General Optical Council Approved CET For Optometrists
General Optical Council Approved CET For Dispensing Opticians

TABLE 1
Causes of glare

Refractive aberration	Keratoconus
	Lenticonus
	Following sight correction
	Radial keratectomy
	Excimer laser (PRK, Lasik, Lasek)
Defective tear film	Dry eye
	Red blood cells. White blood cells
Corneal epithelium	Epithelial opacity
	Epithelial dystrophies
	Epithelial keratitis
	Epithelial oedema
	Cornea vorticellata
Corneal stroma	Keratitis
	Corneal scar
	Superficial corneal haze following PRK or Lasek
	Corneal dystrophies
	Corneal oedema
	Interface defects: Lasik
Corneal endothelium	Endothelial degenerations
Abnormal corneal curvature	Keratoconus
Aqueous	Flare in uveitis
	Haemorrhage
Iris	Albinism
	Pigment dispersion syndrome
	Post-surgical defects
Lens anterior capsule	Capsule opacities
	Pseudoexfoliation
Lens stroma	Normal age change
	Non-opaque lens defects
	Opacities (cataract)
	Oedema
	Lens implant
Posterior capsule	Opacities
	Post-cataract operation capsule fibrosis
Vitreous	Opacities
	Haemorrhage
Retina	Oedema
	Cone dystrophy
	Pigment epithelial defects

Glare

Part 1 – Classification and causes

In the first of two CET articles on glare and vision, **Nicholas Phelps Brown** describes types of glare and some conditions responsible. C7481, one standard CET point for optometrists and dispensing opticians

Glare is produced by optical imperfections in the refractive media of the eye which consist of: the tear film, the corneal epithelium, the corneal stroma, the corneal endothelium, the aqueous, the anterior lens capsule, the lens substance, the posterior lens capsule and the vitreous. Some glare is also due to diffraction at the pupil margin which increases with miosis. Glare may also be due to light passing through the iris or to light scattering within the retina (Table 1).

Types of glare

Patients complain of glare using the terms: 'glare', 'star bursts' and 'haloes'. The word 'glare' itself encompasses both star bursts and haloes, and so it pays to ask the patient to be a little more descriptive when they complain of glare.

The 'star burst' is a name used in astronomy to describe a cosmic centre radiating energy which is considered to represent a new galaxy that is forming rapidly. Patients usually use the name to describe radiating lines of light from a light source. It is typically seen in the presence of cortical spoke cataract (Figures 1 and 2).

The halo is a ring of light emanating from a point light source with a dark circle immediately surrounding the light and then a bright ring, as in the halo depicted in a religious icon. The halo may be rainbow coloured. It is typical of acute glaucoma (Figure 3).

Simulated types of glare

You can visualise some of these entoptic glare effects for yourself: Take a piece of oven foil and pierce a pinhole in it. Wrap the oven foil around the tip of the bulb of a pen torch and in a darkened room view the pinhole light source with one eye at a distance of about 15cm. You will see your ciliary corona, as described by Tscherning,[1] as fine radiating lines of light with a hint of colouring of up to 14 degrees in diameter (Figure 4). It is not a phenomenon which patients complain of, but it is one of the causes of glare in the normal eye. You will also see the shape of your pupil centrally and in silhouette within the pupil circle you may see a lens opacity, if you have one.[2] The ciliary corona was considered by Tscherning to arise by diffraction in the radially arranged pattern of the lens fibres (Figures 5 and 6). The lenticular cause of the ciliary corona is recently confirmed.[3]

Now take a piece of plane glass and hold it close to your eye. Breathe on the glass to create a light haze and on looking at the pinhole light you will see a halo-like glare around it due to diffraction in the water droplets on the glass (Figure 7). Smear the glass with a little eye ointment and you will see glare (Figure 8). Take a piece of clear plastic sheet and make radial scratches on it and it will simulate glare in a star burst shape (Figure 1).

Classification of glare

Glare has been divided into discomfort glare and disability glare. Disability glare has also been called 'dazzling glare'.[4] Discomfort glare occurs when a patient who is affected by a condition causing photophobia views an overall bright subject, such as a snowfield. The causative conditions include keratitis and iritis. Discomfort glare also occurs in retinal disorders, such as albinism, cone dystrophy, and in retinitis pigmentosa.

Disability glare occurs when non-focused light from a light source reaches the retina. The light source causing glare is not necessarily the object of interest and may be elsewhere in the field of vision (Figure 9). The non-focused light causing glare is produced in the eye by defective refraction in the optical media of the eye, by light scattering, by diffraction, or by fluorescence and in some cases it is due to light scattering within the retina.

Quantification of glare

The effect of glare is to produce a veil of light over the object being viewed and

Figure 1 Star burst glare produced by a simulated grade 3 cortical spoke cataract and point light source

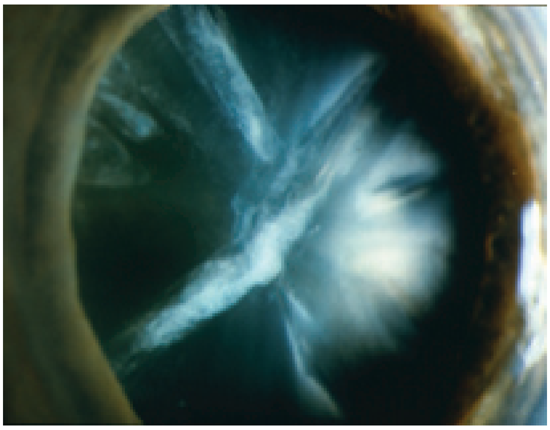

Figure 2 A grade 3 cortical spoke cataract

Figure 3 The diffraction halo of lycopodium spores, which mimics the glaucoma halo

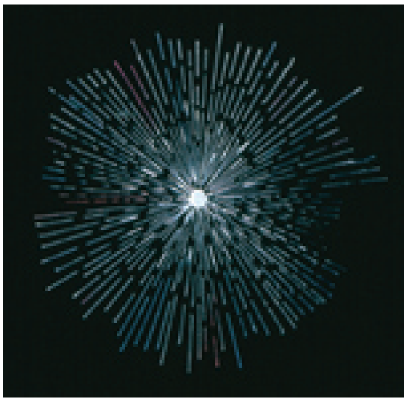

Figure 4 Artist's impression of the ciliary corona

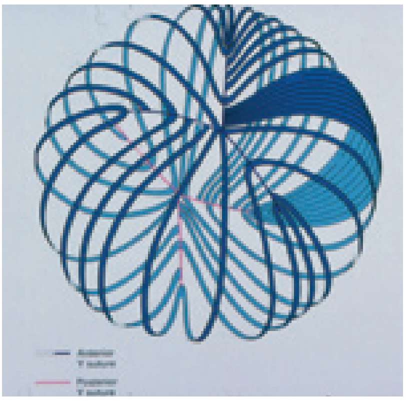

Figure 5 The arrangement of the lens fibres

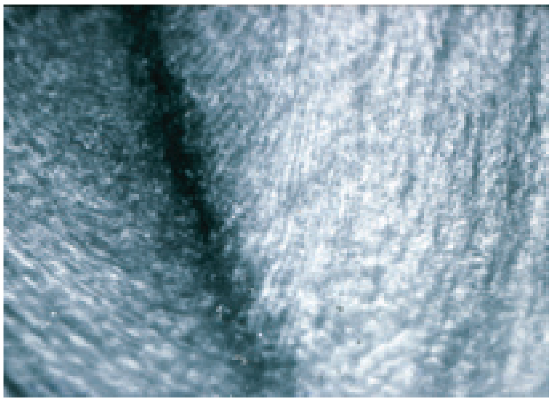

Figure 6 Specular microscopy of the lens fibres in vivo

thus to reduce the contrast and consequentially the visibility of the object. The effect of glare on contrast is expressed as a percentage by the equation:

$$\text{Contrast} = \frac{I_o - I_b}{I_o + I_b}$$

Where I_o = object illumination and I_b = background illumination.

Glare in the normal eye

Some glare, mainly due to light scattering, occurs in the normal eye. It is also the light scattering in the optical media of the normal eye which permits the visualisation of the cornea and of the lens by focal illumination at the slit lamp.

In the young adult the cornea accounts for 30 per cent of the light scattering, the lens for 70 per cent, and the aqueous plus vitreous contribute less than 1 per cent. The scattering increases with age particularly in the lens of the eye. This increase is partly due to the increased distance which the light has to traverse through the lens and partly due to an increase in the scattering properties of the lens substance. The sagittal width of the lens increases by about 20 per cent between the ages of 18 years and 70 years.[5] The growth of the lens is brought about by the incorporation of new fibres throughout life and this is partially offset by compaction of the fibres centrally.[6] The fibre compaction is a factor causing the increasing scattering of the lens substance with age.

The increase in scattering of the lens with age makes itself apparent to persons over the age of 50 years, so that it is not unusual for persons of 50-plus with a normal lens to complain of glare when night driving. A careful examination should be conducted to look for abnormalities in the refractive media and if not found, the patient should be reassured and advised to use glasses with their distance refraction, preferably with anti-reflection coating, but not with a tint.

The other factor in lens glare is fluorescence. The lens gives out a greenish fluorescent glare when stimulated by UV and by deep blue light. This effect increases with age and with diabetes.[7] It is further increased in the development of nuclear cataract, particularly when this is the brunescent type.

The development with age of the non-opaque lens defects, water clefts, fibre folds and lens vacuoles[8] further increases the scattering. The scattering then becomes yet further increased by the development of minor degrees of cataract, short of those requiring any surgical attention. Eventually, a mature cataract produces only glare and no image.

Some causes of glare

Corneal aberrations

Even the best cornea is not aberration free so that light rays, particularly through the periphery of the cornea are not brought to an exact focus on the retina. The degree of corneal aberration varies between individuals and the adverse effect is increased by pupil dilatation in poor light. Glare due to corneal aberrations is seen in excess in diseases of curvature of the cornea, such as keratoconus.

Corneal aberrations may be increased by excimer laser sight correction and glare after laser sight correction has been reported to be related to pupil size and to the level of correction applied.[9] It has now been shown that wavefront-guided correction is less likely to induce aberrations causing glare and may reduce the pre-existing aberrations.

Iris defects

Iris defects which permit the transmission of light through the iris allow unfocused light to reach the retina and cause glare. The causes include albinism, pigment dispersion syndrome, trauma, and surgical trauma, as in cataract and lens implant surgery.

Figure 7 Halo-like glare produced by breathing on glass

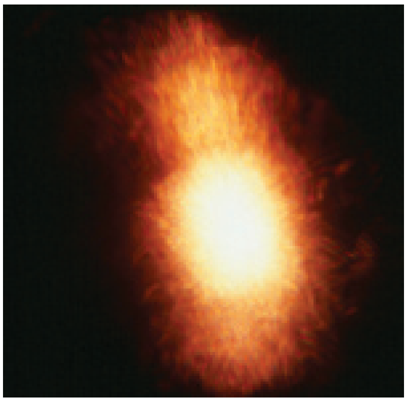

Figure 8 Glare produced by a smear of eye ointment on glass

Figure 9 Street at night. Disability glare caused by a grade 3 simulated cortical cataract

Lens implants

Glare is commonly complained of by patients with lens implants, which can be difficult to explain. There are identifiable causes which include corneal oedema, iris defects, lens decentration, poor implant lens transparency and capsule opacification. But in other cases it is not easy to define the cause. The lens implant does not have an anti-reflection coating like the elements of a quality camera lens and it does have a noticeably more reflective surface than the human lens. It is possible that this leads to reflections of light reaching the retina.

Laser sight correction

Following laser sight correction, patients may complain of glare, haloes, or of star bursts. As noted above, laser sight correction may cause glare by aggravating the corneal optical aberrations.

In the surface treatments of PRK and Lasek there may develop some corneal stromal surface haze which tends to resolve with time but may not disappear. With Lasik there is initially some interface imperfection producing scatter. This tends to resolve within the first few months.

Persistent glare in the presence of a clear cornea following laser sight correction is probably due to optical aberrations and is related to the numerical level of correction.[9] It has been noted to be related to the pupil diameter particularly if the pupil diameter in poor light is greater than the diameter of the corneal treatment zone, then unrefracted light will reach the retina. Even with a treatment zone larger than the pupil, inadequately refracted light will reach the periphery of the retina.[10]

Retinal conditions

Glare occurs in the retina due to light scattering within the retina, or to light which has passed through the retina being reflected back into the retina. Scattering glare may occur within the retina in retinal oedema. The healthy pigment epithelium absorbs light which has passed through the retina and so prevents light being reflected back into the retina. Light may be reflected back into the retina in disorders of the pigment epithelium, including retinitis pigmentosa and albinism.

Haloes

Haloes are a fascinating entoptic glare phenomenon. There was great interest in the nature of entoptic haloes in the first half of the 20th century and in trying to determine their mechanism,[4,11,12] but haloes were first described long before this in 1637 by Descartes.[13] Entoptic haloes are seen typically in acute glaucoma and are also described by patients with other causes of corneal oedema. Haloes are described following excimer laser sight correction (PRK, Lasik, Lasek). Haloes are also seen when there are cells in the tear film such as red cells due to haemorrhage (Figure 10) and with white cells in purulent conjunctivitis.

Haloes may be produced by refraction or by diffraction. The halo that may be seen around the sun and the moon was described by Descartes[13] and the diffractive nature of these haloes was later established. The sun and moon haloes have a dark inner circle which typically subtends 22 degrees. These haloes are understood to occur when the light strikes atmospheric ice crystals of a critical size which has been calculated at 20.5µm diameter. In these crystals the light rays are deviated by refraction and the halo given rainbow colours by dispersion. Smaller atmospheric particles can produce haloes with a smaller ring size by diffraction.

Diffraction causes the deviation of light around small particles to cause a halo and can also be responsible for a halo having rainbow hues.[14] It is well recognised that a rainbow produced by the dispersion of light through a prism is equally well produced by the diffraction of light through a diffraction grating.[4] Interestingly, the order of the rainbow hues in a diffraction halo is the opposite to that in a refraction halo. The diffraction halo has red on the outside and blue on the inside. The diffraction causing haloes is due to a finely spaced spread of fine particles such as lycopodium spores[11] (Figure 3). The particle size is critical to the production of a diffraction halo and from the angular size of the halo it is actually possible to calculate the particle size. The smaller the particle the larger the diameter of the halo ring.[1] This principle is used in the halometer, which is an instrument for calculating the size of red blood cells.

It was early recognised that the halo seen in acute glaucoma was due to corneal oedema and by 1922 Tscherning[1] recognised that the halo was due to diffraction in the oedematous corneal epithelium. Tscherning observed that the glaucoma halo measured 10 to 11 degrees which he considered corresponded to the size of the deepest cells in the corneal epithelium which are smaller than the more superficial cells. Subsequent authors have confirmed this.[15] Haloes are seen in snow blindness in which the UV damage induces oedema confined to the epithelium, which is corroborative of an epithelial cause in glaucoma. Diffraction and dispersion were each previously considered in the possible mechanisms and it is now considered that the entoptic halo of corneal oedema is a diffraction phenomenon in the corneal epithelium.[16,17]

The mechanism by which oedema in the corneal epithelium causes a halo appears to be by water entry into the intercellular space with a refractive index differing from that of the intracellular fluid. This has the effect of creating a diffraction grating.[18] The cell boundaries being oriented in all possible directions account for the circular halo, unlike the laterally separated pattern of a linear diffraction ▶

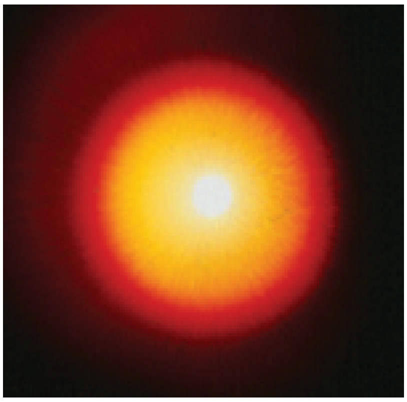

Figure 10 Halo produced by a blood film

grating. Miller and Benedek[18] calculated an epithelial cell size of 10µm.

Corneal haloes occur in other causes of corneal oedema, such as contact lens anoxia[19] and can be produced artificially by immersing a volunteer's cornea in distilled water. Caldicott and Charman[15] used this method to make a direct comparison between the halo size and the epithelial basal cell size in individual subjects using *in vivo* specular microscopy to measure the cell size. The haloes measured from 10-12 degrees and the epithelial basal cell size measured from 11.0-11.9µm.

This confirms the work of previous authors that the halo originates in the epithelial basal cells.

Haloes in the normal eye

Patients sometimes complain of haloes when no pathological basis can be found. In these cases the halo is most likely to be lenticular in origin and being caused by diffraction in the regular arrangement of the normal lens fibres (Figures 5 and 6).[12]

The lenticular haloes are smaller in diameter, about 6 degrees, than the corneal epithelial haloes, which corresponds to the lens fibres being wider than basal corneal epithelial cells. Each lens fibre varies in width throughout its length and this has been estimated at 9-20µm (Figure 6).[20] Lenticular haloes may be distinguished from corneal haloes by the Emsley Fincham test.[21] A stenopeic slit is passed across the eye and the lenticular halo is seen to break up and rotate. The corneal halo remains intact as the stenopeic slit is passed.

Descartes[13] described a halo with coloured rings of red and green 4-8 degrees in diameter, which he observed on opening his eyes after long closure. This phenomenon has become known as Descartes corona and probably originates in the corneal epithelium. ●

MULTIPLE-CHOICE QUESTIONS

1 Which of the following is most likely to occur with ocular albinism?

A Disability glare
B Dazzling glare
C Discomfort glare
D Dissatisfaction glare

2 In a young healthy adult, how much of the light scatter is due to the crystalline lens?

A 1 per cent
B 30 per cent
C 70 per cent
D 100 per cent

3 By how much does the sagittal width of the crystalline lens increase between the ages of 18 and 70?

A 5 per cent
B 10 per cent
C 15 per cent
D 20 per cent

4 Which of the following regarding glare and refractive surgery is NOT true?

A Smaller pupils will prevent glare impact upon peripheral retina
B Initial interface glare with Lasik usually resolves within months
C Laser intervention may exacerbate corneal aberration effects
D Patients may report haloes, glare or starbursts following refractive surgery

5 Which of the following is least likely to result in haloes?

A Angle closure glaucoma
B Blood cells in the tear film
C Retinitis pigmentosa
D Corneal oedema

6 What is the estimated width of lens fibres which may be estimated by the diameter of haloes they produce?

A 6 microns
B 9 to 20 microns
C 20 to 35 microns
D 11.9 microns

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● **Nicholas Phelps Brown** is a consultant ophthalmologist based in Harley Street