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Underestimation of Intraocular Pressure in Eyes After Laser In Situ Keratomileusis

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Purpose: Retrospectively, we reviewed the records of 65 patients (115 eyes) regarding the intraocular pressure (IOP) after laser in situ keratomileusis (LASIK).

Methods: The mean patient age was 31.2 ± 10.5 years. The average preoperative spherical equivalent was −6.85 ± 2.54 diopters. A noncontact pneumatic tonometer and a Goldmann applanation tonometer were used in measuring the IOP.

Results: The IOP after LASIK was significantly lower than that before surgery (Mann-Whitney *U*-test). The IOP correlated significantly with the corrected diopter value, corneal thickness, and corneal curvature (Spearman rank correlation).

Conclusions: The postoperative IOP can be underestimated due to decreased corneal thickness and curvature. When evaluating IOP after LASIK surgery, this possibility should be carefully investigated. **Jpn J Ophthalmol 2002;46:645–649** © 2002 Japanese Ophthalmological Society

Key Words: Intraocular pressure, laser in situ keratomileusis, refractive surgery, underestimation.

Introduction

In recent years, various types of refractive surgery have been developed and the use of this surgery has gradually increased. Refractive surgery for the cornea can improve an anomaly of refraction by changing the morphology of the cornea. However, several complications of this surgery resulting from the changed morphology of the cornea have been reported. Postoperative underestimation of the intraocular pressure (IOP) is one of them.

It has already been reported that the IOP after refractive surgery is underestimated. In Japan, Uozato[1] has conducted a study on refractive surgery and the IOP. We have also reported on the underestimation of the IOP after minimally invasive radial keratotomy (hereinafter referred to as mini-RK)[2] and excimer laser photorefractive keratectomy (hereinafter referred to as PRK).[3]

On the other hand, the procedures in refractive surgery have changed. Laser in situ keratomileusis (hereinafter referred to as LASIK) has come into wide use for the past several years in the United States and Japan. This is a type of operation whereby a corneal flap is made, the stroma is irradiated by excimer laser, and the corneal flap is put back into place. LASIK has become the most frequent type of main refractive surgery because of its advantages, such as relief of post-

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operative pain, early recovery of vision, and lower incidence of complications. While the underestimation of the IOP following this type of operation, as in other surgery[12,17,18] has been pointed out, there has been no clinical report on IOP underestimation in Japan. Therefore, we compared the IOP of patients before and after LASIK and retrospectively studied the possibility of postoperative underestimation of the IOP.

Materials and Methods

The subjects included 65 patients (115 eyes; 47 men, 18 women) who underwent LASIK for correction of myopia at the Department of Ophthalmology, Musashino Red Cross Hospital. Their ages averaged 31.2 ± 10.5 years. The preoperative spherical equivalent averaged −6.85 ± 2.54 D. With emmetropia as the target in all cases, the cases having astigmatism of more than 2.0 D were excluded. The preoperative IOP averaged 14.7 ± 2.6 mm Hg. The preoperative corneal thickness averaged 533 ± 30.9 μm. The preoperative corneal curvature averaged 43.8 ± 1.5 D. Refractive surgery was not indicated for the cases in which eye diseases other than myopia were confirmed before surgery (see "Guideline of Excimer Laser Refractive Surgery," *Journal of Japanese Society of Ophthalmology*).[4] In the majority of patients who requested bilateral correction of myopia among the cases selected for this study, both eyes were operated on simultaneously on the same day to avoid the disadvantages of anisometropia. The informed consent of all subjects was obtained before surgery.

VISX STAR (optical zone = 6.0 mm; Visx, Santa Clara, CA, USA) was used as the excimer laser. LSK (MORIA, Antony, France) and Auto Corneal Shaper (Chiron, Claremont, CA, USA) were used as the microkeratome. LASIK was performed by the same ophthalmologist (KS) in all cases. The surgical method has already been reported.[5] Topical 0.1% fluorometholone (Flumetholon, Santen, Osaka) and ofloxacin (Tarivid, Daiichi Pharmaceutical, Tokyo) were applied four times a day for 1 week after surgery in all cases.

The IOP was, in principle, measured with a noncontact pneumatic tonometer (NCT) (Canon T-2; Canon, Tokyo) and also measured with a Goldmann tonometer (GT; Zeiss, Oberkochen, Germany) if possible. In the present study, the values measured before, 1 week, 1 month, and 3 months after LASIK were used. Corneal thickness was measured with the ultrasonic pachymeter (DGH 500; DGH Technology, Exton, PA, USA) before and 3 months after surgery. Corneal curvature was measured with an auto refractometer (Canon RK-3; Canon) at each clinical visit.

As parameters for this study, the IOP values measured with NCT at each measurement before and after LASIK were compared with the preoperative IOP (Mann-Whitney *U*-test). Comparison was made of the IOP values in the cases in which the IOP could be measured with the GT and NCT at each measurement (Mann-Whitney *U*-test). In addition, the correlations between the IOP (NCT) 3 months after surgery on the one hand and the corrected diopter value, corneal thickness, and corneal curvature on the other were determined.

Results

The postoperative IOP measured with NCT at each measurement after LASIK showed a statistically significant decrease compared with the preoperative IOP (Figure 1, $P < .01$, Mann-Whitney *U*-test). Comparison was made of the IOP at each measurement with GT and NCT; no statistically significant difference was found between the measurements made with the two instruments at any measurement time (Table 1).

We analyzed the corrected diopter value and the IOP. The larger the corrected diopter value, the larger the decreased amount of the postoperative IOP; a positive correlation was found between the two (Figure 2, n = 54, $r_s = 0.32$, $P < .05$, Spearman rank correlation). We also analyzed the corneal thickness and the IOP found in the cases in which corneal thickness could be measured at 3 months after surgery. The larger the difference in corneal thickness before and after surgery (ie, in the cases showing a larger decrease in corneal thickness) the more the decline in the postoperative IOP; a positive

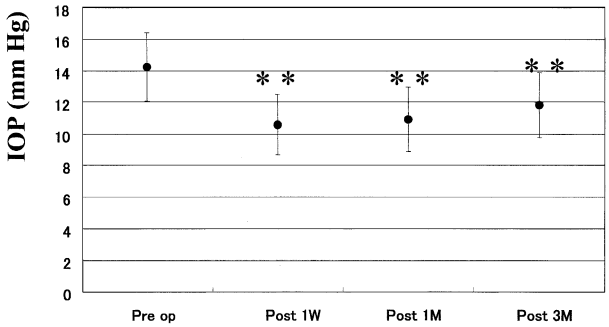

Figure 1. Intraocular pressure (IOP) before and after laser in situ keratomileusis (LASIK). Comparison of IOP in 32 eyes that could be followed up for 3 months after surgery. IOP decreased at every clinical visit. n = 32, $P < .01$, Mann-Whitney *U*-test. W: week, M: month.

Table 1. Comparison of Intraocular Pressure—Goldmann Tonometer (GT) vs. Noncontact Pneumatic Tonometer (NCT)

	Preop (n = 17)	Post-1 W (n = 50)	Post-1 M (n = 41)	Post-3 M (n = 25)
GT(mm Hg)	15.96 ± 2.70	12.22 ± 2.40	12.59 ± 2.13	12.87 ± 2.80
NCT(mm Hg)	14.68 ± 2.61	11.70 ± 2.14	11.56 ± 1.73	11.86 ± 1.76

*There were no statistical differences between the two methods at any point. (Mann-Whitney U-test). W: week, M: month, n: number of eyes.

correlation was found between the two (Figure 3, n = 28, $r_s = 0.41$, $P < .05$).

We analyzed the corneal curvature and the IOP. The more the decrease of postoperative corneal curvature, the more the decline in the postoperative IOP; a positive correlation was found between the two (Figure 4, n = 48, $r_s = 0.4$, $P < .05$).

Discussion

We studied the changes in the IOP values measured before and after LASIK. The first question to consider was selection of the method to measure the IOP. Generally, the GT is regarded as the standard at present because it makes possible an exact measurement of the IOP with high reproducibility.[6] However, this method is not free from influence, although it is said to be the least affected by change in corneal thickness and morphology compared with the other methods. Regarding the IOP in cases where no refractive surgery has been performed, there have been several reports on the under- or overestimation of the IOP due to differences in corneal thickness. Ehlers et al[7] have reported that the IOP is underestimated by 5.2 mm Hg when corneal thickness is 0.45 mm against the true IOP of 20 mm Hg and is overestimated by 4.7 mm Hg when corneal thickness is 0.59 mm. Wolfs et al[8] have reported that the actual measured value of the IOP increases by 0.19 mm Hg every time the central corneal thickness increases by 10 μm. Regarding changes in the IOP values measured after changes in corneal curvature, Mark[9] has reported that when corneal curvature increases by 1 D, the IOP increases by 0.34 mm Hg. Therefore, it can easily be imagined that the actual IOP changes when an operation to change corneal morphology has been performed.

On the other hand, there have been recent studies on the comparison of two or more methods to measure the IOP. Matsumoto et al[10] studied the influence of corneal thickness and corneal curvature on the IOP values measured with both an NCT and a GT in normal individuals, reporting that the thicker the cornea, the higher the IOP value. Hirano et al[11] have also reported that the reading of the IOP measured with NCT is higher with thicker corneal thickness cases and lower with thinner corneal thickness cases, if compared with GT. However, opinions are divided over the method of measurement where corneal thickness or morphology has changed extremely, as in the case of eyes after refractive surgery. For example, Zadok et al[12] compared the IOP values measured with NCT and GT in patients after LASIK and reported that the IOP value measured with NCT is

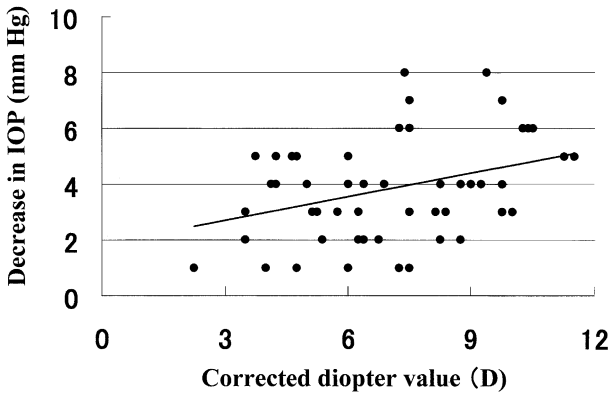

Figure 2. Correlation between corrected diopter value and decrease in intraocular pressure (IOP). There was a positive correlation between corrected diopter value (D) and decrease in IOP mm Hg. Spearman rank correlation, n = 54, $r_s = 0.32$, $P < .05$.

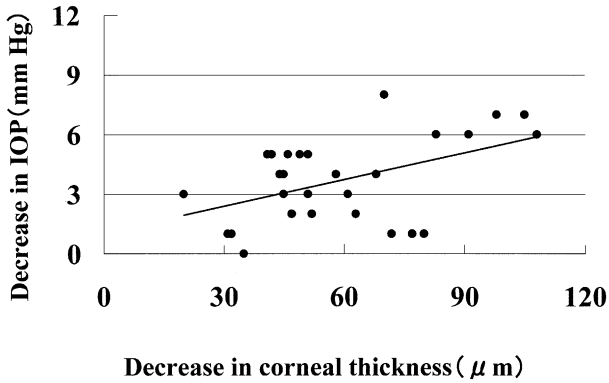

Figure 3. Correlation between corneal thickness and decrease in intraocular pressure (IOP). There was a positive correlation between decreased amount of corneal thickness (μm) and decrease in IOP mm Hg. Spearman rank correlation, n = 28, $r_s = 0.41$, $P < .05$.

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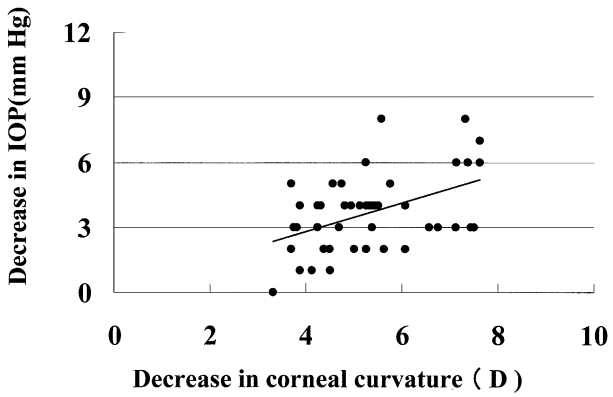

Figure 4. Correlation between corneal curvature and decrease in intraocular pressure (IOP). There was a positive correlation between decreased amount of corneal curvature and decrease in IOP (mm Hg). Spearman rank correlation, n = 48, $r_s = 0.4$, $P < .05$.

less influenced by the decreased corneal thickness and flattening of the cornea after LASIK. At present, there is no unified opinion as to which shows the more accurate values, NCT or GT, in normal eyes and in eyes after refractive surgery. At our department we, in principle, measure the IOP with GT, but in the case of patients with infections, patients immediately after surgery who should preferably be protected from contact, and patients immediately before analysis of corneal morphology or those immediately before LASIK, we use NCT for measuring the IOP. In the present study, therefore, when the comparison was made of the IOP values measured simultaneously by the two methods, no significant difference was found in the data obtained by the two measuring methods before and after surgery. There were more cases measured with NCT in the present study, so values obtained with NCT were used.

Levy et al[13] compared Tono-Pen with GT in the measurement of the IOP after PRK and reported that the IOP measured with Tono-Pen was less affected by changes in corneal morphology after PRK. In this study, we were unable to use Tono-Pen; hence, no comparative study of these two methods could be made.

With respect to the IOP after refractive surgery, Mardelli et al[14] have reported that the IOP decreased by an average of 0.5 ± 2.1 mm Hg after PRK (preoperative average spherical equivalent, −3.7 ± 1.5 D). Faucher et al[15] have reported that the IOP drop was an average of 1.0 ± 3.21 mm Hg after RK (preoperative average spherical equivalent, −3.17 ± 1.42 D) and an average decrease of 2.4 ± 3.02 mm Hg after PRK (preoperative average spherical equivalent, −7.27 ± 2.78 D). On the other hand, Chatterjee et al[16] have reported that the IOP after PRK (preoperative average spherical equivalent, −4.21 ± 1.83 D) was proportional to the corrected diopter value, as in Equation (1):

$$\textit{IOP decrease (mm Hg)} = 1.6 + 0.4 \times \textit{corrected diopter value (D)} \quad (1)$$

Fournier et al[17] have reported that the IOP decreased by an average 1.9 ± 2.9 mm Hg after LASIK (preoperative average spherical equivalent, −5.6 ± 4.0 D). Emara et al[18] studied the IOP and central corneal thickness after LASIK, reporting that the IOP decreased by 1 mm Hg every time central corneal thickness decreased by 37.8 μm.

The results of our present study showed that the amount of decrease in IOP after LASIK can be expressed by Equation (2):

$$\textit{IOP decrease (mm Hg)} = 1.8 + 0.3 \times \textit{corrected diopter value (D)} \quad (2)$$

in the group with the corrected diopter value being −6.85 ± 2.54 D (−2.5 D to −11.0 D).

This was consistent with the results in our previous report.[16] Therefore, this means that the IOP value decreases by about 5 mm Hg where myopia of 10.0 D has been corrected. For example, when the IOP measured after LASIK without knowledge that it is an operated eye is thought to be 18 mm Hg, it means that the actual IOP of 23 mm Hg is being underestimated.

Therefore, basing therapy on the IOP value after LASIK is likely to lead to misdiagnosis and mistakes in clinical treatment. According to the results of IOP evaluation after PRK previously reported by us,[3] the amount of decrease in IOP could be expressed by Equation (3):

$$\textit{IOP decrease (mm Hg)} = 0.7 + 0.4 \times \textit{corrected diopter value (D)} \quad (3)$$

Some difference arises in the formula because the myopia in our previous PRK cases was milder, with the corrected diopter value −4.2 ± 1.9 D, than in the LASIK cases in the present study. There also was a difference in the type of operation, PRK and LASIK. With PRK, a corneal flap is not made after detachment of the corneal epithelium and the stroma is irradiated by the excimer laser. Whichever type of operation is used, the postoperative IOP is being significantly underestimated.

A method to determine the true IOP after refractive surgery of all types has to be developed. The formula presented in Equation (2) is a kind of standard but it cannot convert values into the true IOP after LASIK. That is because it is not known whether the postoperative value measured by the GT is accurate or not. If a pressure sensor is inserted into the eye for measurement, more accurate values may be obtained, but it is impossible to do so in actual clinical practice. Therefore, further studies on the decrease in the amount of the true IOP and a conversion formula are needed. As far as the results of our present study are concerned, the postoperative IOP measured by two methods, NCT and GT, was significantly decreased compared with the preoperative IOP. Furthermore, the IOP after LASIK was decreased in proportion to the corrected diopter value, decreased amount of corneal thickness, and decreased amount of corneal curvature compared with the preoperative IOP. From these results, it can be concluded that there is a strong possibility that the IOP after LASIK is being underestimated.

Many patients wishing to undergo refractive surgery, particularly LASIK, have high myopia. High myopia is said to be one of the risk factors for glaucoma.[19,20] So there is the danger of an erroneous treatment protocol being drawn up owing to the underestimation of the IOP after LASIK, which may lead to the development of glaucoma in some patients in the future. As the standard for management, it is important to assess the optic disc and nerve fiber layer and not only the IOP value. In addition, care must be exercised in evaluating IOP in patients who undergo LASIK.

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