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Time Course of Q Value after Myopic Laser-assisted *In Situ* Keratomileusis[△]

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Objective To assess the time course of Q value after myopic laser-assisted *in situ* keratomileusis (LASIK) and preliminarily evaluate the determinants of the difference of Q value between before and after LASIK.

Methods We performed a retrospective, longitudinal investigation on patients undergoing wave-front optimized LASIK therapy for emmetropization. A total of 418 eyes from 222 cases were examined preoperatively, and partly followed up at one week (172 eyes), one month (134 eyes) and three months (51 eyes) after surgery. The horizontal, vertical and total Q values of cornea were calculated from eccentricity measured at the central 6-mm corneal zones respectively. Potential determinants of the change of Q value were analyzed using multiple linear regressions.

Results The mean Q value was -0.17 ± 0.13 preoperatively, and 0.99 ± 0.70 , 0.97 ± 0.66 , and 0.86 ± 0.41 one week, one and three months postoperatively, respectively. One way analysis of variance (ANOVA) demonstrated significant differences between measurements made before surgery and at all post-operative times (at one week, one and three months; all $P < 0.0001$, Bonferroni post hoc), but no significant differences were found among postoperative groups. Significant differences of Q values between horizontal and vertical meridians were found before surgery and at all postoperative times (all $P < 0.0001$). Multiple regression analysis revealed that change of Q value significantly correlated with manifest refraction spherical equivalent ($r = 0.116$, $P < 0.0001$) and axial length ($r = 0.264$, $P < 0.0001$).

Conclusions Over the study period, the primary changes in Q value occur within 1 week after surgery, and then become slightly decreased and nearly stable. Manifest refraction spherical equivalent and axial length play a significant role in the change of postoperative Q value.

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LASER *in situ* keratomileusis (LASIK) has been reported to be a safe and effective refractive surgery to correct myopia by removing a certain volume of corneal tissue to flatten the central corneal surface in a short and long term.¹⁻³ Conventional refractive surgery, however, induces a change in corneal asphericity, bringing about an increase in high order aberrations and degrading postoperative visual quality.^{4,5} In order to obtain the optimal effect of correction, many studies have been focused on aspheric character of cornea.^{6,7} It is generally accepted that the human cornea is assumed to be a conic section, and most normal human corneas conform to a prolate ellipse and flatten from the center to the periphery.⁸ The physiologically corneal asphericity coordinates with other optical components to help establish a natural aberration balance and minimize the spherical aberration in the human eye.⁹ To maintain the preoperative corneal asphericity and reduce the tendency towards oblate shift after surgery, Q-value customized corneal ablation surgery was recommended to produce even better quality of vision.¹⁰ The corneal asphericity coefficient Q describes the rate of curvature variation of the cornea from its center to the periphery and specifies the type of conicoid that best represents its shape where Q=0 describes a perfect sphere, Q>0 describes an oblate ellipse, and -1<Q<0 describes a prolate ellipse.¹¹

After conventional myopic or astigmatic LASIK surgery, Q value increased from negative to positive, accompanied by the deterioration of the visual function, like impaired contrast sensitivity. It has been reported that a new laser therapy with Q-value-based individualized ablation resulted in a better visual function postoperatively.¹⁰ However, there are two issues still existing in the application of Q value to refractive surgery. One is the setting of target Q-value to obtain optimum visual performance; another is to determine influential effects on the postoperative Q value. In present study, we observed the time course of Q value after LASIK and preliminarily evaluated the influence of some ocular parameters on the postoperative Q value.

PATIENTS AND METHODS

Study population

Four hundred and eighteen consecutive eyes were analyzed preoperatively from 222 patients undergoing LASIK surgery at the Department of Refractive Surgery, Shanghai First People's Hospital, Shanghai, China. Mean patient age was 25.25 years ranging from 17 to 51 years and mean manifest refraction spherical equivalent (MRSE) was -6.65 D ranging from -17 D to -1 D. The number of subjects

followed up at one week, one and three months postoperatively was 90 (172 eyes), 69 (134 eyes) and 27 (51 eyes), respectively. All patients had a best spectacle-corrected visual acuity (BSCVA) of 20/20 or better before surgery and had satisfactory visual outcomes after laser treatment. The Wavelight Rondo microkeratome (Moria, France) was used to cut the corneal flaps with a nasal hinge in all cases. LASIK was completed without complication in all cases. This study adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from all patients after explaining the purpose of the research and the procedures to be used in collecting the data.

Measurements

Manifest refraction was performed using standard clinical techniques. Corneal Q value was calculated from eccentricity measured at the central 6-mm corneal zones by a videokeratoscope (Wavelight-ALLEGRO Topolyzer, Oculus, Germany). The average eccentricities (e) of horizontal meridians, vertical meridians of cornea, as well as the whole cornea, were obtained by software. Intraocular pressure (IOP) and refractive state were obtained from both eyes in the sitting position at the same time of a day by trained technicians. Central corneal thickness (CCT) was measured under topical anesthesia using an ultrasound pachymeter (US-800, Nidek, Japan) with one or two drops of 0.5% proparacaine instilling into patient's eye just before the procedure. The value of CCT was the average of three consecutive readings. Thickness of residual stromal bed (RSB), central corneal ablation depth (CCAD), and flap thickness (FT) in LASIK surgery were obtained from the operational records.

Statistical analysis

The results were expressed as mean±SD. All statistical evaluations were performed using the SPSS statistical software package (version 17.0). Inpatient correlation of Q values between left and right eyes was tested by Pearson correlation to determine whether both eyes could be included in the study. The result showed that correlation coefficient between fellow eyes was fairly low ($r=0.012$) and both eyes of each patient were included in the analysis. After data were assessed for normality using 1 sample Kolmogorov-Smirnov normality test, multiple linear regression analysis was applied to identify which factors would be potential determinants of postoperative Q value of cornea. Differences of Q values between corresponding two parts of all eyes were assessed by Paired-Samples T Test. Differences between Q values among groups were analyzed using one way analysis of variance (ANOVA) with

Bonferroni post hoc. A *P* value less than 0.05 was considered statistically significant and a value of 0.01, highly statistically significant. All tests were two-tailed.

RESULTS

Mean Q value before and after surgery

The Q value was -0.17 ± 0.13 preoperatively, and 0.99 ± 0.70 , 0.97 ± 0.66 , and 0.86 ± 0.41 one week, one and three months postoperatively, respectively. Multiple comparisons demonstrated highly significant differences between measurements made before surgery and at all postoperative times (at one week, one and three months; all $P < 0.0001$, respectively, ANOVA with Bonferroni post hoc). On the other hand, no significant differences were found between measurements made one week and one month ($P = 0.990$), one and three months ($P = 0.883$), one week and three months ($P = 0.438$) after surgery, respectively.

Q values of horizontal and vertical meridians

One week postoperatively, Q values of different meridians both changed into positive from negative, as detailed in Table 1. Preoperatively, Q values of horizontal and vertical meridians were -0.20 ± 0.14 and -0.18 ± 0.18 , respectively. After surgery, mean horizontal Q value was even more than 1.0. Paired-Samples T Tests demonstrated highly significant differences between horizontal and vertical Q values before surgery ($P < 0.0001$). Highly significant differences still existed between horizontal and vertical Q values at all postoperative times (all $P < 0.0001$, respectively).

Factors related to the change of Q value

As there was no significant difference between any two groups of postoperation, we chose the change of Q value (ΔQ) between preoperation and one month after surgery

for regression analysis. Associations between ΔQ , MRSE, CCT, axial length (AL), FT, CCAD, IOP and RSB were studied by a multiple linear regression (Method: Stepwise), with ΔQ as the dependent variable and the others as independent variables. CCT, FT, CCAD, IOP and RSB were excluded by the statistical software automatically, and the regression equation for ΔQ was as follows: $\Delta Q = -6.458 - 0.116 \times \text{MRSE} + 0.264 \times \text{AL}$.

The coefficient of determination (R^2) and adjusted R^2 for the equation were 0.679 and 0.673, respectively. From the equation, 1 mm increase in AL and 1 D increase in MRSE would result an increase and decrease in ΔQ by 0.264 and 0.116, respectively. In addition, the standardized coefficients for MRSE and AL were -0.445 and 0.434 .

DISCUSSION

Cornea laser ablation surgery has been well accepted as a reliable myopic treatment because of its high safety, effectiveness and predictability. The development of technology allows patients to achieve a better visual function after the surgery. Understanding the regular pattern of corneal biomechanical characteristics and its tissue response after surgery help us improve the design of operation. In this study, corneal Q value thereby has been examined as an important parameter which is customarily applied to describe the morphologic characteristic of anterior surface of cornea to form basic data and analyzed to better clinic practice.¹²

Over the study period, the most notable finding was a significant crest of Q value after corneal ablation within one week, then it went down slightly, and became stable latter. This indicated that the change of structure of cornea mainly occurred within one week postoperatively. Thereafter, the structure of cornea kept fairly stable without significant change. From Q value perspective, the topography of

Table 1. Pre- and postoperative clinical data[§]

Time	Number of eyes	Age (yrs)	IOP (mm Hg)	FT (mm)	CCAD (mm)	SE (D)	CCT (mm)	RSB (mm)	Total Q value	Horizontal Q value	Vertical Q value
Preoperation	418	25.25±7.31	16.77±3.04	-	-	-6.65±2.76	560.24±28.08	-	-0.17±0.13	-0.20±0.14	-0.18±0.18**
1 week post-operatively	172	24.95±6.86	16.84±3.12	108.14±7.26	95.30±30.00	-	-	339.69±43.73	0.99±0.70*	1.32±0.87	0.92±0.67**
1 month post-operatively	134	24.81±7.19	16.94±3.13	106.52±7.62	96.83±28.29	-	-	335.76±36.85	0.97±0.66*	1.26±0.80	0.90±0.65**
3 months postoperatively	51	24.78±8.07	16.61±2.85	107.25±6.95	100.04±27.07	-	-	341.02±40.85	0.86±0.41*	1.20±0.62	0.82±0.53**

§: Plus-minus values are means±SD.

IOP: intraocular pressure; FT: flap thickness; CCAD: central corneal ablation depth; SE: spherical equivalent; CCT: central corneal thickness; RSB: residual stromal bed; -: not measured.

* $P < 0.01$ compared with the value measured before surgery; ** $P < 0.01$ compared with the horizontal Q value.

anterior surface of cornea soon reached to and preserved stability. In the present study, Q value was calculated from eccentricity measured at the central 6-mm zones that was inside central corneal ablation. Consequently, ablation rim, transition zone and wound healing impacted little on the time course of Q value from central 6-mm zones. A recent study made by Kamiya and his associates¹³ reported that primary changes of corneal biomechanical parameters occurred within one week after LASIK, and then became nearly stable without progressive deterioration of the corneal biomechanics at any time during the 6-month follow-up period. Their findings were well supported by our research through evaluating the time course of postoperative Q value. Findings from our study, together with Kamiya *et al*'s, demonstrated that corneal structure attained and kept stability in a short time postoperatively not only from morphology perspective but also biomechanics.

In the present article, Q value was examined in two main meridians instead of simply a total one, which is obviously more agreeable with the clinic practice and with more practical significance. Preoperatively, mean horizontal Q value was more negative than vertical and significant difference was found between them ($P < 0.0001$). When we compared horizontal and vertical Q values calculated from eccentricity measured at the central 9-mm corneal zones, however, the difference between them was not still significant ($P = 0.199$). The difference between mean Q values obtained from a smaller (6 mm) and larger (9 mm) central corneal zones indicated that human cornea had different regional properties. Of note, horizontal Q value was more negative and positive than vertical Q value preoperatively and postoperatively, respectively. Although significant differences were found between them before and at all postoperative periods, the character of corneal structure had changed. The effects of this change on the postoperative visual performance needed to investigate further.

In order to find which variables related to the difference of Q value between pre- and postoperation (ΔQ), we applied multiple linear regression to analyze the effects of parameters such as MRSE before surgery, AL, preoperative CCT, FT, CCAD and RSB. As a result, only MRSE and AL were significantly correlated with ΔQ (both $P < 0.0001$). The effect of CCT, FT, CCAD and RSB on ΔQ was weak and not significant. To our surprise, CCAD and RSB were not significantly contributing factors to ΔQ . In theory, thinner RSB and thicker CCAD brought about less stable biomechanical structure and predisposed to induce distortion in corneal structure. The reason for present result might be partly explained by recent studies. Sun *et al*¹⁴ reported that the

displacement of forward shift of the posterior corneal surface had no correlation with the residual corneal thickness and CCAD. Moreover, some authors concluded that there were no significant changes in the posterior corneal surface.^{15, 16} There was something in common among these papers and our article, in that mean preoperative or correction refraction was moderate or slightly high, namely -4.5 ± 1.8 D,¹⁵ -6.02 ± 2.10 D,¹⁶ -4.33 D for correction¹⁶ and 6.65 ± 2.76 D in our article, respectively. From these researches, we could assume that corneal structure was not altered induced by varied RSB and CCAD; thereby they were not concerned with the change of Q value in a certain refractive correction range. MRSE and AL were preoperative ocular parameters, which related to the model of laser ablation and determined the final corneal shape of anterior surface. Therefore, they became the primary factors to the change of Q value (ΔQ) and explained a large part of reason for it (adjusted $R^2 = 0.673$).

In our research, no clinically apparent keratectasia occurred throughout the follow-up periods. According to other researchers, however, delayed-onset keratectasia after LASIK has been documented.¹⁷⁻¹⁹ If after the surgery corneal deformation develops slowly over time for some biomechanical reasons or wound healing responses, it is important to determine at what time keratectasia occurs during the late postoperative period. So there come the limitation of the study, the follow-up time was short, a further long-term study with a large number of patients is required to confirm and consummate the authenticity of our findings.

In conclusion, over the study period, the primary changes in Q value occurred within one week after surgery, and then became slightly decreased and nearly stable. LASIK markedly changed corneal structure after surgery, and the change was irreversible and subsequently stabilized with no further deterioration over the 3-month observation period. AL and MRSE were main determinants of the change of Q value in our study.

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