, intraocular pressure, corneal topography, pachymetry, slit-lamp examinations, contrast sensitivity, corneal topography, and corneal aberration.

UCVA and BSCVA were tested both pre- and postoperatively. Refraction was measured preoperatively under cycloplegia and postoperatively using the fogging technique (high plus). Contrast sensitivity was measured using a KM-888 Contrast Glaretester (Wuxi Kangming Medical Device Corp, Wuxi, China) under low luminance condition. The KM-888 has six types of ring-like targets with 12 levels of contrast for measurement. The target sizes are 6.3°, 4°, 2.5°, 1.6°, 1.0°, and 0.7° visual angles, which correspond to 5, 7.5, 12, 18.5, and 43 cycles/degree (cpd) of the spatial frequency. The corneal topography system AstraMax (LaserSight) was used to measure anterior corneal topography and corneal aberrations. The accuracy of the topography system was calibrated before examination with the model eye provided by the manufacturer. Topography examinations were performed by skilled technicians at least six times consecutively for each eye. These maps were captured for analysis. The anterior corneal asphericity and corneal high order aberrations (HOAs), including coma-like and spherical aberrations, were acquired from an average of three repeatable and highly reproducible maps which were selected from the six consecutive maps by the AstraPro 2.2Z software. The average of three repeatable and highly reproducible maps was used in customized ablation pattern design. Decentration was measured on the topographer and was defined as the distances between the apex of the cornea and the center of the ablation zone after the retreatment.

Customized ablation pattern

The LaserSight topography-guided laser ablation system consisted of an AstraMax stereo-topographer, an AstraPro2.2z custom ablation planning software, and a LaserScan LSX (LIS5.3 version, AstraScanXL configuration, LaserSight Technologies, Inc.). The AstraPro 2.2z was used to prepare the ablation pattern, and the associated software links data obtained with the use of the AstraMax elevation topography to the small-spot scanning LaserScan LSX laser, thereby generating a topography-guided ablation pattern.

Preliminary steps of the procedure required obtaining an average of three repeatable and highly reproducible maps which were selected from six consecutive maps by the AstraPro 2.2Z software.

The AstraMax data, together with a corrected manifest refraction and an asphericity index of desired postoperative corneal shape, were processed by the AstraPro 2.2z software to obtain a customized altimetric ablation profile, which was then transferred, via a 3.5-inch floppy, to the LaserScan LSX. The ablation profile was designed to obtain a postoperative corneal shape with an asphericity index of –0.26 in all eyes and emmetropic refraction in 16 of the eyes. Mild myopia was targeted in two eyes because of impending presbyopia. The optical zone was always enlarged and deepened with respect to the default value suggested by the software. The average diameter was 6.2±0.38 mm.

Surgery technique and follow-up

LASIK enhancement procedures were performed in standardized methods with an initial flap lift. Before the flap was lifted, the patient was asked to fixate on a blinking red LED light in the center of an illuminated ring. The center of reflex ring on the cornea can be thought as the apex of the cornea when the patient fixated on the red LED light. Since the eye tracker tracks the center of the pupil, the software allows for an offset (the difference between the pupil center and the treatment center) to be entered so that the scanning laser beam can be “offset” to treat the correct ablation center. The cornea was marked using a gentian violet stain corneal marker. Then, the flap edge from the previous surgery was traced using a hook, the edges were lightly teased, and the separation between the flap and the corneal bed was extended with a blunt iris spatula. The flap was then fully lifted and folded onto itself. During laser ablation, the patient was asked repeatedly to fixate on the blinking red LED. Fortunately, all patients were able to maintain fixation during the laser treatment because the ablation could made in a short time. After performing the laser ablation, the flap was floated back into position, and the stromal bed was irrigated with balanced salt solution (BSS). Flap alignment was checked using gentian violet premarkings on the cornea, and a striae test was performed to ensure proper flap adherence.

Dexamethasone 0.1% and tobramycin 0.3% (Tobradex, Alcon) were then instilled. The patients rested for 30 minutes with their eyes closed, and then the flap was rechecked and the patient dismissed. Postoperatively, fluorometholone 0.1% was prescribed four times a day (QID) for 1 week, and then tapered within 1 month. After the initial early evaluation at 24 hours, the scheduled follow-up appointments were set at 1 week, 1 month, 3 months, and 6 months later.

Data analysis

The efficacy of enhancement was assessed both subjectively and objectively. Subjectively, patients were asked to rate improvement as follows: worse, none, mild (small diminution of symptoms), moderate (significant diminution, but still experiencing some difficulties in dim conditions), or marked (complete or almost complete disappearance of the symptoms). Objectively, changes in ablation center, visual acuity, contrast sensitivity, and cornea aberrations for the retreated eyes were analyzed and compared with those from the control group.

Statistical analysis was performed using Excel (Microsoft, Inc.) and SPSS for windows v 11.0.1. Results are presented as means ± 1 standard deviation (SD) and were compared with the Student two-tailed *t*-test for paired samples. A p value of less than 0.05 was considered statistically significant.

RESULTS

Decentration distance

The average decentration was significantly reduced from 1.32±0.28 mm (range 0.82 to 1.9 mm) to 0.61±0.23 mm (range 0.25 to 1.06 mm) after enhancement ($t=16.24$, $p<0.001$). No significant difference was found when the

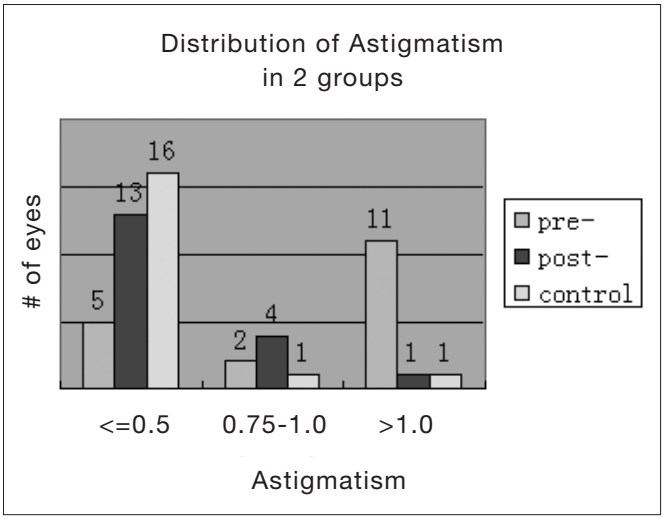

Fig. 1 - *The distribution of astigmatism in both groups. The mean cylindrical refractive error was significantly less than preoperative levels (p<0.01), and was not significantly different compared to the control.*

decentration after retreatment was compared to that of the control group with a mean decentration of 0.54±0.16 mm (range 0.2 to 0.85 mm) (t=2.04, p>0.05).

Visual acuity

The mean UCVA was improved significantly from 0.43±0.21 logMAR (range 0.1 to 0.7) to 0.03±0.11 logMAR (range –0.1 to 0.3) (t=9.28, p<0.001), whereas the mean BSCVA improved from 0.08±0.09 logMAR (range 0 to 0.3) to 0.01±0.11 logMAR (range –0.1 to 0.3), significantly (t=4.58, p<0.01). Moreover, no eye lost a line of BSCVA; two eyes gained two lines, nine eyes gained one line, and the other eyes remained preoperative BSCVA. The mean gain was 0.72 lines for BSCVA. The BSCVA after retreatment was not significantly different from that of the control group (0.01±0.09, ranged from –0.1 to 0.2).

Refraction

The mean preoperative spherical equivalent (SE) was –1.87±1.38 D. At the last follow-up time, mean SE was –0.13±0.57 D. A total of 66.7% of the postoperative eyes (n=12) were within ± 0.5 D and 88.9% (n=16) were within ±1 D. The other 2 eyes (11%) were between –1 and –1.5 D of the desired postoperative refraction. The postoperative mean cylindrical refractive error was –0.35±0.45 D (range 0 to –1.25 D), which was significantly less than preoperative level of –1.01±0.76 D (range 0 to –2.25 D) (t = 4.24, p<0.001), but not significantly different from the mean astigmatism of –0.28±0.35 D (range 0 to –1.25 D) of the control group (t=0.62, p>0.05). The distributions of astigmatism in both groups are shown in Figure 1.

Corneal aberration

Table I shows the root-mean-square (RMS) value of the anterior corneal aberrations for a 6-mm optical zone in both groups. Postoperative aberrations were significantly less than the preoperative levels in higher-order aberrations (HOAs) (t=3.33, p<0.01), coma-like aberration (t=3.19, p<0.01), and spherical aberration (t=3.28, p<0.01). However, the aberration levels were still higher than those in the control group (t=3.16, p<0.01 for HOAs; t=3.87, p<0.01 for coma-like aberration; and t=2.42, p<0.05 for spherical aberration).

TABLE I - ROOT-MEAN-SQUARE (RMS) OF ANTERIOR CORNEAL SURFACE ABERRATIONS IN THE 6 mm OPTICAL ZONE IN BOTH GROUPS

Groups	Mean RMS of HOAs (µm, mean ± standard deviation)		
	HOAs	Coma-like	Spherical-like
Experimental			
Pre	1.89±0.64	1.33±0.69	1.36±1.61
Post	1.5±0.20*†	0.99±0.55*†	1.02±0.95*†
Control	1.01±0.63	0.38±0.20	0.83±0.57

*p<0.05; Difference was statistically significant compared with preoperative values.
†p<0.05; Difference was statistically significant compared with the control.
HOAs = Higher order aberrations

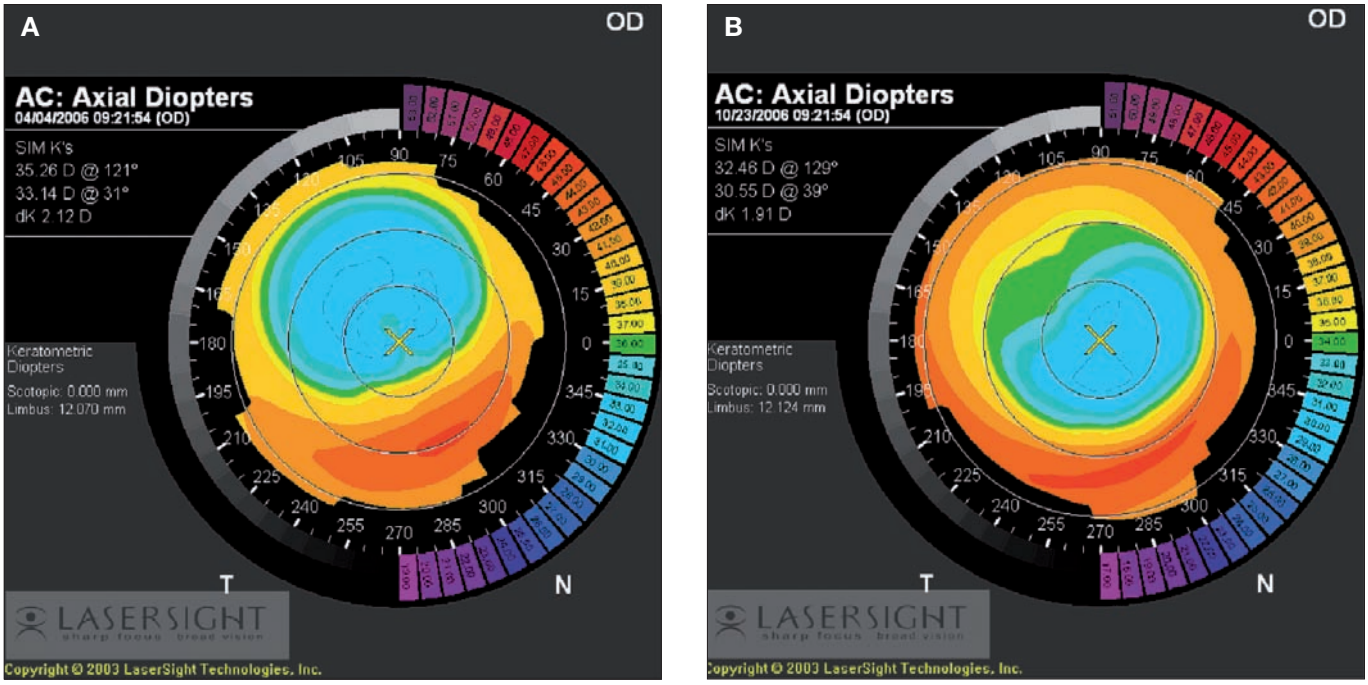

Fig. 2 - *Case 1.* **(A)** *Preoperative topographical power map.* **(B)** *Postoperative power map.*

Contrast sensitivity

The changes of contrast sensitivity are shown in Table II. Significant improvements of contrast sensitivity were at 1.0°, 0.7° spatial frequencies after retreatment (t=2.75, p<0.05; t=3.96, p<0.01, respectively), and no difference is found compared to the control group at 1.0° spatial frequency (t=1.46, p>0.05). However, at 0.7° spatial frequency, it was inferior to the control group (t=2.38, p<0.05).

Patient satisfaction

All patients reported an improvement in visual quality: 6 rated marked, 10 rated moderate, and 2 rated mild. No one rated worsened acuity.

TABLE II - THE CONTRAST SENSITIVITY THRESHOLD OF PRE–POST IN TWO GROUPS (Log2 CYCLE/DEGREE)

Group	Spatial frequency (0)	
	1.0	**0.7**
Experimental		
Pre-	3.81±0.55	4.86±0.41
Post-	3.36±0.74*	4.25±0.43*†
Control	3.13±0.68	4.08±0.52

*p<0.05; Difference was statistically significant compared with preoperative values.
†p<0.05; Difference was statistically significant compared with the control

CASE REPORTS

Case 1

A 35-year-old man presented with decentered laser ablation in the right eye with symptoms of glare, halos, a UCVA of 0.5 logMAR, a BSCVA of 0.1 logMAR, and sph –2.25 cyl –1.75 x250. Topography-guided ablation was performed in April 2006 on the right eye. Six months later, UCVA improved to 0 logMAR, and refraction was sph –0.25 cyl –0.75 x100 (Fig. 2A, Fig. 2B).

Case 2

A 45-year-old man had myopic LASIK (sph –8.25) in May 2004. He was referred to the Eye and ENT hospital of Fu-

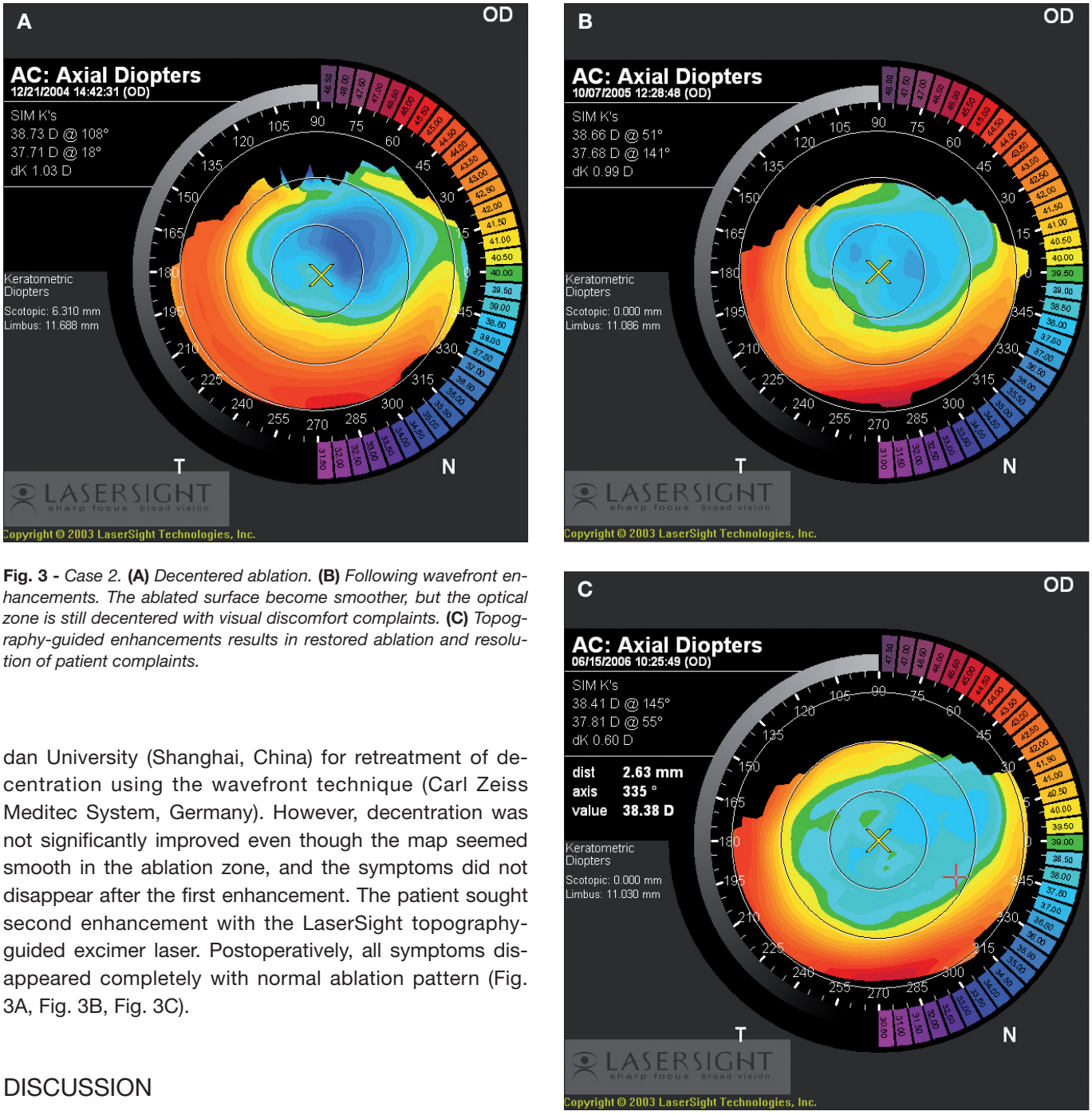

Fig. 3 - *Case 2.* **(A)** *Decentered ablation.* **(B)** *Following wavefront enhancements. The ablated surface become smoother, but the optical zone is still decentered with visual discomfort complaints.* **(C)** *Topography-guided enhancements results in restored ablation and resolution of patient complaints.*

dan University (Shanghai, China) for retreatment of decentration using the wavefront technique (Carl Zeiss Meditec System, Germany). However, decentration was not significantly improved even though the map seemed smooth in the ablation zone, and the symptoms did not disappear after the first enhancement. The patient sought second enhancement with the LaserSight topography-guided excimer laser. Postoperatively, all symptoms disappeared completely with normal ablation pattern (Fig. 3A, Fig. 3B, Fig. 3C).

DISCUSSION

In this study, decentration of ablation was retreated for 18 eyes using the LaserSight Excimer Laser and satisfactorily reduced after the surgery. The retreated eyes reached a level of ablation centration comparable with that for the eyes successfully ablated at the first surgery. The results suggest that topography-guided ablation using LaserSight excimer laser can effectively correct decentration.

Usually, the decentration was defined as the distance between the ablation center and the center of the entrance pupil. This definition describes the precision of ablation centration relative to the entrance pupil center (11), but has some limitations, because the entrance pupil center varies under different illumination, and the pupil center

does not lay on the visual axis and so on. The apex, the corneal intercept of the visual pathway, is believed to be the perfect center of ablation (12). In the present study, the apex was used as the ablation center, so the decentration was defined as the distance between the apex and the center of ablation, as that used in evaluation of orthokeratology lenses (13).

Decentration causes irregularity of the corneal surface that could be described as corneal aberrations. In this study we have shown that postoperative aberrations were significantly decreased for HOAs, coma, and spherical aberration, but still at levels worse than the control group. The results mean that optical quality of the cornea with decentration of ablation is hard to recover to normal level even if the decentration had successfully corrected.

Decentration is one of the causes disturbing visual performance. Although all patients have subjectively reported high or moderate satisfaction after retreatment and with significantly improved BSCVA and contrast sensitivity, the retreated group was still worse in contrast sensitivity at 0.7° than the control group. The results could suggest that visual quality for patients with decentration cannot recover to the level of those with initially centered ablation.

Currently, there are other topography-guided techniques available in the market for treatment of decentration (9, 10), such as C-CAP (custom-contoured ablation pattern) and CIPTA (corneal interactive programmed topographic ablation). The C-CAP technique requires a surgeon to select and calculate irregular zone in topography, and it relies too heavily on both the surgeon's experience and the empirical calculation. CIPTA has linked to earlier LaserSight excimer and made some successes in correcting irregular astigmatism, but the CIPTA was designed to treat the postoperative cornea as spherical surface. However, the AstraPro2.2z Custom Planning software directly processes the decentration maps and the desired postoperative corneal aspherical index of refraction. Therefore, the design process is easier and simpler.

Another promising customized approach is wavefront-guided ablation technique. In previous studies, it was controversial whether the wavefront-guided technique has advantage in correcting irregular astigmatism over the topography-guided technique (14-19). From the results of Case 2, we believe that the topography-guided ablation technique might be better to treat decentration.

We acknowledged that LaserSight's topography-guided excimer laser system does not account for cyclotorsion of the eye by the topographer or the laser eye-tracker in the current software and hardware, which may partly account for inferior visual quality and optic quality of the retreatment (20) compared to the originally centered ablation.

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