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Influence of IOP measurement through the wrong eyepiece of the slit lamp on Goldmann applanation tonometry

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PURPOSE. *This study examined whether intraocular pressure (IOP) measurements through the wrong eyepiece of the slit lamp may be a source of error.*
METHODS. *Seven skilled observers measured the IOP from seven healthy subjects. The observers used a Haag-Streit Goldmann applanation tonometer with two types of slit lamps (Haag-Streit and Rodenstock). In the Haag-Streit slit lamp the prism of the tonometer is aligned with the right part of the slit lamp optics. Conversely, in the Rodenstock slit lamp, the prism is aligned with the left. Each observer measured the IOP of each subject through the right eyepiece, through the left eyepiece, and under binocular vision.*
RESULTS. *The IOP measured with the left eyepiece of the Haag-Streit slit lamp was significantly higher than that measured with the right eyepiece and binocular vision. The IOP measured with the right eyepiece of the Rodenstock slit lamp was significantly higher than that measured with the left eyepiece and binocular vision.*
CONCLUSIONS. *IOP measurement through the wrong eyepiece of the slit lamp may be a source of error. (Eur J Ophthalmol 2008; 18: 910-4)*

KEY WORDS. *Glaucoma, Goldmann applanation tonometry, Intraocular pressure, Slit lamp*

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INTRODUCTION

Accurate estimation of intraocular pressure (IOP) is a key component of the diagnosis and treatment of glaucoma. Goldmann applanation tonometry (GAT) is used worldwide and is considered to be the gold standard in the clinical environment (1), because it is recognized as an accurate way to measure the IOP. A thin cornea has been recognized as a risk factor for the progression of glaucoma and a significant predictor of glaucomatous damage at the initial examination. Thin corneas are associated with an underestimation of GAT IOP, and thick corneas are associated with an overestimation (2, 3). Other factors that influence Goldmann applanation readings include corneal astigmatism, corneal curvature, tight necktie, fluorescein and tear film volume, poor illumination, interobserver error, number of tonometer contacts, and calibration error (4-7). It is a necessary prerequisite for accurate measurement to avoid the sources of error due to a setting or technical error of GAT. Goldmann applanation tonometer is fitted up with a slit lamp. IOP is usually measured under binocular vision using a slit lamp. However, the optics of GAT is agreement with a monocular vision of the mounted slit lamp. This study attempted to elucidate whether IOP measurements obtained through the wrong eyepiece of the slit lamp may be a source of error of GAT.

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METHODS

Seven skilled observers (glaucoma specialists) measured the IOP in the right eye from seven normal volunteer healthy subjects. The subjects included five men and two women without any ocular pathology. The average age of the subjects was 37.4±11.6 years (range: 29–59 years). The refraction and corneal curvature radius (CCR) was calculated with an auto-kerato-refractometer (KR-8100PA, Topcon, Co., Tokyo, Japan), and the central corneal thickness (CCT) was measured with an ultrasound pachymeter (AL-3000, Tomey, Co., Tokyo, Japan). Refraction was represented by a spherical equivalent. The observers used the Haag-Streit GAT (Koeniz-Berne, Switzerland) equipped with two types of slit lamps (Haag-Streit BQ900, Switzerland, and Rodenstock Ro2000SE, Germany). The observers used two different tonometers, each mounted to their respective slit lamp, and calibrated and verified them to provide identical results under standard conditions. The optics for the GAT of the Haag-Streit slit lamp is right and that of Rodenstock is left. Each observer measured the IOP on the right eye of each subject three times: through the right eyepiece, through the left eyepiece, and under binocular vision. The order of the eyepiece used for measurement was randomly determined. The measurements were performed in the evening (between 16 and 19 o'clock) over several days within 2 weeks. Tonometry intervals were longer than 10 minutes. The IOP values were evaluated among three groups (right, left eyepiece, and binocular vision groups). The inter- and intraobserver variations SD of the measurements were compared among the three groups. The statistical analysis was done using Friedmann test. A p value of <0.01 was considered statistically significant.

RESULTS

Table I shows the data of the subjects and their IOP readings (mean±SD) by seven observers. The mean refraction was –4.71±4.06 (range: –10.5–0.75) D. The mean horizontal CCR was 7.94±0.21 (range: 7.61–8.21) mm, and the mean vertical CCR was 7.80±0.22 (range: 7.37–8.03) mm. The mean CCT was 537±19 (range: 507–565) µm.
The IOP measured with the left eyepiece of Haag-Streit slit lamp was 13.0±2.0 (mean±SD) mmHg, which was sig-

TABLE I - DATA OF THE SUBJECTS AND THEIR IOP READINGS (mean ± SD) BY SEVEN OBSERVERS

		Subject						
	Mean	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Age	37.4	59	48	35	31	30	30	29
Sex	M:F=5:2	M	M	M	M	F	F	M
Refraction (D)	–4.71	+0.75	–10.50	–8.50	–3.25	–6.50	–4.25	–0.75
CCRH (mm)	7.94	7.61	7.77	7.97	8.15	8.21	7.99	7.88
CCRV (mm)	7.80	7.37	7.66	7.90	7.94	8.03	7.91	7.78
CCT (µm)	537	551	538	545	528	565	507	525
Haag–Streit BQ900								
Right	11.77	10.48	13.19	13.57	10.14	12.57	11.95	10.48
SD	1.90	0.54	1.78	1.49	0.88	0.86	0.62	2.72
Left	13.03	11.71	14.57	14.38	12.05	13.95	13.14	11.43
SD	2.00	1.37	2.01	2.27	0.70	1.27	1.50	2.12
Binocular	12.03	10.80	13.43	14.00	11.00	12.71	11.71	10.62
SD	1.95	0.88	2.15	1.62	1.06	1.30	0.71	2.50
Rodenstock Ro2000SE								
Right	12.90	11.43	13.62	14.10	11.38	14.57	13.62	11.57
SD	1.91	1.61	1.13	0.71	1.22	0.76	1.67	2.54
Left	11.24	9.33	12.43	12.62	9.86	12.38	12.38	9.67
SD	1.88	1.22	1.44	1.13	0.81	1.28	1.30	1.76
Binocular	11.88	10.05	12.95	13.52	10.76	12.95	12.76	10.19
SD	1.94	0.62	1.72	1.09	1.07	1.38	1.18	2.39

CCRH = Horizontal corneal curvature radius; CCRV = Vertical corneal curvature radius; CCT = Central corneal thickness

TABLE II - IOP READINGS WITH USE OF RIGHT, LEFT EYEPIECE, AND BINOCULAR VISIONS

Slit type	IOP (mmHg)		p	
	Range	mean±SD		
Haag-Streit BQ900				
Right eyepiece	7.3–16.0	11.8±1.9	p <0.0001	p=0.55
Left eyepiece	9.3–18.0	13.0±2.0	p <0.0001	
Binocular vision	7.0–16.3	12.0±2.0		
Rodenstock Ro2000SE				
Right eyepiece	8.7–16.0	12.9±1.9	p <0.0001	p <0.0001
Left eyepiece	7.0–15.3	11.2±1.9	p 0.0002	
Binocular vision	8.0–14.7	11.9±1.9		

The IOP measured with the left eyepiece of the Haag-Streit slit lamp was significantly higher than that measured with the right eyepiece and under binocular conditions. The IOP measured with the right eyepiece of the Rodenstock slit lamp was significantly higher than that measured with left eyepiece and under binocular vision

TABLE III - INTEROBSERVER VARIATION SD

Slit type	Interobserver variation SD			
	Range	mean±SD	p	
Haag-Streit BQ900				
Right eyepiece	0.54–2.72	1.27	p=0.41	p=0.87
Left eyepiece	0.70–2.27	1.61	p=0.17	
Binocular vision	0.71–2.50	1.46		
Rodenstock Ro2000SE				
Right eyepiece	0.71–2.54	1.38	p=0.86	p >0.96
Left eyepiece	0.81–1.76	1.28	p=0.96	
Binocular vision	0.62–2.39	1.35		

There are no significant differences in the interobserver variation SD among the three different methods

TABLE IV - INTRAOBSERVER VARIATION SD OF HAAG-STREIT AND RODENSTOCK SLIT LAMP

Observer	Range (mmHg)			p value		
	R	L	B	R:L	R:B	L:B
Haag-Streit BQ900						
A	0–1.53	0–1.73	0.58–1.15	0.57	0.48	0.99
B	0–1.53	0–2.00	0–1.53	0.20	0.90	0.08
C	0–1.73	0.58–1.15	0.58–1.53	0.72	0.13	0.47
D	0–2.31	0–2.52	0–1.15	0.99	0.69	0.79
E	0–2.08	0–1.53	0–2.31	0.38	0.65	0.07
F	0–1.00	0.58–1.0	0.58–1.0	0.90	0.67	0.90
G	0–1.73	0–1.53	0–2.08	0.81	0.72	0.98
Rodenstock Ro2000SE						
A	0.58–1.53	0–1.15	0–2.08	0.89	0.89	1.00
B	0–1.15	0–1.15	0–1.15	0.21	0.94	0.37
C	0.58–1.15	0.58–1.73	0.58–2.31	0.87	0.87	1.00
D	0–1.53	0–0.58	0–0.58	0.99	0.99	0.94
E	0.58–1.53	0.58–1.53	0.58–1.53	0.32	0.96	0.48
F	0.58–2.65	0.58–2.65	0.58–2.65	0.39	0.62	0.93
G	0–2.00	0–2.52	0–2.52	0.61	0.61	1.00

There are no significant differences in the intraobserver variation SD among the three different methods. R = Right eyepiece; L = Left eyepiece; B = Binocular vision; R:L = p value of the difference in the SD between right and left eyepiece; R:B = p value of the difference in the SD between right eyepiece and binocular vision; L:B = p value of the difference in the SD between left eyepiece and binocular vision

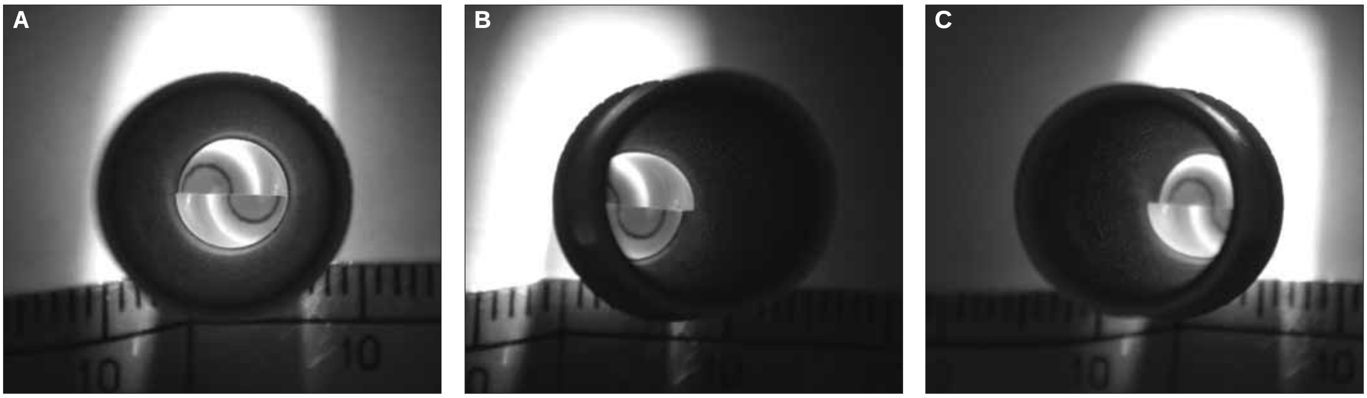

Fig. 1 - *When the prism is applied to a drawn circle measuring 3.06 mm in diameter, the inner borders of the two fluorescein half circle rings meet* **(A)**. *When the prism is shifted toward the wrong eyepiece, the inner borders of the two fluorescein half circle rings deviate to the side* **(B, C)**.

nificantly higher than that measured with the right (11.8±1.9 mmHg) eyepiece and under binocular (12.0±2.0 mmHg) vision. There was no significant difference between the right eyepiece and binocular vision. The IOP measured with the right eyepiece of the Rodenstock slit lamp was 12.9±1.9 mmHg, which was significantly higher than that measured with the left (11.2±1.9 mmHg) eyepiece and binocular (11.9±1.9 mmHg) vision. A significant difference was observed between the left eyepiece and under binocular vision (Tab. II).

Table III shows the interobserver variations SD. There were no significant differences in the variations among the three different methods. The ranges of interobserver variation SD were 0.54–2.72 mmHg in the right eyepiece, 0.70–2.27 mmHg in the left eyepiece, and 0.71–2.50 mmHg in binocular vision of the Haag-Streit slit lamp. The ranges were 0.71–2.54 mmHg in the right eyepiece, 0.81–1.76 mmHg in the left eyepiece, and 0.62–2.39 mmHg in binocular vision of the Rodenstock slit lamp. Table IV shows the intraobserver variations SD. There were no significant ($p>0.05$) differences in the variations of each observer among the three different methods. The ranges of intraobserver variation SD were 0–1.73 mmHg in observer A, 0–2.00 in observer B, 0–1.73 in observer C, 0–2.52 in observer D, 0–2.31 in observer E, 0–1.00 in observer F, and 0–2.08 in observer G with a Haag-Streit slit lamp. The ranges were 0–2.08 mmHg in observer A, 0–1.15 in observer B, 0.58–2.31 in observer C, 0–1.53 in observer D, 0.58–1.53 in observer E, 0.58–2.65 in observer F, and 0–2.52 in observer G with a Rodenstock slit lamp.

DISCUSSION

Accurate measurement of IOP is crucial to appropriate glaucoma management. There are some errors associated with using a GAT (2-7). Sources of error due to setting or technical errors of GAT should be avoided. The present study showed that the IOP measured with the left eyepiece of the Haag-Streit slit lamp was significantly higher than that measured with the right eyepiece and binocular vision. The IOP measured with the right eyepiece of the Rodenstock slit lamp was significantly higher than that measured with left eyepiece and under binocular vision. The optics for the GAT of the Haag-Streit slit lamp is right and that of the Rodenstock is left. Therefore, the IOP readings measured through the wrong eyepiece (the eyepiece not to be used for the IOP measurement) were significantly higher than those measured through the correct eyepiece (the eyepiece used for the IOP measurement) and binocular vision. The IOP measurement through the wrong eyepiece of the slit lamp may thus be a source of error in GAT. If the setting on the Goldmann applanation tonometer is correct, then clinicians do not need to check whether the correct eyepiece is being used, because it is automatic. When the setting of GAT or adjustment of the eyepiece refraction is incorrect, the examiner may measure IOP through the wrong eyepiece of the slit lamp.

There are two basic models of the Goldmann applanation tonometer for the Haag Streit slit lamp. The first type is mounted on the end of a lever that is hinged on the slit lamp. This metallic lever, apart from its purpose of maintaining the tonometer suspended in its position, serves to occlude the observer's view of the prism through the wrong eyepiece. Binocular tonometry is also impossible to perform with this device. A second model of the tonometer is directly mounted on a platform and binocular tonometry is possible, and therefore this phenomenon allows for a potential misalignment.

The IOP of the same eye was measured with three different methods (through the right, left eyepiece, and under binocular vision), therefore corneal variables including corneal thickness, astigmatism, and curvature are negligible for the sources of error. Only skilled observers (glaucoma specialists) performed IOP measurements in the present study. Table I shows the IOP reading of each subject measured by each observer. Table III shows the interobserver variation SD, and Table IV shows the intraobserver variation SD. Several SD values were greater than 2 mmHg in both the interobserver and intraobserver variations; however, there were no significant differences in the variations among the three different methods. Although intraobserver and interobserver variations are therefore not considered to be negligible, the IOP readings measured through the wrong eyepiece were significantly higher than those measured through the correct eyepiece and under binocular vision.

The present study was conducted to evaluate whether the IOP through the wrong eyepiece of the slit lamp may be a source of error of GAT in normal volunteer healthy subjects. This study has some limitations. The number of subjects was small. The subjects included only normal IOP volunteers; no OHT or POAG patients were included in this study. It remains to be determined whether the IOP readings measured through the wrong eyepiece may be higher than those measured through the correct eyepiece on OHT patients. Further studies are needed to address these problems. The measurements were performed in the evening over a period of several days in the present study. IOP fluctuations of different times and days are not negligible. The IOP fluctuations and repeated measurements over several days may also be considered to be possible factors that could have influenced the present results.

Goldmann applanation has two prisms which divide the image in two halves, the halves being displaced from each other by 3.06 mm. Two half circles are observed through the microscope when the prism comes in contact with the cornea. When sufficient force is applied to flatten cornea to a diameter of 3.06 mm, the inner borders of the two fluorescein half circle rings meet (8). When the prism is shifted to the direction of uncorrected eyepiece, then the inner borders of the two fluorescein half rings slide to the side (Fig. 1). Therefore, the IOP readings measured through the wrong eyepiece are higher than those measured through the correct eyepiece.

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