Tonometry after Laser in Situ Keratomileusis Treatment: A Preliminary Study in Thai Patients

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Objective: *To evaluate the change in intraocular pressure (IOP) measurement by Goldmann applanation tonometer after Laser in Situ Keratomileusis (LASIK) for myopia and myopic astigmatism, and to assess the correlation between the changes of IOP reading and the reduction of central corneal thickness (CCT) after LASIK in Thai patients.*
Study design: *Prospective correlational study.*
Material and Method: *LASIK was performed on 65 eyes of 33 patients for correction of myopia and myopic astigmatism. IOP was measured by Goldmann applanation tonometer before and 3 months after LASIK. The correlation between the change in IOP reading and the change in central corneal thickness were evaluated.*
Results: *IOP reading was significantly reduced by mean of 2.9 ± 2.5 mmHg (p = 0.0001). The authors used Pearson analysis to study the correlation between the change in IOP and the reduction of CCT. In subgroup analysis the patients were divided by degree of myopia: group 1, myopia less than -3 diopters (D) (n = 14); group 2, myopia -3 to -6 D (n = 31); group 3, myopia greater than -6 D (n = 20)). The result showed more correlation in higher myopia group (Pearson; r = 0.158 in group 3, r = -0.098 in group 2 and r = -0.102 in group 1).*
Conclusion: *Goldmann applanation tonometry underestimates the IOP in thin cornea. Variability in CCT is a potent confounder of this tonometry technique. Therefore, it has important implications for considering CCT measurement incorporated with Goldmann applanation tonometry for glaucoma diagnosis especially in myopic patients who undergo LASIK surgery.*

Keywords: *Goldmann applanation tonometry, Intraocular pressure, Laser in Situ Keratomileusis, Central corneal thickness*

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Refractive procedures have become a popular surgical option for the treatment of myopia. Laser in Situ Keratomileusis (LASIK) has become the most accepted surgical modality for the correction of a wide range of myopia. LASIK is performed routinely in more and more patients. LASIK corrects myopia by altering the thickness and curvature of the central cornea. Myopia has been implicated as one risk factor in the development of glaucoma[1]. The procedures for diagnosis and treatment of glaucoma are visualization of the optic nerve head, visual field examination and measurement of the intraocular pressure (IOP). However, visual field and optic nerve head examination are difficult in some myopic eyes. In these cases, accurate evaluation of IOP is of particular relevance.

Goldmann applanation tonometry is considered the gold standard for measuring IOP. It is based on the modified Imbert-Fick law, which takes into account the corneal rigidity force, affected by central corneal thickness. Variations in central corneal thickness (CCT) should yield variable corresponding IOP. The relationship between IOP and CCT has been confirmed[2,3]. Hansen[4] reported with normotensive eyes a positive linear correlation existed between

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CCT and IOP measured by Goldmann applanation tonometry. The other study demonstrated a reduced corneal thickness in a group of patients with low-tension glaucoma[2]. The present study correlated with the study in ocular hypertensive patients, the corneal thickness is greater than normal leads to artificially high estimations of IOP[5]. Therefore, the corneal thickness has a major influence and should be taken into consideration when evaluating Goldmann applanation tonometry reading[6,7]. The meta-analysis confirms that eyes with low CCT values can result in low tonometry readings and high CCT values can result in elevated tonometry readings by Goldmann applanation tonometry[10]. Therefore, LASIK can change the accuracy of intraocular pressure measurements by Goldmann applanation tonometry.

This prospective study evaluates the changes that occur in IOP measurements by Goldmann applanation tonometry after LASIK for myopia and myopic astigmatism in a Thai population.

Material and Method

Sixty-five eyes of 33 myopic or myopic astigmatism patients who had LASIK in one or both eyes were enrolled in the present study. Patients selected for the study met the inclusion criteria including myopic or myopic astigmatism patients without any active ocular disease, received LASIK at Siriraj Hospital and accepted for joining the study. All patients signed their individual informed consent forms. Exclusion criteria included patients who had contraindication for LASIK and who used topical steroid for more than 4 weeks - to avoid steroid-induced ocular hypertension.

Complete eye examinations including visual acuity measurement, manifest refraction, CCT measurements by pachymetry (OBSCAN), and IOP measurements by Goldmann applanation tonometer were performed before and 3 months after LASIK. LASIK was performed in all patients by the staff in the refractive surgery unit of Siriraj Hospital. A corneal flap was created with microkeratome (Hansatome or Automated Corneal Shaper). Photoablative keratectomy was applied to the bed of the cornea with Technolas excimer laser. All of the patients received antibiotic eye drops and steroid eye drops (fluorometholone, 1% methylprednisolone) or combine antibiotic and steroid eyedrops (Spersadexolin , Dexamytrex) after LASIK range from 1-4 weeks (mean 1.7 weeks).

Data were analyzed with descriptive statistics (mean ± SD and range) the paired t test. The Pearson product-moment correlation coefficient was used to access the relationship between the reduction of IOP readings and the mean reduction of the central corneal thickness.

Results

Thirty-three patients including 17 females (52.3%) and 16 males (47.7%), with a mean age of 30.9 ± 7.1 years (range 16-42 years) were studied. The uncorrected visual acuity of almost all patients before LASIK procedure was 20/200 or worse. The mean preoperative spherical equivalent was -5.1 ± 2.2 D (range -1.5 to -11.5 D). After LASIK procedure, almost all patients had uncorrected visual acuity of 20/25 or better. The mean postoperative spherical equivalent was -0.2 ± 0.5 D (range -1.25 to 1.75 D). The mean preoperative CCT was 523.7 ± 24.0 microns (range 483 to 583 microns). The mean postoperative CCT was 450.9 ± 43.3 microns (range 362 to 537 microns). The mean reduction of CCT after LASIK was 73.6 ± 36.2 microns (range 13 to 147 microns). The mean preoperative IOP was 13.6 ± 2.6 mmHg (range 8 to 21 mmHg) and the mean postoperative IOP was 10.7 ± 2.2 mmHg (range 6 to 18 mmHg) (Table 1). The mean reduction of IOP was 2.9 ± 2.5 mmHg (range 5 to 8 mmHg). Mean IOP pre- and post LASIK showed a significant difference (p = 0.0001). Then, the patients were classified into 3 subgroups depending on the degree of myopia (group 1: myopia less than -3 D, group 2:

Table 1. The preoperative and postoperative data (n = 65 eyes)

	Preoperative	Postoperative
Age (years)	30.9±7.1 (16-42)	
SE (diopters)	-5.1±2.2 (-1.5 to -11.5)	-0.2±0.5 (-1.25 to 1.75)
CCT (microns)	523.7±24.0(483-583)	450.9±43.3(362-537)
IOP (mmHg)	13.6±2.6 (8-21)	10.7±2.2 (6-18)**

SE = spherical equivalent, CCT = central corneal thickness, IOP = intraocular pressure
** p = 0.0001

myopia -3 to -6 D and group 3: myopia greater than -6 D) for subgroup analysis. There were 14, 31, 20 eyes in each group respectively. The more myopia the patients had, the more the reduction in CCT was. The reduction of IOP correlated with the reduction of the CCT. So the patients in group 3 had the lowest reduction of IOP (3.3 +/- 1.9 mmHg). However, the IOP was significantly reduced in all 3 groups (p = 0.018, p < 0.001, p < 0.001 respectively) (Table 2). The Pearson product-moment correlation coefficient was used to assess the relationship between the reduction of IOP readings and the reduction of central corneal thickness. There was a low correlation between the reduction in IOP values measured by Goldmann applanation tonometry and the reduction of CCT (Pearson r = 0.09, p = 0.481). When this correlation was done in subgroup analysis, the result was the same (Table 3), but there was a tendency of correlation in group 3 that had more myopia than others.

Table 2. The change of IOP and CCT in each subgroup

	No. of yrs	CCT change (microns)	IOP change (mmHg)	
< -3 D	14	44.3±27.4	2.0±2.8	p = 0.018
-3 to -6 D	31	65.1±26.7	3.2±2.6	p < 0.001
> -6 D	20	110.1±25.2	3.3±1.9	p < 0.001

CCT = central corneal thickness, IOP = intraocular pressure, D = diopters

Table 3. The Pearson correlation coefficient in each subgroup

Group	r	p
< -3 D	-0.102	0.730
-3 to -6 D	-0.098	0.611
> -6 D	0.158	0.532

D = diopters

Discussion

IOP measurement is an important part of ophthalmic practice; it is essential for screening, early diagnosis and management of many eye diseases especially glaucoma. The most common way to assess IOP is by Goldmann applanation tonometer, which gained widespread and rapid acceptance after its introduction in the 1950s. Goldmann applanation tonometry's status as a gold standard went largely unchallenged for 50 years, even though Professor Goldmann himself recognized various potential sources of error for the device in his first description of his tonometer. In particular, Goldmann and Schmidt acknowledged that their design assumptions were based on a CCT of 500 microns and that the accuracy of their device would vary if CCT deviated from this value[8]. The mean central corneal thickness in healthy subjects are 520 microns with a Gussian distribution[4].

Many investigators have shown that CCT may exert a large influence on applanation measurements; thin cornea produces a false low reading, as does a thick cornea swollen with edema. In contrast, thick cornea secondary to increased collagen content results in false-high reading[9]. Ehlers and co-workers[9] calculated from their linear regression equation that at a true IOP of 20 mmHg, applanation tonometry would produce a mean underestimation of 5.2 mmHg in eyes with a corneal thickness of 450 microns and on overestimation of 4.7 mmHg if the corneal thickness were 590 microns. A mean error of approximately 5 mmHg in the Goldmann applanation tonometer reading at a true IOP of 20 mmHg for each 70 microns change in the corneal thickness. Whitacre and co-workers[3] predicted a smaller mean error of 3.5 mmHg for a decrease in corneal thickness of 70 microns. Doughty and Zaman[10] found from linear regression model predicted that a 10% difference in CCT would result in 1.1 ± 0.6 mmHg difference in IOP measures by Goldmann applanation tonometer (p < 0.05).

Singh and co-workers[11]. assessed the correlations between CCT and tonometry in eyes with normal-pressure glaucoma and primary open angle glaucoma. They found that CCT was lowest in normal-pressure glaucoma, highest in eyes with ocular hypertension with a 0.2 mmHg change per 10 microns variation in central corneal thickness.

Refractive surgery procedures (Photorefractive keratectomy - PRK, LASIK) leading to the decrease of CCT. In all eyes after laser surgery procedures, IOP was lower because of the decrease of CCT[12]. Many studies have shown a decrease in IOP reading from Goldmann applanation tonometer. Mardelli and co-workers[7] showed in their retrospective study of a correlation between the reduction of CCT after PRK and IOP measurements; 23 ± 23 microns reduction in the CCT associated with a 0.5 ± 2.4 mmHg mean reduction in tonometry reading. Thinning of the cornea after LASIK affect tonometry readings. IOP difference before and after LASIK was statistically significant[13].

In 85 eyes, Emara and co-workers[14] measured a mean decrease of 2.5 ± 2.7 mmHg after LASIK. They found a significant correlation between IOP after LASIK and postoperative central corneal thickness (p < 0.002), but there was no significant correlation between the decrease in IOP and the decrease in central corneal thickness. Fournier et al[15] reported a mean decrease of 1.9 ± 2.9 mmHg in a retrospective study of 145 patients who received LASIK. Rashad et al[16] found a mean decrease in Goldmann applanation tonometry of 3.69 ± 1.63 mmHg after LASIK for myopia, although the relationship between IOP and CCT was not assessed. Montes-Mico and Charman[17] found the reduction in measured IOP following refractive surgery (PRK,LASIK), by about 0.5 mmHg/D of myopic correction. No statistically significant differences were found between the results obtained following the two types of surgery. Duch and co-workers[18] showed the correlation between CCT and IOP measured with Goldmann applanation tonometer by regression analysis was a decreased 2.9 mmHg per 70 microns reduction in CCT.

In the present study, the mean IOP measured by Goldmann applanation tonometer decreased 2.9 ± 2.5 mmHg after 3 months post-LASIK, this was a statistically significant difference (p = 0.0001) (Table 1). However, there was no correlation between the mean IOP reduction by Goldmann applanation tonometry and the reduction of CCT by Pearson analysis, this may be attributed to small sample size in the present study (Table 2). But after the authors analyzed in subgroups depending on the degree of myopia, it was found that there was a tendency of correlation in the higher myopic group (Table 3).

In conclusion, the Goldmann applanation tonometer simply measures the force needed to deform the cornea in a standardized manner. IOP is derived from the force measurement indirectly, based on a number of assumptions about corneal deformability. Corneal deformability in turn represents a summation of the corneal curvature, elastic properties, surface tension, and the IOP. Central corneal thickness is probably the major component of corneal elasticity. Therefore, IOP is overestimated for thicker corneas and underestimated for thinner values. Currently, there is no consensus on the magnitude of IOP measurement error with thin or thick corneas. It is not known whether this relation is linear or nonlinear across the range of corneal thickness in the general population. It is also not known whether the iatrogenically thinned cornea after LASIK has the same implications in terms of tonometric artifact as do naturally thin corneas. However, there is an increasing need for awareness of underestimation of IOP measured by Goldmann applanation tonometer after LASIK. This has important implications for myopic patients who undergo LASIK surgery and may be at risk to develop glaucoma. Their pressures will be read as normal or low because the cornea is thin as a result of LASIK. The authors suggest measuring the CCT and IOP by Goldmann applanation tonometer pre- and post-LASIK in all cases to avoid a misleading diagnosis of early glaucoma in this group of patients in the future.

References

1. Thomas JV. Primary open angle glaucoma. In: Albert DM, Jakobiec FA, eds. Principles and Practice of Ophthalmology. Philadelphia: Saunders, 1994: 1342-5.
2. Ehlers N, Hansen FK. Central corneal thickness in low-tension glaucoma. Acta Ophthalmol 1974; 52: 740-6.
3. Whitacre MM, Stein RA, Hassanein K. The effect of corneal thickness on applanation tonometry. Am J Ophthalmol 1993; 115: 592-6.
4. Hansen FK. A clinical study of the normal human central thickness. Acta Ophthalmol 1971; 49: 82-9.
5. Argus WA. Ocular hypertension and central corneal thickness. Ophthalmology 1995; 102: 1810-2.
6. Chatterjee A, Shah S, Bessant DA, et al. Reduction in intraocular pressure after Excimer Laser Photorefractive Keratectomy. Ophthalmology 1997; 104: 355-9.
7. Mardelli PG, Piebenga LW, Whitacre MM, et al. The effect of Excimer Laser Photorefractive Keratectomy on Intraocular Pressure Measurements Using the Goldmann applanation tonometer. Ophthalmology 1997; 104: 945-8.
8. Brandt JD. Corneal thickness in glaucoma screening, diagnosis, and management. Current Opinion in Ophthalmology 2004; 15: 85-9.
9. Ehlers N, Bramsen T, Sperling S. Applanation tonometry and central corneal thickness. Acta Ophthalmol 1975; 53: 34-43.
10. Doughty MJ, Zaman ML. Human corneal thickness and its impact on intraocular pressure measures: A review and meta-analysis approach. Surv Ophthalmol 2000; 44: 367-408.
11. Singh RP, Goldberg I, Graham SL, et al. Central corneal thickness,Tonometry and Ocular Dimensions in Glaucoma and Ocular Hypertension. J Glaucoma 2001; 10: 206-10.
12. Filipecka I,Gierek-Ciaciura S.Influence of corneal thickness changes after refractive surgery on intraocular pressure measurements. Klin Oczna 2001; 103: 25-7.
13. Arimoto A, Shimizu K, Shoji N, et al. Underestimation of intraocular pressure after LASIK. Nippon Ganka Gakkai Zasshi 2001; 105: 771-5.
14. Emara B, Probst LE, Tingey DP, Kennedy DW, Willms LJ, Machat J. Correlation of Intraocular pressure and central corneal thickness in normal myopic eyes and after laser in situ kera-tomileusis. J Cataract Refract

Surg 1998; 24: 1320-5.
15. Fournier AV, Podtetenev M, Lemier J, et al. Intraocular pressure change measured by Goldmann tonometry after laser in situ keratomileusis. J Cataract Refract Surg 1998; 24: 905-10.
16. Rashad KM, Bahnassy AA. Changes in Intraocular Pressure after Laser in Situ Keratomileusis. J Cataract Refract Surg 2001; 17: 420-7.
17. Montes-Mico R, Charman WN. Intraocular pressure after excimer laser myopic refractive surgery. Ophthalmic Physiol Opt 2001; 21: 228-35.
18. Duch S, Serra A, Castanera J, et al. Tonometry after Laser in Situ Keratomileusis Treatment. J Glaucoma 2001; 10: 261-5.
19. Whitarce MM, Stein R. Sources of error with the use of Goldmann type tonometers. Surv Ophthalmol 1993; 38: 1-30.
20. Goldmann H. Applanation tonometry. In: Newell FE.ed. Glaucoma: Transactions of the second conference. New York: Josiah Macy, Jr Foundation, 1957: 167-220.
21. El Danasoury MA, El Maghraby A, Coorpender SJ. Change in intraocular pressure in myopic eyes measured with contact and non-contact tonometers after laser in situ keratomileusis. J Cataract Refract Surg 2001; 17: 97-104.
22. Faucher A, Gregoire J, Blondeau P. Accuracy of Goldmann tonometry after refractive surgery. J Cataract Refract Surg 1997; 23: 832-8.
23. Park HJ, Uhm KB, Hong C. Reduction in intraocular pressure after laser in situ keratomileusis. J Cataract Refract Surg 2001; 27: 303-9.

การวัดความดันตาภายหลังการทำเลสิค: การศึกษาในคนไทย

งามแข เรืองวรเวทย์, อติพร ตวงทอง, พนิดา โกสียรักษ์วงศ์, ภิญนิตา ประภาสะวัต, วิภาวี บูรณพงศ์, สบง ศรีวรรณบูรณ์

วัตถุประสงค์: *เพื่อศึกษาการเปลี่ยนแปลงของค่าความดันตา โดยการวัดด้วยเครื่องวัด Applanation ในผู้ป่วยที่ได้รับการทำเลสิคเพื่อรักษาสายตาสั้นและสายตาเอียง และศึกษาความสัมพันธ์ระหว่างการเปลี่ยนแปลงของค่าความดันตา และการลดลงของความหนาของกระจกตาในผู้ป่วยไทย*

วิธีการศึกษา: *การศึกษาแบบไปข้างหน้า*

วัสดุและวิธีการ: *ผู้ป่วย 33 ราย (65 ตา) ที่ได้รับการทำเลสิค เพื่อแก้ไขสายตาสั้นและสายตาเอียง ได้รับการตรวจตาอย่างละเอียด และวัดความดันตาก่อนและหลังการทำเลสิค เป็นเวลา 3 เดือน โดยดูความสัมพันธ์กับค่าความหนาของกระจกตาก่อนและหลังทำเลสิค*

ผลการศึกษา: *ค่าความดันตาที่วัดได้ หลังทำเลสิคลดลงเฉลี่ย 2.9 $\pm$ 2.5 มม. ปรอท ($p = 0.0001$) และเมื่อศึกษาถึงความสัมพันธ์ระหว่างการลดลงของค่าความดันตา กับการลดลงของความหนากระจกตา โดยแบ่งผู้ป่วยเป็น 3 กลุ่ม กลุ่ม 1 สายตาสั้นน้อยกว่า -3 ไดออฟเตอร์ กลุ่ม 2 สายตาสั้น -3 ถึง -6 ไดออฟเตอร์ และกลุ่ม 3 สายตาสั้นมากกว่า -6 ไดออฟเตอร์ พบว่ามีแนวโน้มที่จะมีความสัมพันธ์กันในกลุ่มที่มีสายตาสั้นมากกว่า -6 ไดออฟเตอร์ ขึ้นไป*

สรุป: *การวัดความดันตาด้วยเครื่อง Applanation จะให้ค่าที่ต่ำลงในผู้ที่มีกระจกตาบาง ดังนั้น การวัดความดันตาด้วยเครื่อง Applanation เพื่อใช้ในการวินิจฉัยโรคต้อหิน ควรคำนึงถึงค่าความหนาของกระจกตาร่วมด้วย โดยเฉพาะผู้ป่วยที่ได้รับการทำเลสิค*