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Comparison of 2 interferometers for predicting visual acuity in patients with cataract

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SUMMARY Two clinical interferometers generated gratings directly on to the retina in young experienced observers and also in patients about to undergo cataract surgery. Eyes in the patients with no media opacities were used as controls. We agreed with the manufacturers' claims that gratings are seen on the retina independent of refractive state and that gratings can still be seen through most cataracts. However, we did not find that preoperative retinal visual acuity was of any value in predicting postoperative Snellen visual acuity. Reasons for this are discussed.

There are 2 commercially available instruments, the Rodenstock Retinometer and the Haag-Streit Visometer, that can, independently of the optics of the eye, project an interference grating on to the retina. In the presence of marked ametropia and mild to moderate cataract it is still possible to project a high-contrast grating of known spatial frequency. It has been claimed that by increasing the spatial frequency of the grating until a patient can no longer describe the (randomly presented) orientation of the lines, a measure may be made of the so called 'retinal visual acuity' before cataract extraction. It has also been claimed that preoperative retinal visual acuity is of some value in predicting postoperative letter acuity.[1–5]

A recent report[6] has thrown some doubt on the value of the Haag-Streit Visometer. This instrument generates gratings in a rather different way from the Rodenstock Retinometer. An accurate predictive test would have obvious benefit in cataract patients with chronic simple glaucoma, or a history of amblyopia, or a suspicion of macular disease, in whom lens extraction is considered.

We decided to compare these 2 instruments, taking special note of the presence of concurrent eye disease. Our experiment had 2 parts. Firstly, in 2 normal persons we compared the effect of a range of plus and minus 10 dioptres of defocusing on Snellen visual acuity (with and without a pinhole) with the same amount of defocusing on retinal acuity using the interferometers. Secondly, we tested a group of 50 consecutive cataract patients operated on at the Oxford Eye Hospital. Twenty-two eyes in these patients were aphakic or had a clear lens, and these were used as control eyes to check the calibration of the instruments. In the 50 cataractous eyes we compared preoperative retinal acuity, using both interferometers, with postoperative Snellen acuity to see if the latter correlated well with the preoperative prediction.

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Materials and methods

SUBJECTS

The 2 authors acted as subjects for the first, defocusing, experiment. For the main part of the experiment 50 consecutive and unselected cataract patients were recruited. Their average age was 73 years, range 49 to 92. All patients were able to do the tests. Twelve patients were suspected from their history or preoperative clinical examination to have coincident eye disease that might reduce visual acuity; this included senile macular degeneration, diabetic retinopathy, and chronic simple glaucoma.

APPARATUS

Each interferometer easily attached to the Haag-Streit slit-lamps used in our clinic. The slit-lamp controls can be used to guide the interfering beams into the patient's eye.

The Rodenstock Retinometer[1] has a helium-neon laser, wavelength 633 nm (red light), whose beam is split into 2 which are focused to 2 adjacent points close to the nodal points of the eye.[4] These 2 points act as point sources of coherent light, and their overlapping beams produce an interference pattern on the retina whose spatial frequency depends only on the distance between the point sources and the wavelength of light. In particular the spatial frequency of the grating, expressed as lines per degree of visual angle, is independent of the length of the eye. Good pattern contrast is maintained even if one beam is attenuated by media opacities. The area of retina covered subtends 5° of visual angle. The spatial frequency can be adjusted from a Snellen equivalent of 6/6 (calibrated by the manufacturer as being equal to 33 cycles of grating per degree of visual angle), in 9 approximately logarithmic steps, to a Snellen equivalent of 2/60 (one cycle per degree). A 4-position knob allows the grating to be set in a horizontal, vertical, or either of the 2 oblique orientations, and an attenuator allows the power incident on the cornea to be 1·0 or 0·1 microwatt.

The Haag-Streit Visometer[7,8] has an incandescent light source. This illuminates a pinhole which is imaged on to the pupil of the subject. In the light path are 2 identical high spatial frequency gratings (100 lines per mm) placed in contact with each other. Diffraction effects produce, by interference, a large depth of field grating image in the eye. As one of the two identical gratings is rotated with respect to the other, Moiré fringes are generated whose spatial frequency varies with grating position. There is therefore a smooth adjustment of grating spatial frequency from a Snellen equivalent of 6/6 (calibrated by the manufacturer as being equal to 30 cycles per degree of visual angle) to 6/60. (In fact much higher spatial frequency gratings may be produced, over 60 cycles per degree—Snellen equivalent 6/3. We were only interested to see if our cataract patients had 6/6 visual acuity, which in any case is the highest spatial frequency that the Rodenstock Retinometer can produce. We therefore tested patients using the full range of the settings, but subsequently recorded a retinal visual acuity of 6/6 for any patient who saw 6/6 or finer grating. Similarily we also recorded Snellen acuities up to a 6/6 maximum.) The area covered by the grating may be adjusted to 1·5, 2·5, or 3·5° of visual angle; we used the 3·5° setting. Two brightness settings are available, and additionally a green field may be used, which is recommended for assessing cataract patients in place of the usual white. In both cases the lines of the grating appear black. As in the Rodenstock Retinometer the grating orientation may be altered round the clock in 45° steps.

FIRST EXPERIMENT

Cycloplegia was induced in the 2 normal subjects with 1% cyclopentolate. A standard Snellen chart was then viewed through a randomly presented range of trial lenses from +10 to −10 dioptres, and the visual acuity recorded. This was then repeated with a pinhole. The same set of lenses was then used with the interferometers to see if they had any effect on retinal visual acuity. For consistent results gratings were presented, unknown to the subject, in either horizontal or vertical orientation. We avoided oblique settings, as it is known that these are less easily discriminated.[9]

The subject's task was to identify the orientation of each grating. A staircase method of adjusting spatial frequency was used; after a correct response a more difficult (higher spatial frequency) grating was presented, but after an incorrect response an easier grating was shown (Fig. 1). Each point where the increments of spatial frequency changes direction is called a 'reversal'. The values of 8 reversals were averaged to give a retinal acuity. Step size is fixed on the Retinometer, while on the Visometer we used 0·1 increments of the adjustment knob. For each instrument the brightness setting used was that which the subject found easiest to see.

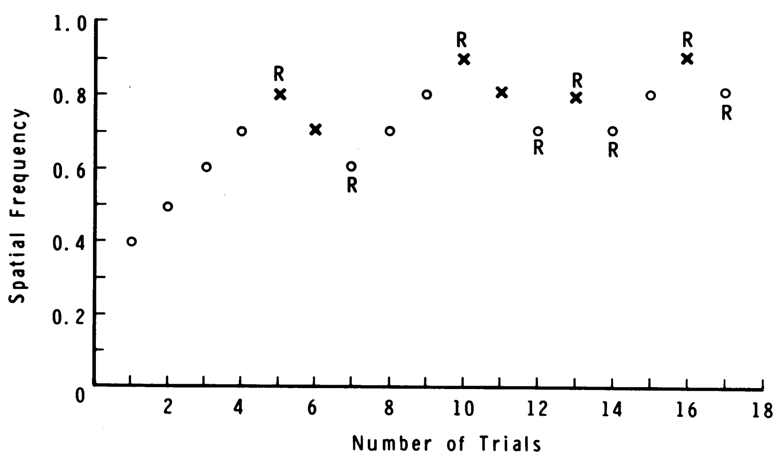

Fig. 1 *A staircase of responses. The range of spatial frequencies is represented on the vertical axis in a decimal scale (i.e., 0·5 is equivalent to 6/12 and 0·7 to 6/9). The trial number is shown on the horizontal axis and 8 reversals, marked R, are shown. The open circles (○) represent a positive response to a stimulus, and the crosses (×) represent a negative response. The average of the values of the spatial frequencies at the 8 reversals gives the value of spatial frequency.*

SECOND EXPERIMENT

Fifty cataract patients were tested. For each eye a best Snellen acuity was recorded, with glasses if worn, and with a pinhole and pupil dilatation if this helped. All eyes were dilated prior to testing with the Retinometer and with the Visometer on both the green and white backgrounds. The brightness setting in each case was that which the patient found easiest to see. A staircase procedure was used, as in the previous experiment, but only 4 reversals were averaged to save time. Testing took 15 to 20 minutes per patient. Some patients had difficulty in appreciating the grating at first, but only 9 eyes could not see the grating at all, and 8 of these were classified as having mature cataracts. It was found important to work in a completely darkened room, and to scan the light beams across the cataract to find the position where the gratings were most easily seen; this was often quite peripheral. With care and patience the gratings could be seen through surprisingly dense cataracts.

Selection of eye for cataract extraction was done by the surgeons on clinical grounds; the results of interferometry were not available to them. Most extractions were straightforward intracapsular, but extracapsular extractions and lens implants were also performed. Other than a transient rise in intraocular pressure in a few patients there were no perioperative complications. One patient died before refraction, so an extra one was recruited. One patient developed postoperative cystoid macular oedema.

Refraction was performed by a qualified optician at about 2 months postoperatively. The optician did not know the predicted visual acuity. A second refraction was carried out later in a few cases where there was poor visual acuity at the first testing.

Results

EXPERIMENT 1

Almost identical results were obtained for each of the two subjects. Fig. 2 shows one set of results. Snellen visual acuity or retinal visual acuity is shown on the ordinate on a linear decimal scale, where 1·0 is equal to 6/6 and 0·5 is equal to 6/12. The abscissa shows the trial lens used. In the cyclopleged eye with dilated pupil the Snellen acuity dropped to 50% of its maximum with only 1 dioptre of defocusing. When a pinhole was used, 3 dioptres were tolerated before 50% acuity was reached. The Retinometer showed no decrement of acuity with defocusing; the 6/6 grating was seen with whichever trial lens was used. However, subjectively the laser image was less clear with the higher value lenses, but because the Retinometer cannot produce a grating finer than 6/6 this effect is not apparent from the graph. The Visometer did show reduced acuity with defocusing, but the effect was minimal. Even in the worst case shown here, with +10 dioptres, an acuity of 0·78 (approximately 6/7·5) was recorded. Both instruments could therefore produce good retinal visual acuity in the presence of a marked degree of spherical ametropia.

EXPERIMENT 2

In any one subject almost identical readings were obtained from the Visometer when it was used in either the green or the white positions (correlation coefficient r=0·92). We show results from the recommended settings, i.e., white for normal and green for cataract eyes.

Control eyes

Best Snellen acuity was plotted against Retinometer and Visometer retinal acuity for the 22 eyes with no media opacities. Good correspondence was obtained. For 19 eyes the Retinometer acuity (rounded up or down to the nearest Snellen line) was the same as the actual Snellen acuity. This was true over a range of acuities from 6/36 to 6/6. However, 3 eyes recorded a much better Retinometer than Snellen acuity, despite optimal optical refraction when reading the Snellen chart; a 6/36 eye saw 6/6 with the Retinometer, a 6/18 eye saw 6/7·5, and a 6/12 eye saw 6/7·5.

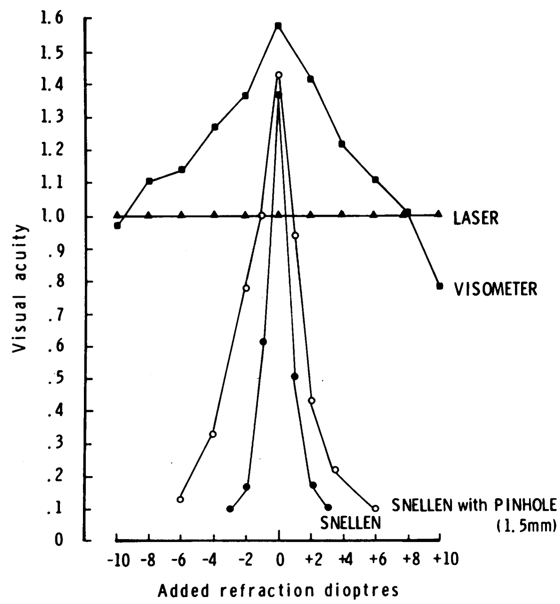

Fig. 2 *Visual acuity (decimal scale) is plotted against added refraction (amount of defocusing) from emmetropia. Results are shown for Snellen (●), Snellen with pinhole (○), visometer (■), and laser interferometer (▲) visual acuities. In every case the subject was fully dilated and cyclopleged.*

Almost exactly similar readings were given with the Visometer. The same idiosyncratic set of 3 eyes saw gratings better than the letter chart.

Thus, apart from the small number of eyes (approximately 15%) that saw gratings of a finer spatial frequency than would be expected from the Snellen chart, the calibration of the instruments appeared accurate.

Cataract eyes

The postoperative Snellen acuity (achieved) was plotted against the preoperative retinal visual acuity (predicted) for the Rodenstock Retinometer (Fig. 3) and the Haag-Streit Visometer (Fig. 4). On each graph the 2 lines encompassed an area within which the achieved acuity was reasonably close to the predicted acuity (on a decimal scale, acuity plus or minus 25% of predicted). For instance a 6/9 prediction was satisfied if the achieved acuity was between 6/7·5+1 and 6/12.

For any given eye similar predicted acuities were obtained from the 2 interferometers (correlation coefficient r=0·80). However, the achieved acuity was often quite different from the predicted acuity. On each graph less than 45% of the points lay between the continuous lines.

Discussion

We compared 2 commercially available interferometers, firstly for their ability to record retinal visual acuity in the presence of marked spherical ametropia, and secondly in predicting postoperative acuity in cataract patients. Each instrument was accurately calibrated and could resist up to 10 dioptres of defocusing and still give high values of retinal visual acuity. However, neither instrument was good at predicting postoperative visual acuity. The results of the Retinometer will be discussed in detail, but the Visometer results are essentially the same.

A total of fifty eyes were operated on. Twenty-two fell in the area where the achieved acuity approximately equalled the predicted (Fig. 3). Of the rest, 20 patients saw better than predicted, leaving 8 who failed to reach expectation. The 8 patients with mature cataract all failed to see the gratings and are shown as open triangles on the graph. It may be that the other patients who did better than predicted were either poor at grating recognition or else had cataracts dense enough to decrement the quality of the retinal image at the higher spatial frequencies. This group certainly had significantly denser cataracts on preoperative assessment.

It is more difficult to explain how 8 patients saw fine gratings through their cataract yet were unable to recognise the equivalent letters on a Snellen chart postoperatively. One patient, as has already been mentioned, developed cystoid macular oedema, but in the rest there was no evidence of operative complication being responsible. Clinical examination of the remaining 7 showed diabetic retinopathy in 2, senile macular degeneration in 2, and 3 normal eyes

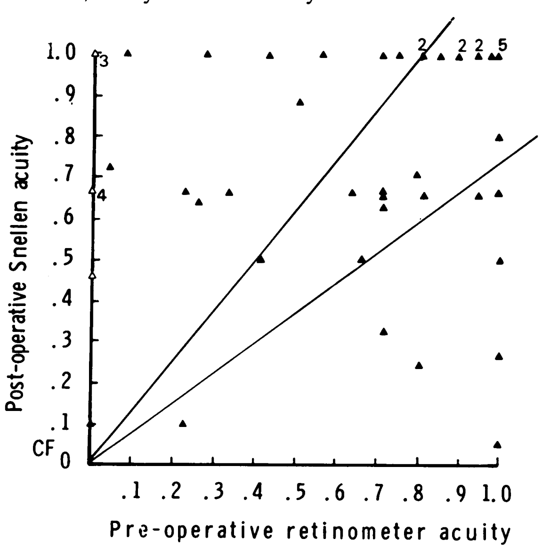

Fig. 3 *The postoperative (achieved) Snellen visual acuity is plotted against the preoperative (predicted) retinal visual acuity as given by the laser interferometer for each of the 50 operated eyes. The open triangles (△) are for mature cataracts.*

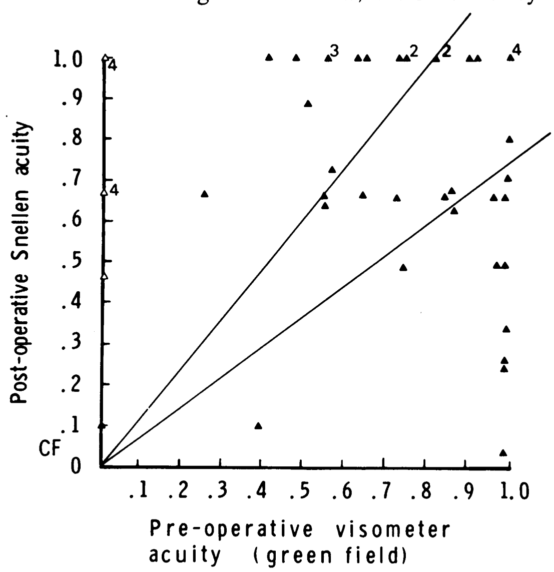

Fig. 4 *The postoperative (achieved) Snellen visual acuity is plotted against the preoperative (predicted) retinal visual acuity as given by the visometer for each of the 50 operated eyes. The open triangles (△) are for mature cataracts.*

which may be assumed to have some degree of amblyopia.

We had found that in our series of control eyes 3 out of 22 had markedly higher grating than Snellen acuity. Two of these were amblyopic and one had macular degeneration.

Thus there exists a group of patients who discriminate inappropriately high spatial frequency gratings. This is not unexpected, as the 2 tasks, grating and letter recognition, are quite different. It is known that amblyopes are better with gratings[10] and that grating acuity falls off, as a function of distance from the fovea, slower than letter recognition.[11] This may explain how our patients with macular disease or amblyopia get overoptimistic predictions on the interferometers.

Preoperatively eye disease was suspected in 12 patients. It was later demonstrated in a further 5 (from this analysis is excluded the patient who developed cystoid macular oedema). It is interesting to compare the value of the interferometer prediction in the 2 groups of patients, those with suspected or proved eye disease and those with none. In the former group, of 17 patients, no fewer than 12 (70%) had an inaccurate preoperative interferometer prediction. In the 32 eyes with no disease only 45% did not fall in the area of correct prediction on the graph.

Many previous reports emphasised the percentage of patients who were successfully predicted. Rassow and Wolf[1] stated that 67% were accurately assessed, and concluded that the test is useful. But by our criterion (final visual acuity plus or minus 25% of predicted) 40% of their patients had an incorrect preoperative prediction. Rassow and Ratzke[3] described the method as valuable, yet 13% of their patients failed to achieve the preoperative prediction, a figure near our 16% (8 patients). They reported that 73% had an accurate interferometric prediction of an improvement in visual acuity postoperatively; one does not need an expensive interferometer to make this kind of judgment, since most patients do well after cataract extraction in any case. It is important in any analysis to separate out the group of patients with suspected disease, as it is in these that an accurate prediction is most needed. Green[2] produced good results yet failed to make any clinical comments on the patients. Bernth-Petersen and Naeser[6] considered the presence of eye disease, and reached similar conclusions to our own on the unreliability of this type of test.

It has been suggested that smaller fields more accurately centred on the fovea may be more selective in patients suspected of having macular disease,[8,12] thereby avoiding the possibility of grating recognition on parafoveal retina. The Visometer can produce smaller fields than the 3·5° that we used, but it is very difficult to get these smaller fields of gratings recognised by the patient. This is because the beam is often projected through the cataract peripherally, and it is impossible to aim it selectively at the fovea.

We conclude that, although the interferometers can project gratings through quite marked cataract and ametropia, the visibility of the gratings is affected by cataract, and the grating acuity does not in any case correspond with postoperative Snellen acuity, especially in those patients in whom the test is most needed. These interferometers have little practical use in preoperative assessment. Any surgeon relying on them would seriously misjudge the visual potential of many patients.

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