Ophthal. Physiol. Opt. 2002 **22:** 560–564

Clinical performance of the Reichert AT550: a new non-contact tonometer

J. Jorge[1], J. A. Díaz-Rey[1], J. M. González-Méijome[1], J. B. Almeida[1] and M. A. Parafita[2]

[1]Department of Physics (Optometry), School of Sciences, University of Minho, Braga, Portugal and [2]Department of Surgery (Ophthalmology), School of Optics and Optometry, University of Santiago de Compostela, Spain

Abstract

The aim of the present study was to assess the level of accuracy for measurements of intra-ocular pressure (IOP) obtained with a new non-contact tonometer (NCT) the Reichert AT550®. Measurements were compared against those obtained with the Reichert Xpert Plus, Goldmann applanation tonometer and Perkins tonometer. Thirty-five university students were assessed with the four tonometers in a randomised order, with non-contact tonometry performed first. Each of the four measurement devices had its own trained clinical observer. Plots of differences of IOP as a function of the mean for each pair of instruments were obtained. No statistically significant differences were found when comparing the AT550® NCT with contact applanation tonometry (AT) ($p > 0.05$), displaying the closest level of agreement (as represented by the lowest mean difference and the narrowest confidence interval) with the Goldmann tonometer (limits of agreement, 0.12 ± 2.17). In conclusion, readings of IOP with the AT550® NCT are clinically comparable with those obtained with Goldmann tonometry in a population with IOP within the normal range.

Keywords: accuracy, applanation tonometry, intraocular pressure, non-contact tonometry

Introduction

The assessment of intra-ocular pressure (IOP) is an important part of the ocular examination, particularly in those subjects at risk of suffering visual impairment from an increase in IOP. The use of non-contact tonometry (NCT) is now well established in clinical practice (particularly among optometrists) as part of a screening protocol for glaucoma, as its use does not require topical anaesthesia.

Intraocular pressure as measured with the Goldmann contact applanation tonometer (AT) is the clinical standard against which all other types of tonometers are compared. Because of its mechanical design, this instrument has been demonstrated to have less variation in repeated measurements of IOP than NCT (Thorburn, 1978). However, for some patients it is not the instrument of choice (Wingert *et al*., 1995; Cho and Lui, 1997).

Grolman introduced the first NCT in 1972 (Lisle and Ehlers, 2000), and since then, many types of NCT have been marketed. The Reichert Xpert Plus (XpertP®) is the fourth generation of the original Grolman's tonometer, and the AT550® has been recently marketed as the most improved version. While for the previous versions of the Reichert tonometer, position of the air output was achieved by manually adjusting the elevation controls with a joystick whilst the patient's head was stabilised by a chin rest, the AT550® achieves the alignment automatically. The operator just presses a button to activate the measurement process, while the patient is positioned against the instrument's forehead rest looking at a fixation light. The puff of air is only released when the instrument is in proper alignment.

Different studies have reported the performance of current NCTs (Cho and Lui, 1997; McCaghrey and Matthews, 2001) as well as the level of agreement when compared with AT (Wingert *et al*., 1995; Mackie *et al*., 1996). Significant differences between modern NCT and

Received: 25 February 2002
Revised form: 17 June 2002
Accepted: 26 June 2002

Correspondence and reprint requests to: Jorge Jorge, Departamento de Física, Universidade do Minho, Campus de Gualtar, 4710 Braga, Portugal.
Tel.: +351 253 604 333; fax: +351 253 678 981
E-mail address: jjorge@fisica.uminho.pt

AT have been observed (Mackie *et al*., 1996), which is important as NCT are used in screening protocols for glaucoma detection. Goldman AT is the preferred instrument for diagnosis and follow-up in glaucomatous patients, where an accurate measurement is required.

The aim of the present study was to assess the level of accuracy for measurements of IOP obtained with a new NCT (AT550®, Reichert) in a young population, by comparing the IOP to that obtained with the Goldman AT. Measurements were compared with those obtained with XpertP® and Perkins tonometer (a portable version of the Goldmann tonometer) by plotting differences against mean values of IOP for each pair of devices.

Subjects and methods

Thirty-five left eyes from 35 optometry students (13 males, 22 females) aged from 19 to 29 years (mean ± S.D., 25 ± 2) were recruited for this study. All subjects were free of ocular disease, had no complaints of excessive lacrimation, were not taking any medications and had normal general health. The study protocol was reviewed by the Scientific Committee of the Faculty of Science at the University of Minho (Portugal). After all procedures were explained, subjects signed informed consent form prior to be enrolled in the study.

Four trained practitioners evaluated each subject with the NCTs and after 5 min with both ATs. Each of the tonometers had its own examiner who recorded the measurement without knowing the measurements of any of the other examiners. This order was established to avoid possible reduction in IOP induced by AT as a result of aqueous massage (Kakau and Wilke, 1971). The order in which non-contact and ATs were applied for each subject was random. The IOP value for the NCTs was taken as the average of three consecutive readings. For the Goldmann and Perkins tonometers, two readings were obtained, and the average was recorded. In order to minimize the effect of diurnal variations in IOP, all measurements were taken between 14.00 and 16.00 hours in the afternoon (Pointer, 1997a, 1997b, 1999; Liu *et al*., 1999; Noel *et al*., 2001).

Measurement procedures vary significantly between instruments. Both NCTs generate a controlled pulse of room air, which flattens the cornea while an optoelectronic infrared device detects the amount of flattening to calculate IOP. After the first measurement, the air pressure is automatically controlled to suit the patient's IOP in the subsequent measurement and excessive air pressure is therefore avoided. The main difference between the two NCTs evaluated in this study rests with the alignment system, being manual for the XpertP® and automatic for the AT550®. Measurements with both NCTs were taken in the automatic mode.

Contact applanation tonometry (AT) obtains IOP values by applying a varying amount of mechanical pressure to flatten a known corneal surface area. Following topical corneal anaesthesia (2.5 mg mL^{-1} oxibuprocaine and 4 mg mL^{-1} fluorescein), two successive measurements were obtained. The drum was reset to 10 after each reading and the biprism was disinfected with 3% hydrogen peroxide between subjects. For the Goldmann tonometer, a magnification of 10× was used in the slit-lamp in conjunction with a cobalt blue filter to detect the applanation end-point.

Previous studies had used the coefficient of correlation to represent the agreement between methods (Cho and Lui, 1997). This statistical procedure has been considered as an inappropriate method when comparing results from different instruments. Bland and Altman (1986) described a method of measuring test agreement using plots of differences against means as the best way to compare measurements with different instruments, when the actual measurement is unknown (Bland and Altman, 1986, 1995; Zadnik *et al*., 1994). In this study, data were analysed using the statistical package SPSS version 10.0. The bias was assessed statistically as the mean of the differences compared with zero. The hypothesis of zero bias was examined by a paired *t*-test. The 95% limits of agreement (mean of the difference ± 1.96 × S.D. of the differences) were also calculated. This type of analysis makes it easier to assess the level of agreement between techniques, spot outliers and see whether there is any trend.

Results

Data obtained from both eyes were initially analysed and no significant differences were found between the left and the right eye. However, only left eye measurements were submitted to analysis, considering the right eye as a demonstration measurement.

Table 1 displays the mean and S.D. of IOP measurements obtained with the four tonometers. These values reflect an underestimation of XpertP® compared with other techniques, with higher variability as observed in S.D. values. Conversely, AT550® shows mean value closer to that of AT with the lowest variability in

Table 1. Summary of results (mean, S.D.) obtained for all instruments

	Mean	S.D.
XpertP®	11.51	2.56
AT550®	12.42	2.08
Goldmann	12.30	2.20
Perkins	12.64	2.41
Total	12.22	2.33

measurements among the whole population as shown by the S.D. value.

Table 2 presents mean difference, level of statistical significance as well as the limits of agreement between each pair of instruments to be compared at the 95% confidence interval.

In order to graphically represent the agreement between measurements obtained with different instruments, plots of differences as a function of the mean for each pair of techniques are displayed in *Figure 1a–f*. This analysis allows any trend in the difference variability as a function of the mean value to be detected.

As expected, close agreement was found between Goldmann and Perkins tonometers. Data show that the XpertP® NCT displays statistically significant differences compared with all the remaining instruments ($p < 0.05$). However, no statistically significant differences were found when comparing the AT550® NCT with either method of contact AT ($p > 0.05$), displaying the closest level of agreement (as represented by the lowest mean difference and the narrowest confidence interval) when compared with the Goldmann tonometer (limits of agreement, 0.12 ± 2.17).

Discussion

The mean values of Goldmann tonometry found in this study are slightly lower than those obtained by other authors in young healthy subjects (Cho and Lui, 1997; Pointer, 1999). This could be explained by the time of day at which the measurements were taken, as IOP has been demonstrated to be lower and more stable for the period between 14.00 and 16.00 hours (Liu *et al*., 1999).

Close agreement was found between Goldmann and Perkins tonometry. This could be expected as both instruments use the same measurement principle and the order of measurement was random. This procedure avoided any potential influence of aqueous massage underestimating the pressure values obtained from one instrument if ATs were systematically applied in the same order and after NCT (Kakau and Wilke, 1971).

Previous comparative studies of IOP values recorded with AT and NCT have shown a close similarity. However, a tendency for earlier models of NCT to overestimate low pressures and underestimate high pressures relative to a Goldmann measurement has been reported (Pointer, 1999). Present results suggest that for the population studied here, the Reichert NCT significantly underestimates IOP when compared with Goldmann tonometer. However, Goldmann and AT550® readings correlate surprisingly well in the present study, with the majority of differences within a narrow confidence interval of approximately ± 2 mmHg (limit of agreement, 0.12 ± 2.17). Considering that both instruments employ totally different measurement principles, to our knowledge this is the best level of agreement achieved so far between NCT and Goldmann tonometry in either normals (Cho and Lui, 1997) or glaucomatous eyes (Wingert *et al*., 1995; Mackie *et al*., 1996).

Present results show how the improvements in NCT have turned this technique into an extremely reliable and accurate method for the determination of IOP. However, previous studies suggest that higher bias is present between methods when values of IOP are compared in glaucomatous subjects (Wingert *et al*., 1995; Mackie *et al*., 1996). Despite most values of mean IOP are within normal ranges, it is apparent from *Figure 1d* that no trend exists to suggest that differences between AT550® and Goldmann tonometry increase as mean IOP increases. These results, in terms of comparability with Goldmann tonometry and apparent independence of difference from the average measured value, supports the assumption that the new version of the Reichert pneumotonometer, AT550®, could be used as a substitute for Goldmann AT and show comparable performance with that when accurate measurements are required in subjects suspected of glaucoma. However, this issue will need to be resolved by a specific study of glaucomatous patients.

In practice, major advantages of the NCT include: no necessity for corneal topical anaesthesia, criterion-free operation reducing bias, and a much-reduced risk of cross-contamination. Also, NCT has proved to be even more accurate than Goldmann tonometry after photorefractive keratectomy (Abbasoglu *et al*., 1998; Garzozi *et al*., 2001). In addition to those advantages the present

Table 2. Mean difference, significance level and 95% confidence interval limits between any two techniques

				Limits of agreement	
	Mean	**S.D.**	***p***	**Mean – 1.96*S.D.**	**Mean + 1.96*S.D.**
XpertP® vs AT550®	−0.90	1.27	0.000	−3.39	1.58
XpertP® vs Goldmann	−0.79	1.61	0.007	−3.94	2.37
XpertP® vs Perkins	−1.13	1.93	0.002	−4.92	2.66
AT550® vs Goldmann	0.12	1.11	0.529	−2.05	2.29
AT550® vs Perkins	−0.22	1.57	0.405	−3.30	2.85
Goldmann vs Perkins	−0.34	1.13	0.081	−2.56	1.87

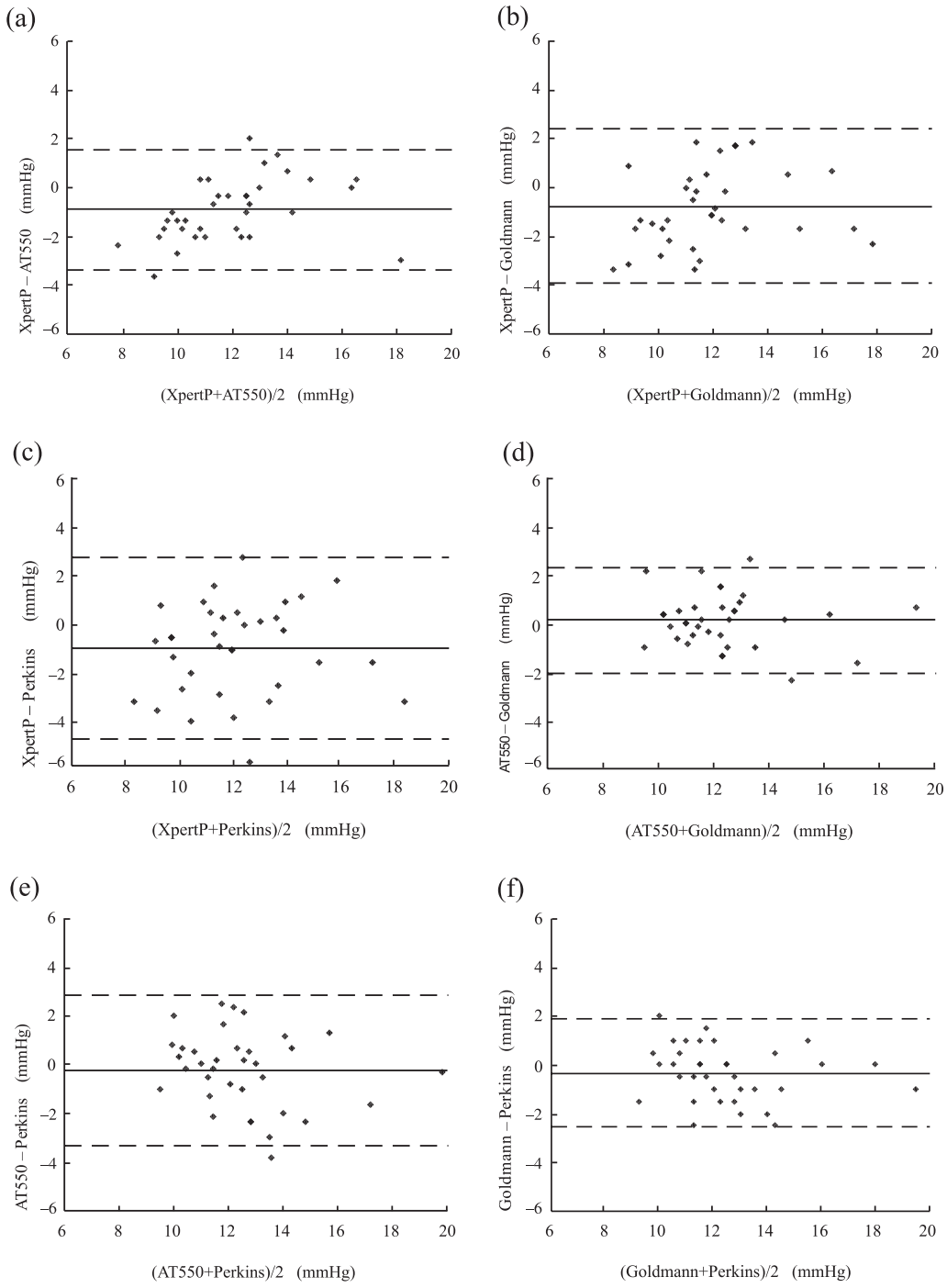

Figure 1. Plots of difference vs mean of IOP values for: (a) XpertP® and the AT550®; (b) XpertP® and the Goldmann; (c) XpertP® and the Perkins; (d) AT550® and the Goldmann; (e) AT550® and the Perkins; (f) Goldmann and the Perkins. The mean of the difference (solid lines) and the 95% confidence interval limits (dashed lines) between techniques are indicated.

results must make practitioners give even closer attention to NCT as a non-invasive standard method when precise and accurate measurements are required.

In summary, results from the present study have shown that the XpertP® NCT significantly underestimates IOP when it is compared with the other three instruments. In all cases, this difference is not clinically relevant in the evaluation of the IOP. Conversely, the improved version of the instrument (AT550®) displays no statistically significant differences with both methods of AT, particularly with Goldmann tonometry. Further work will be necessary in order to confirm if the same conclusions regarding AT550® accuracy could be drawn for a clinical population with increased IOP.

Statement

The authors state that they have no proprietary or commercial interest in Reichert or the AT550® NCT.

Acknowledgements

We thank Optometron, equipamentos técnicos e electrónicos, Lda. for the loan of the Reichert AT550®.

References

Abbasoglu, O. E., Bowman, R. W., Cavanagh, H. D. and McCulley, J. P. (1998) Reliability of intraocular pressure measurements after myopic excimer photorefractive keratectomy. *Ophthalmology* **105,** 2193–2196.

Bland, J. M. and Altman, D. G. (1986) Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* **i,** 307–310.

Bland, J. M. and Altman, D. G. (1995) Comparing methods of measurement: why plotting difference against standard method is misleading. *Lancet* **346,** 1085–1087.

Cho, P. and Lui, T. (1997) Comparison of the performance of the Nidek NT-2000 noncontact tonometer with the Keeler Pulsair 2000 and the Goldmann applanation tonometer. *Optom. Vis. Sci.* **74,** 51–58.

Garzozi, H. J., Chung, H. S., Lang, Y., Kagemann, L. and Harris, A. (2001) Intraocular pressure and photorefractive keratectomy: a comparison of three different tonometers. *Cornea* **20,** 33–36.

Kakau, C. E. T. and Wilke, K. (1971) On repeated tonometry. *Acta Ophthalmol. Scand.* **49,** 611–614.

Lisle, C. and Ehlers, N. (2000) A clinical comparison of the Xpert non-contact tonometer with the Goldmann applanation tonometer after penetrating keratoplasty. *Acta Ophthalmol. Scand.* **78,** 211–215.

Liu, J. H. K., Kripke, D. F., Twa, M. D., Hoffman, R. E., Mansberger, S. L., Rex, K. M., Girkin, C. A. and Weinreb, R. N. (1999) Twenty-four-hour pattern of intraocular pressure in the aging population. *Invest. Ophthalmol. Vis. Sci.* **40,** 2912–2917.

Mackie, S. W., Jay, J. L., Ackerley, R. and Walsh, G. (1996) Clinical comparison of the Keeler Pulsair 2000, American Optical (MkII) and Goldmann applanation tonometers. *Ophthal. Physiol. Opt.* **16,** 171–177.

McCaghrey, G. E. and Matthews, F. E. (2001) The Pulsair 3000 tonometer – how many readings need to be taken to ensure accuracy of the average?. *Ophthal. Physiol. Opt.* **21,** 334–338.

Noel, C., Kabo, A. M., Romanet, J. P., Montmayeur, A. and Buguet, A. (2001) Twenty-four-hour time course of intraocular pressure in healthy and glaucomatous Africans: relation to sleep patterns. *Ophthalmology* **108,** 139–144.

Pointer, J. S. (1997a) Intraocular Pressure Asymmetry is not a clinically-significant feature when using the Pulsair noncontact tonometer. *Ophthal. Physiol. Opt.* **17,** 449–455.

Pointer, J. S. (1997b) The diurnal variation of intraocular pressure in non-glaucomatous subjects: relevance in a clinical context. *Ophthal. Physiol. Opt.* **17,** 456–465.

Pointer, J. S. (1999) Human intraocular pressure and its diurnal variation in healthy subjects. *Ophthal. Physiol. Opt.* **19,** S43–S48.

Thorburn, W. (1978) The accuracy of clinical applanation tonometry. *Acta Ophthalmol. Scand.* **56,** 1–5.

Wingert, T. A., Carl, J., Bassi, C. J., McAlister, W. H. and Galanis, J. C. (1995) Clinical evaluation of five portable tonometer. *J. Am. Optom Assoc.* **66,** 670–674.

Zadnik, K., Mutti, D. O. and Bullimore, M. A. (1994) Use of statistics for comparing two measurement methods. *Optom. Vis. Sci.* **71,** 539–540.