LETTERS TO THE EDITOR

Tono-Pen tonometry

EDITOR,—I congratulate Geyer *et al*[1] on their article warning our colleagues about the problems associated with using a Tono-Pen as a means of measuring intraocular pressure. I have evaluated this instrument in 400 eyes of 200 consecutive patients with normal corneas. The Goldmann measurement was done first and the Tono-Pen second by the same observer. Figure 1 shows our results which are very similar to those reported by Geyer *et al*.

Clinically the term 'intraocular pressure' is the mean ocular pressure around which the pressure varies due to respiratory and arterial pressure waves. This is what is measured with the Goldmann applanation tonometer. Theoretically, repeated measurements with a non-applanating tonometer such as the Tono-Pen should approximate this mean in a reproducible fashion.[2] This is not so. Repeated measurements on the same subject with a Tono-Pen give reproducible results even where this result is markedly different from the Goldmann measurement.[3] Thus, although the Tono-Pen gives reproducible measurements, it is not measuring the same 'intraocular pressure' as a Goldmann tonometer. Future research may show that the tonometer is measuring an important aspect of ocular pressure that has to be taken into account in the management of glaucoma. At the present time the Goldmann applanation tonometer remains the only acceptable way of measuring intraocular pressure for routine patient care.

It is very tempting to use the Tono-Pen because of its portability, disposable tip cover, and ease of use in a sitting or supine position. I therefore think it is timely and important that it is pointed out that the Tono-Pen is not an accurate means of measuring the same 'intraocular pressure' which we have been accustomed to considering in our management of patients with glaucoma over the years.

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1 Geyer O, Mayron Y, Loewenstein A, Neudorfer M, Rothkoff L, Lazar M. Tono-Pen tonometry in normal and in post-keratoplasty eyes. *Br J Ophthalmol* 1992; 76: 538–40.
2 Farrar SM, Miller KN, Shields MB, Stoup CM. An evaluation of the Tono-Pen for the measurement of diurnal intraocular pressure. *Am J Ophthalmol* 1989; 107: 411–6.
3 Moses RA, Arnzen RJ. Instantaneous tonometry. *Arch Ophthalmol* 1983; 101: 249–52.

Reply

EDITOR,—We thank Drs Beaumont and Kang for their comment. Indeed, their results, as shown by their figure are very similar to ours. We completely agree that at the present time the Goldmann tonometer remains the only acceptable way of measuring intraocular pressure for routine patient care. We are pleased to learn that a conclusion similar to ours was derived by Drs Beaumont and Kang after evaluating the instrument on a large series of 400 normal eyes.

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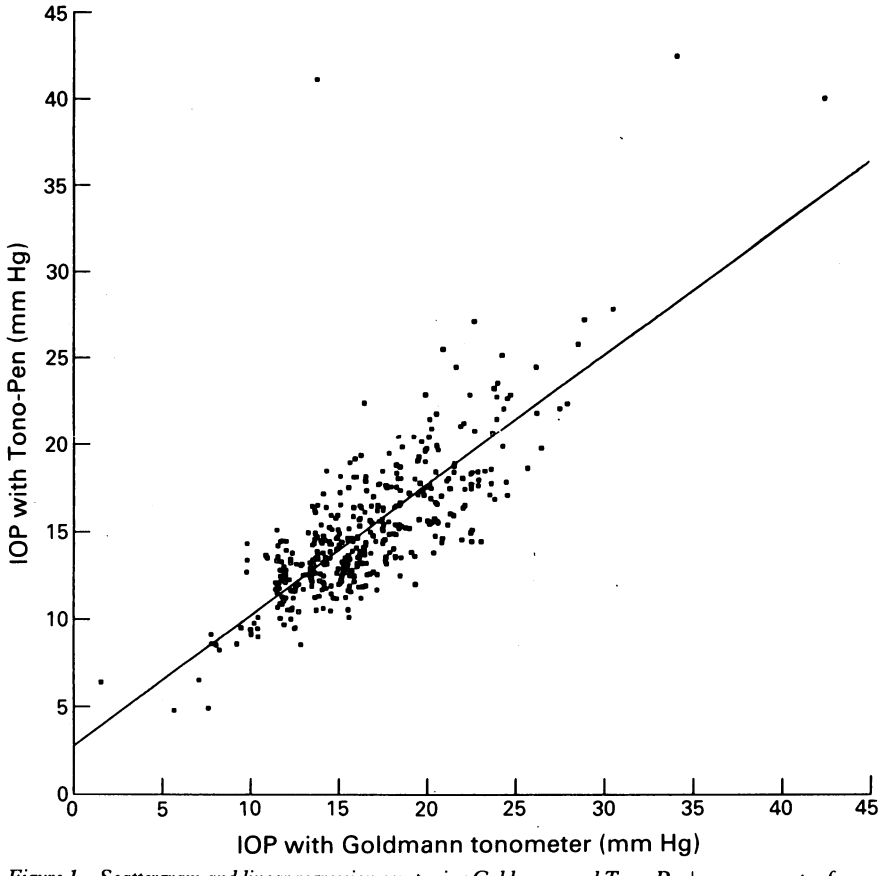

Figure 1 Scattergram and linear regression comparing Goldmann and Tono-Pen measurements of intraocular pressure (IOP), r=0·81.

Comparison between methods of tonometry: time for a change of approach

EDITOR,—Geyer *et al*[1] write that despite good correlation between Tono-Pen and Goldmann measurements, Tono-Pen tended to overestimate the actual intraocular pressure (IOP) in an unpredictable manner. They think Goldmann measurements are to be preferred. (We wonder if there is a misprint in their Table 2/Figure 6, where some absolute paired differences have smaller means than paired differences?) They may be right about Goldmann tonometry, although we found a smaller and clinically insignificant mean difference in normal eyes.[2] We have concluded that Tono-Pen may be a good instrument for general practitioners. Goldmann tonometry is no gold standard representing true pressure, only a method which shows less variation than other methods. However, the point here is that the premises for comparison between two methods of tonometry should change.

Correlation deals with how one variable varies with, and as a consequence of, changes in another variable. It does not deal with agreement between two methods of clinical measurement. The correct method is limits of agreement,[3] which take into account both systematic differences between the two methods as well as other reasons for variation. There are short time pulsations in the IOP of an eye,[4] and the way two different measurements are carried out may vary for the same method. The total spread in measurements may be very important for clinical practice even when two methods show little systematic difference.

Limits of agreement tell how much two methods of tonometry are likely to differ in mm Hg. For example, we found that discrepancies of approximately 5 mm Hg between a Tono-Pen and a Goldmann measurement are within limits of agreement in the sense that 95% of the discrepancies in our population sample were within these limits. It means that for a single Tono-Pen measurement of, say, 17 mm Hg in a normal eye, there is a 95% probability that a Goldmann measurement in the same eye will lie somewhere in the range from 12 to 22 mm Hg, but how close to 17 mm Hg we do not know.[2] Nor do we know how close 17 mm Hg is to actual value. The clinical significance of this varies according to the use in screening or in clinical practice.[5]

Many authors have problems in interpreting the clinical significance of combined correlation coefficients and mean differences, as shown with references in our paper.[2] Limits of agreement show both mean differences and the spread of the measurements. The use of correlation is dubious.

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1 Geyer O, Mayron Y, Loewenstein A, Neudorfer M, Rothkoff L, Lazar M. Tono-Pen tonometry in normal and in post-keratoplasty eyes. *Br J Ophthalmol* 1992; 76: 538–40.

2 Christoffersen T, Fors T, Ringberg U, Holtedahl K. Tonometry in the general practice setting (I): Tono-Pen compared to Goldmann applanation tonometry. *Acta Ophthalmol (Kbh)* 1993; 71: 103–8.
3 Bland M, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986; i: 307–10.
4 Leydhecker W. The intraocular pressure. Clinical aspects. *Ann Ophthalmol* 1976; 8: 389–99.
5 Christoffersen T, Holtedahl K, Fors T, Ringberg U. Tonometry in the general practice setting. (II): Which cut-off point for referral – for which patients? *Acta Ophthalmol (Kbh)* 1993; 71: 109–13

Reply

EDITOR,—Our paper[1] presents the results of making measurements in uniform sequence using a Goldmann and a Tono-Pen tonometer on 82 eyes of 82 patients with normal corneas and on 54 eyes of 54 patients who had undergone penetrating keratoplasty. The stated goal was (1) to determine if the IOP differences between Tono-Pen and Goldmann in normal eyes would be similar to the IOP differences between the two instruments in post-keratoplasty eyes; and (2) to find a correction factor for the Tono-Pen which could be used to make it clinically comparable with the Goldmann tonometer.

The analysis consisted of (1) a scattergram of paired differences between the two instruments; (2) a regression line; (3) a table of mean paired differences, mean absolute value of paired differences and standard deviations from the mean over 5 mm Hg ranges of IOP; (4) a distribution of frequency histogram of paired IOP differences; and (5) a distribution plot of absolute value of paired differences over IOP intervals. This scheme was followed for both the normal and post-keratoplasty groups of data.

Holtedahl *et al* in their letter suggest that a limit of agreement scheme given by Bland and Altman[2] be followed. However, the procedure suggested by Bland and Altman[2] is aimed at a narrower objective than ours; namely, simply to assess agreement between two methods of measurement. Although our paper[1] has broader goals, nevertheless, the ideas of Bland and Altman[2] have essentially been followed and in addition some further statistical analyses have been performed so as to satisfy the larger scope of our paper.

Bland and Altman[2] specify that the first step is to plot the data and draw the line of equality on which all points would lie if the two measurements gave exactly the same reading every time. This has been done in Figures 1 and 4 (except that the reader must draw the line). They state that the correlation coefficient measures the strength of a relation between two variables (not the agreement between them). In our paper[1] the correlation coefficient and regression line have been given for the purpose of establishing a relation (not to establish degree of agreement). Next Bland and Altman are interested in assessing the relation between the differences and the means by showing the mean and the standard deviations. This information is displayed in Tables 1 and 2 and can be viewed by superimposing the means in each IOP interval on to the plots in Figures 1 and 4. Finally, Bland and Altman are interested in the distribution of the differences; and this is shown in Figures 2 and 4. Moreover, the distributions of absolute paired differences are given in Figures 3 and 6.

The limit of agreement method described by Bland and Altman[2] is reasonable; however, the additional statistical analysis involving regression and correlation is necessary in our work[1] since we are seeking to find a relation between measurements on two populations (normal and post-keratoplasty) and correction factors to relate the two groups to one another.

We thank Holtedahl and colleagues for bringing to our attention some misprints in Table 2. Briefly, the absolute paired differences for IOP intervals of 5–9 and 10–14 mm Hg should be replaced by the following: 7·0 (1·4) and 6·2 (3·8) respectively. Figure 6 should be redrawn accordingly. Figures 4 and 5 are correct as drawn. These corrections do not alter any of the conclusions presented in the paper.[1]

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1 Geyer O, Mayron Y, Loewenstein A, Neudorfer M, Rothkoff L, Lazar M. Tono-Pen tonometry in normal and in post-keratoplasty eyes. *Br J Ophthalmol* 1992; 76: 538–40.
2 Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986; i: 307–10.

Editorial comment

The article by Geyer *et al* has produced some thought provoking correspondence. A letter by Beaumont and Kang notes that the reproducible measurements provided by the Tono-Pen may not be measuring the same intraocular pressure as those measurements provided by a Goldmann tonometer. This is always of concern to clinicians who, of necessity, must use indirect methods of measuring IOP. This is an area of even greater concern with the referrals to the hospital eye service of patients discovered on non-contact tonometry to have ocular hypertension.

The letter by Holtedahl and colleagues draws attention to guidelines on statistical methods for assessment agreement between two methods of clinical measurement. The writer suggests that we should consider these when comparing results obtained by two different tonometric techniques.

These thought provoking letters deserve to be read as well as the replies by Geyer and colleagues. Tonometry is with us as part of our daily work; we should all be aware of pitfalls and limitations in this routine measurement method.

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NOTICES

Extracranial Optic Nerve Decompression

A second international meeting will be held 6–7 November 1993, at the Massachusetts Eye and Ear Infirmary, Boston, MA, to discuss extracranial optic nerve decompression, particularly as a treatment of traumatic optic neuropathy. Further information: Michael P Joseph, MD, 243 Charles Street, Boston, MA 02114–3096, USA. (Tel: (617) 573–3192; Fax: (617) 573–3914.)

Quality '93

Quality '93 entitled Raising Quality in the NHS: What progress? is being held on 11 November at The Brewery, London EC1. It is organised by the BMA, the BMJ, the Kings Fund, the College of Health and Quality in Healthcare. The meeting is open to doctors, nurses, all health professionals, managers, politicians, researchers, policy makers, and members of the public. Further details: Pru Walters, BMA House, Tavistock Square, London WC1H 9JP. (Tel: 071 383 6518.)

XV Interamerican Course in Clinical Ophthalmology

The XV Interamerican course in clinical ophthalmology will be held in Miami, Florida on 20–24 November 1993. Details from: Interamerican Course, Bascom Palmer Eye Institute, PO Box 016880, Miami, FL 33101, USA. (Tel: (305) 326–6000.)

Glaucoma Group

The annual meeting of the Glaucoma Group will be held on 25 November 1993 in London at the Central Conference Centre. The Allergan guest lecture will be delivered by Professor Steven Podos, Mount Sinai Hospital, New York. Further details: Dr S Nagasubramanian, secretary, Glaucoma Group, Moorfields Eye Hospital, City Road, London EC1V 2PD. (Tel: 071–253 3411; Fax: 071–253 4696.)

American Academy of Optometry

The Ellerbrock Memorial Continuing Education Program will take place on 9–10 December 1993 at the Copley Connection, Boston Marriott/Weston Hotel, Copley Place, Boston, MA, USA. Further details: American Academy of Optometry, 4330 East West Highway, Suite 1117, Bethesda, MD 20814–4408. (Tel: (301) 718–6500.)

Extended Programs in Medical Education

The UC San Francisco Department of Ophthalmology and the Francis I Proctor Foundation are running a course entitled Cornea and Excimer Update on 9–11 December 1993 at the ANA Hotel and University of California, San Francisco. Further details: School of Medicine, Rm LS-105, Office of Continuing Medical Education, San Francisco, CA 94143–0742, USA. (Tel: (415) 476–4251; Fax: (415) 476–0318.)

Optics '94

Optics '94, an international exhibition on eye wear, technology, and equipment for optometry and opthalmology will be held on 18–20 February 1994 at the World Trade Center, Singapore. A conference on better eye care will be held in conjunction with the exhibition. Further details: Lines Exposition & Management Services Pte Ltd, 318-B King George's Avenue, Singapore 0820. (Tel: (65) 2998611; Fax: (65) 2998633.)