Tono-Pen tonometer and corneal thickness

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Abstract

Purpose To compare the intraocular pressure (IOP) measurements taken at the central cornea with those taken at the mid-peripheral cornea using the Tono-Pen tonometer.

Methods Forty-eight normal human subjects had their IOP measurements taken (i) with the Goldmann tonometer, (ii) with the Tono-Pen at the central cornea and (iii) with the Tono-Pen at the mid-peripheral cornea. The central and mid-peripheral corneal thickness at the site of IOP measurements were then determined by ultrasonic pachymetry.

Results The mean IOP with the Goldmann tonometer was 15.7 ± 3.1 mmHg. The mean Tono-Pen IOPs at the central and mid-peripheral cornea were 15.2 ± 3.2 mmHg and 15.7 ± 3.3 mmHg respectively. The mean mid-peripheral corneal thickness ($578 \mu\text{m}$) was significantly higher than the mean central thickness ($538 \mu\text{m}$) ($p < 0.001$).

Conclusion There was no significant difference between the IOP taken with the Tono-Pen and with the Goldmann tonometer. In addition, no clinically significant difference was observed between the IOP readings of central and mid-peripheral cornea measured by the Tono-Pen.

Key words Corneal thickness, Goldmann tonometry, Intraocular pressure, Tono-Pen

The measurement of intraocular pressure (IOP) is a crucial step in the diagnosis and management of glaucoma. The Goldmann tonometer is widely accepted as the gold standard of measurement. It assumes that the resistance to indentation offered by the cornea is counter-balanced by the surface tension of the tear film. However, this assumption is not true for all patients. Central corneal thickness appears to be positively correlated with the resistance. The Goldmann tonometer is known to register artificially higher IOP values for patients with a thick cornea,¹⁻⁴ and lower IOP values for those with a thin cornea.^{2,5} Variation in central corneal thickness is suggested to be a significant source of variation in IOP measurements between individuals.⁶ The Mentor Tono-Pen is an electronic tonometer that measures IOP using principles similar to those used in the MacKay-Marg tonometer. Its tip has

a strain gauge that is activated once it touches the cornea. Since the Tono-Pen indents a smaller surface area (2.36 mm^2) of the cornea than does the Goldmann tonometer (7.35 mm^2), the effects of corneal rigidity and surface tension of tears would be less significant. It is also known that different parts of the cornea have different thicknesses. This clinical study aimed to investigate whether the Tono-Pen would provide reliable and similar IOP readings when used at different sites on the cornea.

Methods

After full informed consent had been obtained from all subjects, 48 eyes of 48 subjects were enrolled in the study at the Queen Mary Hospital Ophthalmology Clinic, Hong Kong. All subjects had no corneal diseases and no astigmatism greater than 1.5 dioptre cylinder. Since the Tono-Pen readings were not open to interpretation, Goldmann tonometry was first carried out by an optometrist (K.H.M.). Four consecutive Goldmann measurements were made on each subject. Then, using the Tono-Pen XL (Mentor), two sets of IOP measurements (one on the central cornea and the other at the mid-periphery on the temporal side) were obtained from each patient by another optometrist (C.S.L.W.). The Tono-Pen tonometer was calibrated according to the manufacturer's instructions each day. Only the readings of the highest reliability were accepted ($\text{SEM} \leq 5\%$ of the average); where the SEM was greater than 5% of the average the results were discarded and the measurement repeated. The two observers were each masked to the measurements by the other. The thickness of the cornea was then measured with an ultrasonic pachymeter (BVI, France), and its curvature with an auto-kerato-refractometer (KR-3100, Topcon, Japan).

Results

The Goldmann tonometer is most accurate when applied to a central corneal thickness of $520 \mu\text{m}$, and the Perkins tonometer to a thickness of about $550 \mu\text{m}$.⁷ Therefore the collection and interpretation of data in this study were restricted to central corneal thicknesses ranging from 510 to $570 \mu\text{m}$.

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Table 1. Corneal thickness and IOP measured by Goldmann and Tono-Pen tonometers at the central and mid-peripheral cornea (n = 48)

Corneal location:	Central		Mid-peripheral
Thickness (μM)			
Mean ± SD	538 ± 29		578 ± 25
Range	511–568		525–628
Tonometer:	Goldmann	Tono-Pen	Tono-Pen
IOP (mmHg)			
Mean ± SD	15.7 ± 3.1	15.2 ± 3.2	15.7 ± 3.3
Range	9–22	7–22	8–24

No statistically significant difference in the mean IOP readings was observed between the Goldmann and Tono-Pen tonometers (paired Student’s *t*-test, *p* > 0.05) (Table 1). The temporal mid-peripheral corneal thickness was significantly higher than the central thickness (*p* < 0.001). The mean IOP at the temporal mid-peripheral cornea was statistically higher (*p* = 0.02) than that at the central cornea as measured by the Tono-Pen, and the mean absolute difference was 1.2 ± 0.8 mmHg. The correlation coefficient (*R*) of the IOP readings measured by Tono-Pen at the central and temporal mid-peripheral cornea was 0.91 (*p* < 0.001) (Fig. 1).

Discussion

Goldmann applanation tonometer has long been regarded as the clinical gold standard in IOP measurement. The Tono-Pen tonometer measures IOP in a similar fashion to the Goldmann tonometer. Some studies, however, have found that the Tono-Pen underestimated IOP readings in the higher ranges⁸ and overestimated IOP in the lower ranges.^{9,10} Nevertheless, most studies generally agree that there is good correlation between the Goldmann and Tono-Pen tonometers, especially within the normal range of IOP.^{9,11–13} It has also been reported that there is good correlation between IOP measurements with the Tono-Pen and manometric readings in human autopsy eyes.¹¹

The Tono-Pen is a versatile, portable, electronic applanation tonometer. It is especially useful in infants and young children when slit-lamp examination is difficult. Due to the poor fixation of these patients, it is not always easy to place the small tip of the Tono-Pen accurately over the central cornea. Eccentric applanation is also useful in patients with central corneal irregularities, such as scarring and deformation. A study¹⁴ has compared the IOP measured by the Tono-Pen at different corneal locations of cadaveric eyes. The

Fig. 1. Scattergram and linear regression for Tono-Pen IOP measured at the central cornea (*Tcentral*) and the mid-peripheral cornea (*Tperipheral*). Regression line: *y* = 1.50*x* + 0.87; *r* = 0.91, *p* < 0.001.

investigators found that the mean IOP at the mid-periphery or the clear limbal cornea was not significantly different from the IOP at the central cornea, indicating that a non-central corneal IOP reading could be as accurate as a central measurement. However, this *in vitro* study is flawed in that cadaveric eyes do not have physiological variables present in living eyes, such as pre-corneal tear film, a viable corneal epithelium and endothelium, normal corneal thickness and rigidity. The present study aimed to compare the IOP readings taken by the Tono-Pen at two different corneal locations (central and mid-peripheral) of living eyes. Mid-peripheral IOP was highly correlated with the central readings, and about 70% of paired differences were within ± 1 mmHg. Our results suggest that the Tono-Pen gives reliable IOP readings at both the central and the peripheral cornea.

Several studies^{2–4} have shown that the corneal thickness in ocular hypertensive eyes is significantly greater than normal (Table 2). Ehlers and associates⁷ extrapolated from this that the Goldmann tonometer overestimates or underestimates IOP by about 5 mmHg for every 70 μm increase in central corneal thickness, and Wolfs and associates⁴ showed an increase of 0.19 mmHg in IOP for each 10 μm increase in thickness. A significant number of hypertensive patients have normal IOP if corneal thickness is taken into account.³ On the other hand, low-tension glaucomatous patients with a thinner cornea may have a higher IOP if their corneal thickness is also considered. In the present study, although the mean mid-peripheral thickness was significantly higher than the central thickness, only about a 1 mmHg difference in

Table 2. The effect of corneal thickness on IOP measurements

	Argus ¹ (1995)		Herndon <i>et al.</i> ³ (1997)		Wolfs <i>et al.</i> ⁴ (1997)		Present study	
Tonometer:	Goldmann		Goldmann		Goldmann		Tono-Pen	
Subjects:	Normal	OH	Normal	OH	Normal	OH	Normal	
Location:	Central		Central		Central		Central	Mid-peripheral
Thickness (μm)	567	610	561	606	537	553	538	578
Difference (μm)	43		45		16		40	
IOP (mmHg)	15.5	23.2	13.2	21.5	14.6	18.7	15.2	15.7
Difference (mmHg)	7.7		8.3		4.1		0.5	

OH, ocular hypertension.

IOP was observed (Table 2) with the Tono-Pen tonometer. The Tono-Pen tonometer appeared to be less affected by corneal thickness than the Goldmann tonometer, mainly because the Tono-Pen indents a relatively smaller surface area than does the Goldmann tonometer (2.36 mm² vs 7.35 mm²). Our results suggest that the Tono-Pen tonometer might give a more accurate IOP for individuals with a cornea thicker or thinner than normal.

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