Abstract  Background. There are no prospective controlled trials comparing methods of capsulotomy or patterns of capsulotomy openings in similarly graded opacified posterior capsules. This paper aims to investigate the effect of various forms of posterior capsular opacification (PCO) capsulotomy openings on visual function.  Methods: Thirty-six eyes of 34 patients had vision tested and posterior capsules were digitally photographed. Each patient then underwent Nd:YAG laser capsulotomy. Patients returned 1 week later for repeat vision tests and photography. Analyses of areas of pearls and fibrosis were performed using the EPCO software system. Analyses of size and shape of capsulotomy was also done with image analysis software. The capsulotomy characteristics were analysed with respect to improvements in vision, taking into consideration the PCO scores.  Results: No correlation was found between capsulotomy dimensions and visual function improvement, even when PCO details were included in the analyses. Neither capsulotomy area, eccentricity, nor shape irregularity in the ranges measured was found to correlate significantly with eventual visual outcome in terms of contrast sensitivity, near and distance visual acuity, or glare readings.  Conclusion: Performing a small capsulotomy (at least 1.5 mm in diameter), even if decentred up to 1 mm, may allow for satisfactory visual performance as long as the aperture is clear and not obscured by residual strands.

Introduction
Published rates of posterior capsular opacification (PCO) vary widely, but a meta-analysis published in 1998 reported that, overall, 25% of patients undergoing extracapsular cataract surgery developed visually significant PCO within 5 years of the operation [22]. The problems caused by PCO can usually be remedied by laser surgery, using Nd:YAG capsulotomy to create an opening in the posterior lens capsule. However, this procedure is associated with complications such as damage to intraocular lenses (IOLs), [19, 29] postoperative intraocular pressure (IOP) increases [2, 9], cystoid macular oedema (CMO) [2], disruption of the anterior vitreous surface [15, 23] and increased incidence of retinal detachment [20, 22], and must be approached with some caution. In the USA, Nd:YAG capsulotomy is estimated to cost the Medicare programme $250 million per annum [25].

Improvement in visual acuity after Nd:YAG capsulotomy in patients with significant PCO has been well documented [5, 8, 24, 30]. Improvements in glare and contrast sensitivity may also be important outcome measures for many patients [17, 26, 27]. Wilkins et al. [31] report laser capsulotomies improving not only vision but also glare and contrast sensitivity. Not all authors report an association of glare sensitivity with PCO [7], and variations in results [13] are expected due to differences in glare testing methods as well as patient selection. Glare testing with a straylightmeter has been reported as more consistent than that using the brightness acuity tester [27].
There are no prospective controlled trials comparing methods of capsulotomy or patterns of resulting capsulotomy openings in similarly graded opacified posterior capsules. Many authors promote the use of a cross pattern in the centre of the visual axis, with the clinician starting off on both axes away from the centre to avoid pitting the lens centrally [10, 12, 16, 18].

Theoretical optical considerations regarding capsulotomy size were discussed by Holladay et al. in 1984, at the advent of Nd:YAG capsulotomy [11]. They suggested that the minimum theoretical size for a capsulotomy is 2.4 mm in diameter; later authors agreed with this theoretical prediction [4]. Nevertheless, diffraction does not limit visual acuity to below 6/6 vision until 1.4 mm [3]. Holladay et al. also hypothesised that a smaller capsulotomy would cause decreased image intensity and increased problems with glare.

A smaller capsulotomy (2–3 mm) has been shown in clinical trials to be as good as larger openings (5–6 mm) in terms of visual acuity [10]. The requirement for less energy with less dissipation of capsular material would lead to fewer complications involving retinal detachment and increased IOP [1, 6, 14, 21] and perhaps to less CMO [23]. The risk of IOL dislocation may be significantly less, especially with plate haptic silicone IOLs.

Leaving the pupil undilated means the eye can be treated in physiological conditions, with laser applied only to the central functional visual axis with greater ease, resulting in a perhaps smaller but equally effective capsular opening. This would theoretically result in a lower amount of energy being applied, and hence fewer side effects.

However, there is some limited evidence to suggest that although smaller centralised capsulotomy openings are as effective as larger openings in terms of effect on visual acuity, a larger capsulotomy opening, with a dilated pupil, might be necessary to alleviate symptoms of glare [10]. It is postulated that these symptoms are caused by capsule fragments at the edge of the opening increasing forward light scatter.

This paper aims to investigate the effect of various forms of PCO capsulotomy openings on visual function. By analysing patients before and after Nd:YAG capsulotomy it will determine whether capsulotomy size, shape and centralisation have significant effects on the various visual functions. It will also seek to confirm the psycho-physical phenomena of improvements in visual acuity, glare and contrast sensitivity after Nd:YAG capsulotomy.

### Materials and Methods

Thirty-four patients (36 eyes) were recruited from the Eye Pavilion, Edinburgh; all had been clinically assessed as in need of Nd:YAG capsulotomy. Exclusion criteria included severe coexisting ocular disease, including opacifying corneal pathologies and age-related macular degeneration. Also very poorly dilating eyes such as from synechiae were excluded, as this would obstruct photography of the posterior capsule. No patient had signs of significant macular degeneration. Informed consent was obtained from all patients and the study was approved by the local ethics committee. The study was conducted in accordance with the Declaration of Helsinki.

On attendance, patients had vision tested with near and distance LogMar charts. Contrast sensitivity was tested with Pelli–Robson contrast sensitivity charts and glare was measured with the brightness acuity tester (BAT; Mentor O & O, Norwell, Mass.), a handheld instrument that provides background light to a central aperture through which the patient looks at a contrast sensitivity chart. Glare disability was measured as the deficit in ability to read Pelli–Robson contrast sensitivity chart when the instrument is used with glare light on medium setting compared to when the light is not on. The patients’ eyes were dilated with 0.5% tropicamide and the posterior capsules photographed with the ImageX digital photography system and the Topcon camera system at standardised settings. Images were subsequently stored on disc.

All patients underwent Nd:YAG laser capsulotomy via a set protocol by the same surgeon. This involved an initial setting of 1 mJ and subsequent increases of 0.5 mJ as necessary to pierce the posterior capsule. The laser treatment was initiated off axis in a horizontal line across centre, followed by a line in the vertical axis to form a cross. Any obvious lines of capsule tear were treated with laser if deemed beneficial and overall energy used was kept to a minimum. Size of capsulotomy was dictated by ease of making openings, and concerns over energy used. In general the aim was to create an opening using minimum energy, which could be re-treated at follow-up visits if necessary. In the patients studied the capsulotomy openings, although sometimes small, were always clear and not obscured by strands of residual PCO.

Patients returned 1 week later and had further undilated tests of near and distance LogMar visual acuities and glare and contrast sensitivity. Posterior capsule photography at standardised settings was performed after pupillary dilation.

The images had been obtained various forms of analysis were performed. The amount of PCO before and after Nd:YAG capsulotomy was calculated using EPCO 2000 (Evaluation of Posterior Capsular Opacification) software [28] and the difference taken as an opacity score for the area of capsule cleared for each patient.

Scion Image, a freely available software package designed for scientific image analysis, was used to perform additional computations on the digital images of capsulotomy opening. Measurements of the area of the capsulotomy and the perimeter and centre of the best-fitting circle or ellipse (geometric centre of capsulotomy aperture) were recorded. All measurements were taken by one investigator. Test–retest was performed by the examiner five times on each of two images and revealed minimal error of less than 5%.

The ratio of perimeter squared to area is £R2/A £πR2 and perimeter = 2πR:

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R = \frac{\text{Perimeter}}{2\pi} \quad A = \frac{P^2}{4\pi} \quad \frac{P^2}{A} = 4\pi
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Thus a perfect circle would have the above ratio and any deviation from that would have a higher ratio; Fig. 1 shows an example.