International Ophthalmology 9: 207–225 (1986)

The Oxford Clinical Cataract Classification and Grading System

J.M. Sparrow, A.J. Bron, N.A.P. Brown, W. Ayliffe & A.R. Hill
Oxford, U.K.

Key words: cataract, classification, grading

Abstract

A composite slit-lamp based system for the clinical classification and grading of cataract is described. Cataract features are classified morphologically, and individual features are graded by comparison with standard diagrams mounted adjacent to the slit-lamp. Attention has been paid to relevant aspects of measurement theory, with equal interval steps between the grades. The image degrading effect of the cataract is assessed using a 'resolution target projection ophthalmoscope'. The method may be used in conjunction with photographic and image analysing techniques.

Introduction

A well standardised system for the classification and grading of cataract is central to any clinical study of cataract. The Oxford Clinical Cataract Classification and Grading System provides this facility in vivo, and is accessible to anyone with a slit-lamp. This paper describes the method and standardization of the system; the inter-observer variability data will be presented separately. The concepts of the system were originally described by Bron and Brown, (2) since which time, clinical use and theoretical considerations have resulted in the modifications and standardisations presented here.

Many systems of cataract classification relate to extracted lenses. (12–14, 17–19, 20–22, 24, 26, 27, 50, 55) Some systems can be applied in an in vivo situation, (2, 15, 20, 22, 45, 50, 55) and a few informal systems of clinical classification are used which allow the classification of cataracts into broad morphological groups. (36) The image degrading effect of a cataract may be assessed in vivo using a modified 'projection ophthalmoscope'. (22) Some specific cataract types have attracted individual grading systems, such as in Lowe's syndrome (10) and corticosteroid induced cataracts. (23) Such private systems are not of great value when considering the classification of all types of cataract. Photographic methods have been employed with success, both in vitro and in vivo. The two most suitable techniques of in vivo photography employ the Scheimpflug principle for slit-images, (4, 5, 7–9, 33–35, 37, 38, 53, 56, 57) and retro-illumination for 'en face' lens views. (9, 16, 29, 41, 42, 49) These photographs have been used for purposes of cataract classification, (35, 37, 57) and have been analysed by techniques such as linear densitometry of Scheimpflug photographs; (5, 8, 33, 35, 37); area densitometry and pattern analysis of retro-illumination and Scheimpflug photo-

Address for offprints and communication: Mr. J.M. Sparrow, F.R.C.S., Nuffield Laboratory of Ophthalmology, Walton Street, Oxford, United Kingdom.

graphs; (5, 16, 42, 49); colour (58); and fluorescence analysis. (32, 43, 46, 47) Video-imaging systems are also presently in use, although experience with these is so far limited. These image analysing techniques are effective tools, but they essentially quantify opacities, and need to be supported by a clinical classification and grading system. (9) In epidemiological studies, certain 'field' situations may be encountered in which the use of sophisticated photographic and image analysing equipment is precluded. Under such circumstances, a simple, comprehensive and standardized clinical classification and grading system for use at the slit-lamp has particular appeal. The Oxford System is well equipped for such use, while at the same time, it can be used in conjunction with other technology.

Lenticular zones

The crystalline lens may be divided, on the basis of

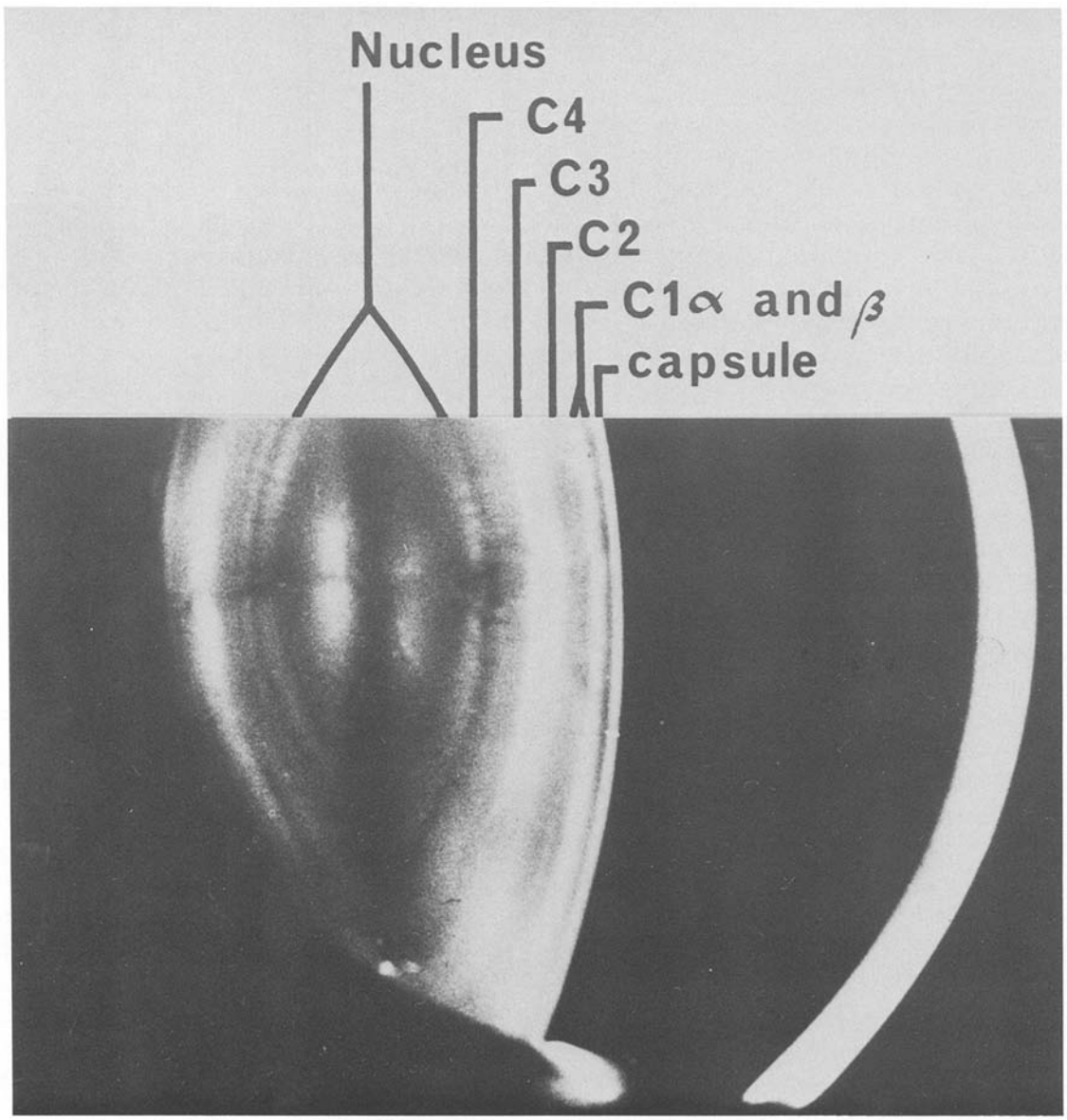


Fig. 1. Scheimpflug slit-image photograph showing the zones of the crystaline lens.

light scattering properties, into a number of discrete concentric shells, (30) demonstrable in optical section. (Fig. 1) The best known of these divisions separates the cortex from the nucleus. The nucleus is regarded as that portion of the post-natal lens which represents the lens as it was, at birth. The lens has a diameter of a little over 6 mm at birth, (25) and this is the size of the nucleus as defined here. It is implicit in this definition that all lens fibres added post-natally are designated as being cortical. The cortex may be subdivided into anterior (A) and posterior (P) cortical zones, C1 to C4. Zone C1 consists of an outer clear shell, and an inner shell of increased light scattering, designated alpha and beta respectively. The outermost clear shell is also referred to as the 'clear zone', and the scattering zone as the 'first zone of disjunction'. (Thus we may speak for example of zone C1,alpha,A as the 'anterior clear zone'). Zones C3 and C4 constitute the 'peri-nuclear' cortex, (which are the zones of greatest autofluorescence). The nucleus may be subdivided into foetal and embryonic parts, but the nuclear zones are not as distinctly visible as those of the cortex. The zone system is best developed in individuals aged approximately 40 years, and may be hardly visible in children.

Cataract features

The features graded include: Anterior sub-capsular opacity, posterior sub-capsular opacity, cortical spoke opacity, waterclefts, vacuoles, retro-dots, focal dots, and anterior clear zone thickness, (cortical features); nuclear brunescence and white nuclear scatter, (nuclear features). Each feature is graded on a 1–5 scale, the grade being entered on a grading chart (Fig. 2) according to feature (rows) and zone of opacity (columns). In practice it is found that certain features are confined to typical zones, so that the matrix in Fig. 2 is only partially filled. In some patients, especially the young, not all the zones are clearly visible. In this situation reliance is based upon the prior knowledge that a certain feature occurs typically in a particular zone, and the feature is scored appropriately. Any other features are recorded as present, but not graded.

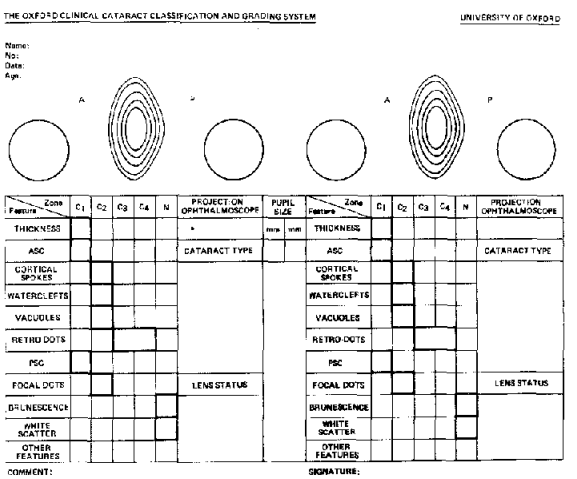


Fig. 2. Recording chart for the Oxford Clinical Cataract Classification and Grading System.

Cortical features

Anterior sub-capsular opacities (ASC) are defined as areas of opacification lying just deep to the lens capsule in the anterior clear zone, (zone C1,alpha,A). They are visible by slit beam and by broad focal illumination as whitish-grey opacities, which may be granular, and sometimes by retro-illumination as shadows against the red reflex. Anterior sub-capsular opacities tend to be round or oval in shape, and may, in addition, have radial prolongations.

Posterior sub-capsular opacities (PSC) lie just anterior to the posterior capsule in zone C1,P, and are visible by both retro- and focal illumination. By retro-illumination the opacity may appear as a disturbance of the red reflex, or if sufficiently dense, it may produce a black shadow. (Fig. 6B) In focal illumination the opacity is typically a saucer-like whitish, granular or vesicular disc, centered on or near the antero-posterior central axis. There may also be radial prolongations of the opacity. Vesicular features, often included in a definitive posterior sub-capsular opacity, are regarded as an integral part of that opacity, and graded with it, not as vacuoles. Specular reflection may demonstrate a polychromatic lustre.

Cortical spoke (cuneiform) opacities, are base out wedges, visible by retro-illumination as shadows in the red reflex, (Fig. 7B) and visible by direct

focal illumination as scattering opacities. There may be a linear array of vacuole-like structures within the spoke, in which case these are regarded as an integral part of the spoke, and graded with the spoke and not as vacuoles. The opacity follows the lens fibre pattern, and may pass from the anterior cortex, round through the equatorial cortex, and so to the posterior cortex in a continuous band occupying zone C2. When the anterior clear zone (C1,alpha,A) is absent, zone C2 is abnormally close to the anterior capsule. In this situation, a cortical spoke in zone C2 may be confused with an anterior sub-capsular opacity. Awareness of this difficulty helps to prevent misclassification.

Waterclefts are radial, fusiform or base out wedge shaped features, producing localized areas of altered refraction and reduced scattering. They are most easily seen by slit beam illumination, appearing as an optically empty segment (Fig. 8). Their extent can be gauged by traversing the slit beam across the lens. The visibility of waterclefts by retro-illumination is variable, they may only just be visible, and their full extent may not be appreciated. They are commonly accompanied by spoke opacities, which may border the watercleft, or be enveloped by it. These associated spoke opacities, when seen by retro-illumination, often have a lace-like appearance, and are less dense than spoke opacities occurring in isolation. Waterclefts are typically found in zone C2.

Vacuoles are small round cystic spaces typically occurring in zone C2. They may lie either anteriorly or posteriorly in the cortex. Optically they behave as a diverging lens, and are therefore assumed to be of lower refractive index than the surrounding lens substance. Their edges are sharply demarcated and they produce no reversal of the retro-illumination pattern. (6) (Fig. 9C).

Retro-dots are somewhat rounded features, distinguished from vacuoles by their slightly larger size, their refractive properties, and their faintly demarcated edges. (2, 3) (Fig. 10C) They behave as converging lenses, producing a reversed retro-illumination pattern, and are believed to be of higher refractive index than the surrounding lens substance. (3, 6) Retro-dots occur in the perinuclear zones, (C3 and C4), and although these zones extend fairly far out towards the periphery of the lens, retro-dots are uncommon peripheral to 3 mm from the central axis. Retro-dots are visible by both retro-illumination and specular illumination. Specular illumination is particularly useful when other opacities obscure the red reflex, thus for example allowing visualization of retro-dots in the presence of a dense nuclear cataract. Retro-dots are poorly seen in focal illumination, and may thereby readily be distinguished from focal dots and coronary opacities. (3)

Focal dots are fine punctate opacities varying in colour from blue through grey to white. They are most prominent in zone C2 and are distributed with increasing frequency towards the periphery of the lens. This varying frequency is considered to be partly a curvature effect, due to optical superimposition of features as the equatorial region is approached, and partly a real increase in feature frequency peripherally. Focal dots are best seen in broad focal illumination, but may also be visible in retro-illumination, as small dark dots. (Coronary lens opacities are not graded with focal dots, their presence is merely noted, under 'other features'.)

The *thickness of the anterior clear zone* (zone C1,alpha,A) is assessed centrally in the optical axis. This zone may be thinned in posterior sub-capsular cataract formation. (11)

Nuclear features

Nuclear brunescence is a colouring of the nucleus, (Fig. 12B) and ranges from pale yellow, through yellow, orange, reddish-brown to brownish black. The colour is graded axially in the posterior nuclear zone, ie. just anterior to the centre of the posterior nuclear shell. This region is chosen specifically because nuclear colour alters continuously from anterior to posterior. This colour change results from spectrally selective absorption by pigmented chromophores, acting as a filter on both the incident, and the exiting scattered light. The effect of this is that the perceived brunescent colour, changes topographically through the nucleus from anterior to posterior.

White nuclear scatter may occur in the absence of brunescence. (Fig. 13B) More commonly in nu-

clear cataract, the two features occur simultaneously, (Fig. 12B) and this makes the grading more difficult. In order to minimize this difficulty, white scatter grading is performed in the anterior nucleus, ie. just posterior to the anterior nuclear shell. This region is least affected by the potentially confusing effects of coexistent brunescence, which is seen to increase with posterior passage through the nucleus.

Other features

Certain other morphological features are noted when present, for example lamellar separation, coronary opacities, pseudo-exfoliation, chalky deposits, capsular opacities, polychromatic lustre of the posterior capsule, lamellar cataract, sutural opacities, or fluorescence. The term lamellar separation is used to denote fine opaque white lines in zone C2, running in the plane of the capsule, and directed at right angles to a meridian. (1) This feature is frequently seen in association with spoke opacities or waterclefts.

Image degradation: The Resolution Target Projection Ophthalmoscope

A modified ophthalmoscope has been described by Cotlier (22) which can be used to assess the effect of a cataract on retinal image formation. The instrument projects an image of a U.S.A.F. 3 bar resolution chart (Fig. 3), into the subject's eye, while the examiner determines which size target, within the projected image, is resolvable on the subject's retina. This image undergoes degradation twice by passage through the patient's ocular media, once as it passes into the eye to be projected onto the retina, and again as the projected image on the retina is viewed by the examiner. The resolution target projection ophthalmoscope score is regarded as an objective index of the image degrading effect of a cataract, and is used in preference to visual acuity or contrast sensitivity, because it does not rely on normal retinal, visual pathway, or higher order functions on the part of the subject.

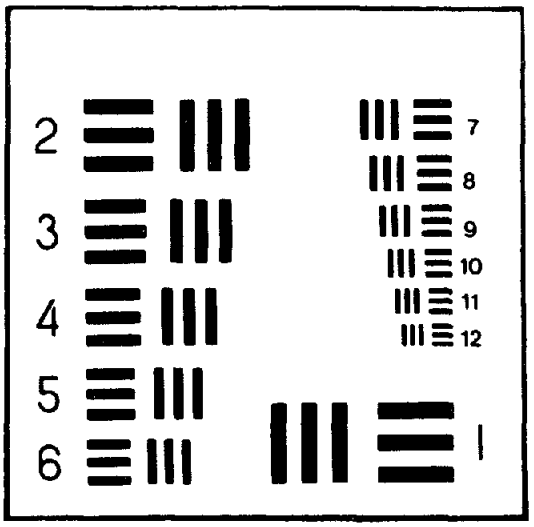


Fig. 3. Modified USAF 3 bar resolution target, illustrating the targets used and the numbering system. (The actual Resolution target projection ophthalmoscope uses the original USAF format.)

Method

The observer uses his visual system as a comparator, making judgments at the slit-lamp with reference to a mounted set of standard diagrams and colour samples, which provide readily available reference criteria for quantification of the cataract features. (A card holder which clips onto the slit-lamp frame serves this function well. (Fig. 4)) Pupillary dilatation is achieved with Tropicamide 1% (or Cyclopentolate 1%) and Phenylephrine 10%, repeated after 15 minutes. This drop combination produces effective mydriasis, with minimum side effects. (54) Most patients dilate to a pupil diameter of 8 mm or more, although occasionally the full grading of a patient is not possible as a result of poor pupillary dilatation. Senile miosis, diabetic autonomic neuropathy and pharmacological miosis may accentuate this problem.

Examination routine

Following dilatation, patients are examined with the resolution target projection ophthalmoscope. This is performed first, in order to exclude observer

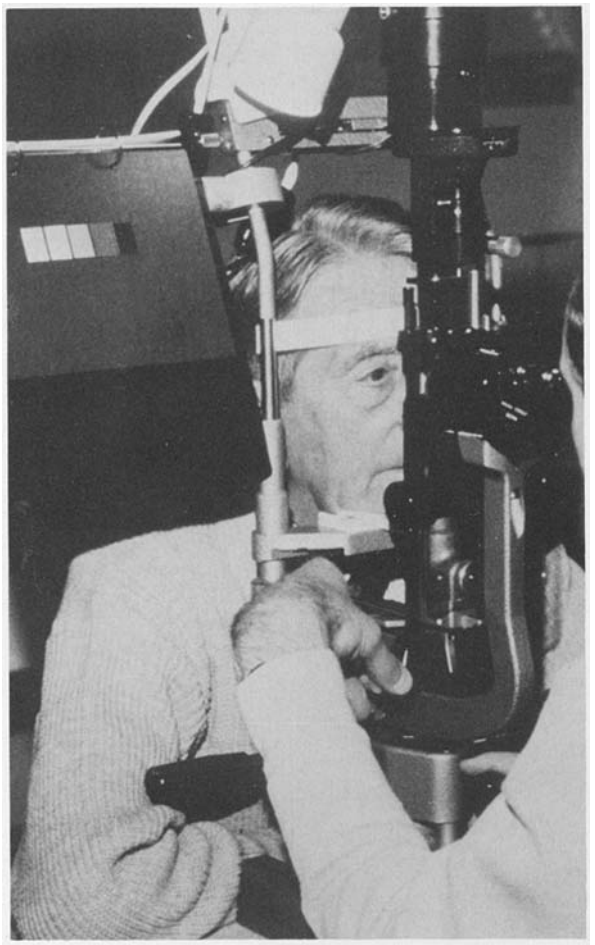


Fig. 4 The system in use, demonstrating the mounted reference cards and lamp.

bias, which may occur if the assessment follows the grading procedure. The patient is then examined at the slit-lamp, and the lens features graded and recorded on the grading chart. (Fig. 2). The pupillary diameter is recorded in mm, using the Haag-Streit 900 slit-beam height measure. The diagrams at the top of the chart are filled in first, thus indicating the major features of the cataract, and their situation. Diagrams include anterior and posterior 'en face' views, as well as a sagittal projection of the lens. These act as a morphological guide to the detailed feature grading to be placed in the matrix below. Each feature should then be assessed in turn, with reference to the appropriate standard diagrams. Finally, the predominant features are summarized under the heading 'Cataract type' and the 'Lens status' is indicated. (Vide infra.)

Grading of individual features

Grading is performed by comparison of the cataract features with standard diagrams and colour samples. The colour samples are standardized matt pigment samples, taken from the internationally accepted Munsell colour system. (52) Assessments are made using an 8 mm pupil diameter, except where otherwise indicated, (eg. retro-dots) or where unnecessary, (eg. nuclear assessments.) Whenever possible an interval scale has been used, with linear or logarithmic relationships between the grades. The standard diagrams are produced to a size which corresponds to the microscope image size of the feature under consideration. These conditions apply when the diagram is held at the same plane as the eye under study, and make comparative assessment easier as no mental adjustment for size is required. (Fig. 4) The apparent feature sizes are used, with no corrections for corneal or lenticular magnification. The magnification setting used for grading is the '10 times' magnification of the Haag-Streit slitlamp. Actual measurement of the magnification of 8 Haag-Streit slitlamps has shown it to be consistently 10.8 times, and diagrams are made according to this. When higher magnification is required for any individual feature, this is indicated in the relevant section, eg. anterior clear zone thickness assessment.

In the following section the features will appear in the same order as is used when the grading is being performed. (Table 1)

The Resolution Target Projection Ophthalmoscope

The amount of cataractous image degradation is assessed by the examiner, in terms of the smallest resolvable target which he can see on the patient's retina. (Fig. 3) The score for the resolution target projection ophthalmoscope is recorded on a 0 to 12 scale, which relates to the different sized targets which compose the projected image. A score of 0 is allocated if no targets are resolvable. The target sizes are linearly related on a log scale. The illumination of the instrument must be maintained at a standard level.

Table I. Recommended order of examination & summary of slit lamp settings.

Assessment	Slit lamp setting
1. Resolution Target Projection Ophthalmoscope	
2. General scan and complete diagrams	
3. Thickness: C1. alpha, A	Slit beam down axis View from 45 degrees 'Narrowest' beam Full power Magnification '16 ×'
4. Anterior sub-capsular opacity	Focal, broad slit
5. Spoke opacity	Focal, narrow slit
6. Watercletts	Focal, narrow slit
7. Vacuoles	Retro-illumination
8. Retro-dots	Retro- & specular illumination
9. Posterior sub-capsular opacity	Retro- & focal ill
10. Focal dots	Slit beam at 45 deg Height 2 mm Width 0.7 mm (No 14) Temporal patch, 3 mm off axis
11. Nuclear brunescence	Slit beam at 45 deg Width 0.3 mm Full power Posterior nucleus
12. White nuclear scatter	Slit beam at 45 deg Width 0.3 mm. Full power Anterior nucleus

Cortical features

Thickness of the anterior clear zone (C1,alpha,A) is assessed by comparison with standard diagrams. The diagrams display slit image photographs of lenses which have been modified, in order to provide standard clear zone thicknesses for reference. (Fig. 5) The standard clear zone dimensions were determined by measurement of Scheimpflug slit image photographs, and are corrected for magnification and angle of view. The 'background photograph' on the clear zone diagram provides contextual cues in order to avoid perceptual errors related to the phenomonon of failure in size constancy. (44) Assessment is made with the slit-lamp microscope angled at 45 degrees to the optical axis, while the slit beam is projected down the optical axis. With the illumination at full power, the beam width is set at the minimum width which provides adequate illumination for assessment. The 16 times magnification is used. The grades are linear, with Grade 3 representative of normality. The diagrams represent borders between one grade and the next.

Grade 1: Anterior clear zone absent or markedly decreased. (< or = 25 micrometers actual size.)
Grade 2: Anterior clear zone decreased. (>25; < or = 75 micrometers actual size.)
Grade 3: Anterior clear zone normal. (>75; < or = 125 micrometers actual size.)
Grade 4: Anterior clear zone increased. (>125; < or = 175 micrometers actual size.)
Grade 5: Anterior clear zone markedly increased. (>175 micrometers actual size.)

Anterior sub-capsular opacities are roughly circular or oval in shape. They are graded according to diameter. When the opacity is not circular, it is mentally 'rounded up' and graded. The grading is linear with respect to diameter, and is made by comparison with the diagram in Fig. 6.

Grade 0: feature absent.
Grade 1: >0; < or = 1st circle.
(>0% to 20% of diameter.)
Grade 2: >1st; < or = 2nd circle.
(>20% to 40% of diameter.)
Grade 3: >2nd; < or = 3rd circle.
(>40% to 60% of diameter.)
Grade 4: >3rd; < or = 4th circle.
(>60% to 80% of diameter.)
Grade 5: >4th circle.
(>80% to 100% of diameter.)

Cortical spoke (cuneiform) opacities are typically radial, base-out wedge segments, and are graded according to area affected in 'pie shaped segments'. When the opacified regions occupy non-adjacent segments, these are apposed in the 'mind's eye' and

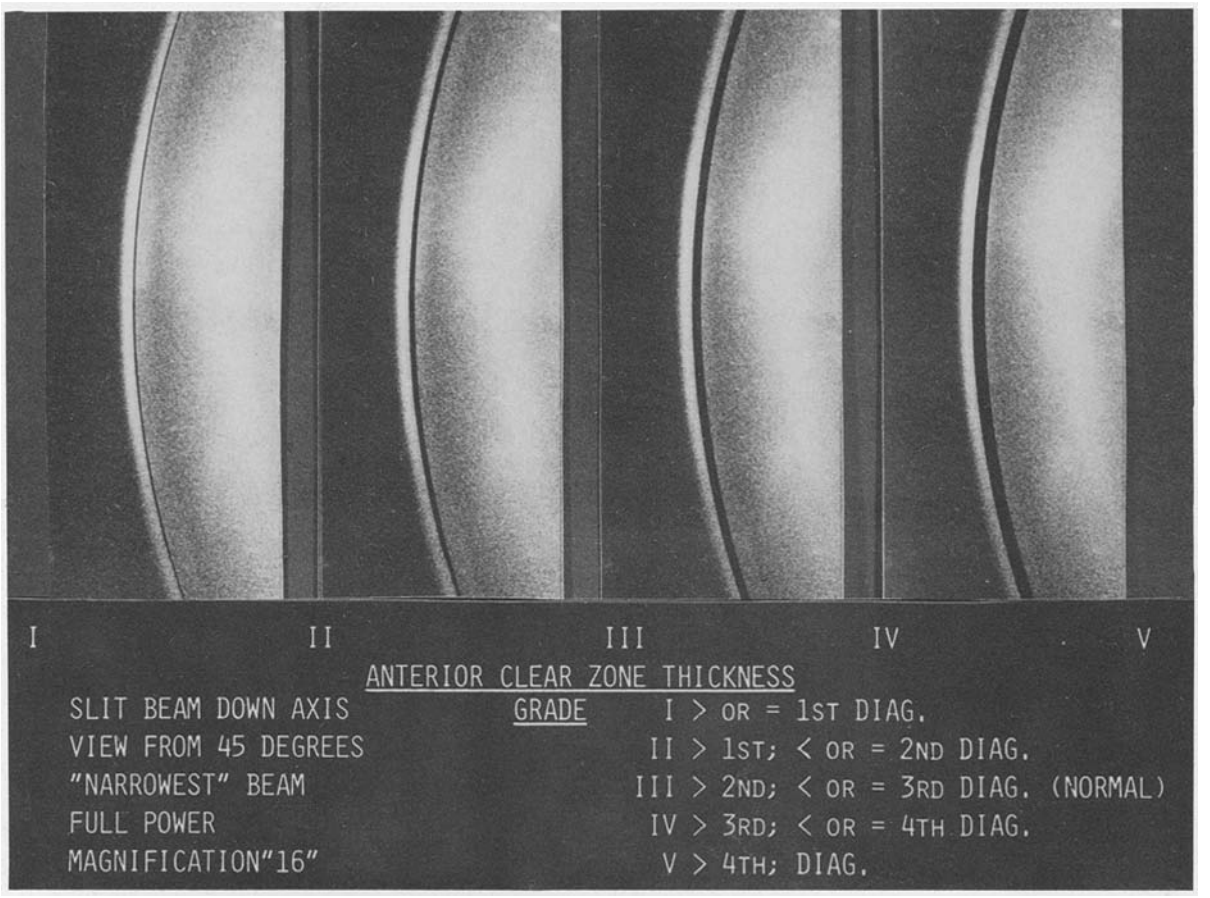


Fig. 5. The 'Anterior clear zone thickness' reference standards.

the overall area guaged. Assessments are made by comparison with the standard diagram in Fig. 7, the anterior and posterior spokes are superimposed against the red reflex and graded together. Grades are linear with respect to area.

Grade 0: feature absent.
Grade 1: >0; < or = 1 pie segment.
(>0% to 20% of area.)
Grade 2: >1; < or = 2 pie segments.
(>20% to 40% of area.)
Grade 3: >2; < or = 3 pie segments.
(>40% to 60% of area.)
Grade 4: >3; < or = 4 pie segments.
(>60% to 80% of area.)
Grade 5: >4 pie segments.
(>80% to 100% of area.)

Waterclefts have a radial configuration, and are therefore suited to the same grading treatment as spokes as described above, anterior and posterior features again being superimposed. The full extent of the waterclefts is gauged by their appearance in focal slit beam illumination. (Fig. 8)

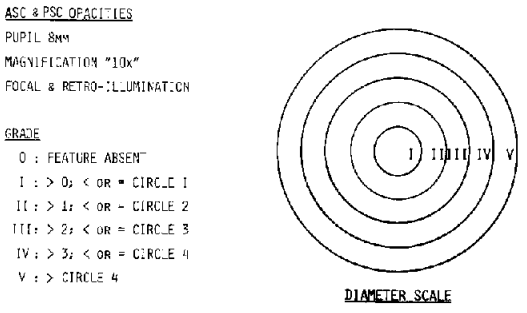


Fig. 6A. The 'Diameter scale' reference standards for anterior and posterior sub-capsular opacities.

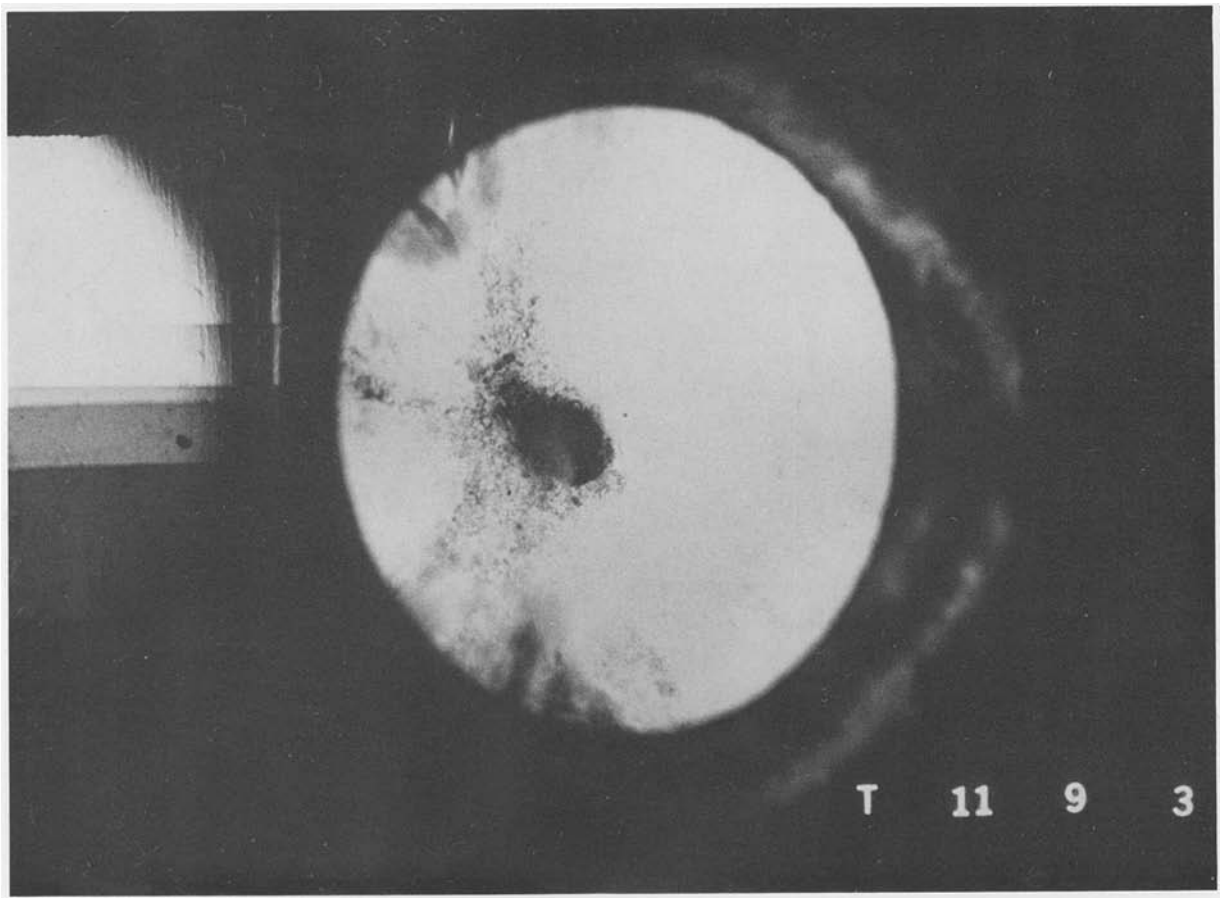


Fig. 6B. An example of a Grade 2 posterior sub-capsular opacity.

Grade 0: feature absent.
Grade 1: >0; < or = 1 pie segment.
(> 0% to 20% of area.)
Grade 2: >1; < or = 2 pie segments.
(>20% to 40% of area.)
Grade 3: >2; < or = 3 pie segments.
(>40% to 60% of area.)
Grade 4: >3; < or = 4 pie segments.
(>60% to 80% of area.)
Grade 5: > 4 pie segments.
(>80% to 100% of area.)

Vacuoles are graded according to their frequency within an 8 mm diameter area. The standard diagrams (Fig. 9) display increasing vacuole frequency on a logarithmic scale. Each diagram represents the border between one grade and the next. The greatest number of vacuoles possible, is taken as that number of 0.2 mm vacuoles, which would cover the total area of an 8 mm diameter circle. From this total number, equal interval logarithmic steps were calculated, and the diagrams based on these. When grading, anterior and posterior features are superimposed and graded together. Where vacuoles form an integral part of another

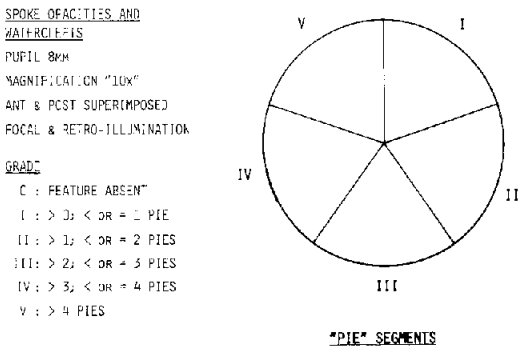


Fig. 7A. The 'Pie segment' reference standards for spoke opacities and watercleft.

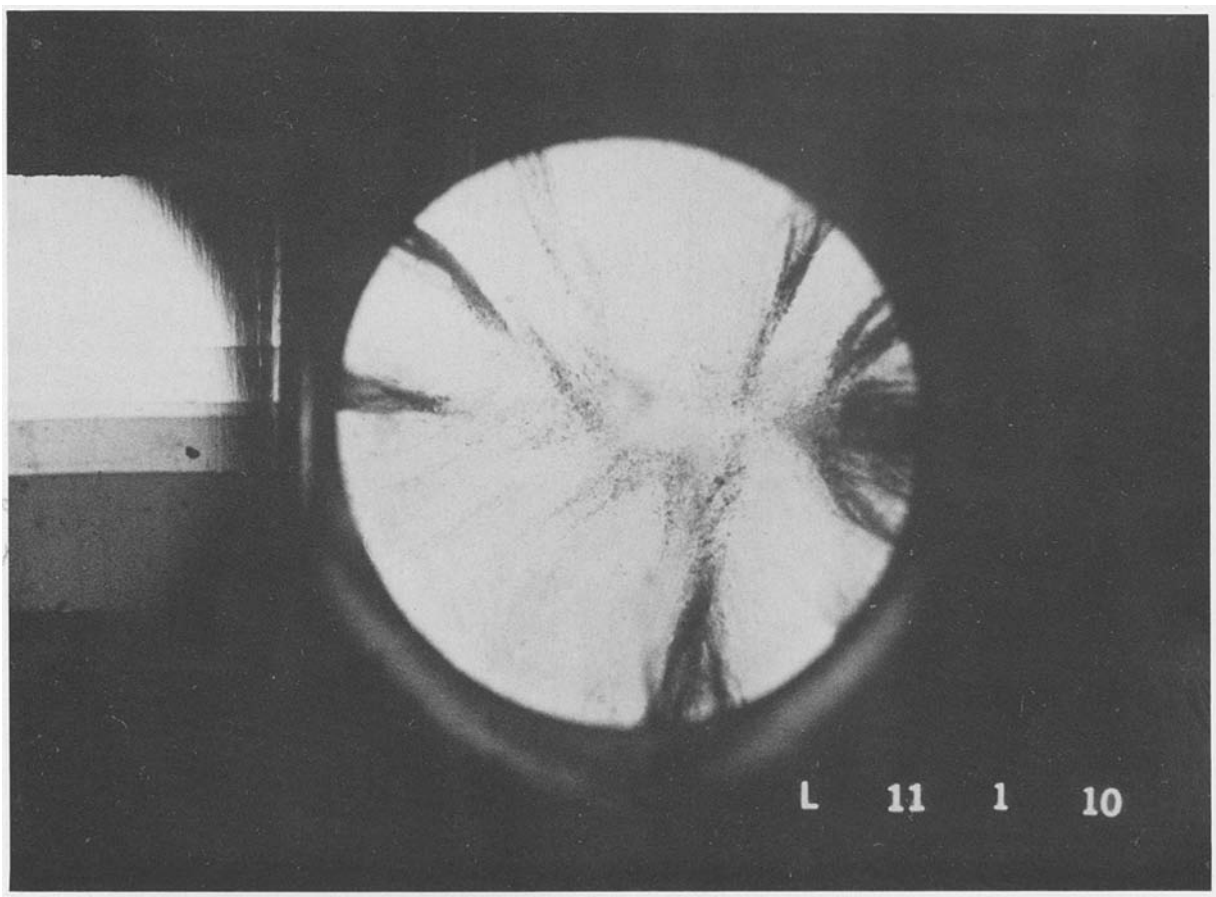


Fig. 7B. An example of Grade 2 spoke opacities.

opacity, as may occur in posterior sub-capsular and spoke opacities, these vacuoles are graded with that opacity.

Grade 0: feature absent.
Grade 1: >0; < or = 1st diagram.
(1 to 4 vacuoles.)
Grade 2: >1st; < or = 2nd diagram.
(5 to 20 vacuoles.)
Grade 3: >2nd; < or = 3rd diagram.
(21 to 90 vacuoles.)
Grade 4: >3rd; < or = 4th diagram.
(91 to 403 vacuoles.)
Grade 5: >4th diagram.
(>404 vacuoles.)

Retro-dots are graded similarly to vacuoles, but with some important differences. Clinical experience has shown that retro-dots usually occur within a 6 mm diameter circular area centered on the optic axis. (3) For this reason retro-dots are graded only within a central 6 mm diameter area. In addition the individual retro-dots are on average slightly larger than vacuoles. The standard diagrams were derived by the same method as that used above for vacuoles, but here a 6 mm diameter area is occupied by 0.3 mm diameter retro-dots. (Fig. 10) The diagrams are again based on a logarithmic scale, and represent borders between grades. Anterior and posterior features are superimposed when graded.

Grade 0: feature absent.
Grade 1: >0; < or = 1st diagram.
(1 to 3 retro-dots.)
Grade 2: >1st; < or = 2nd diagram.
(4 to 11 retro-dots.)
Grade 3: >2nd; < or = 3rd diagram.

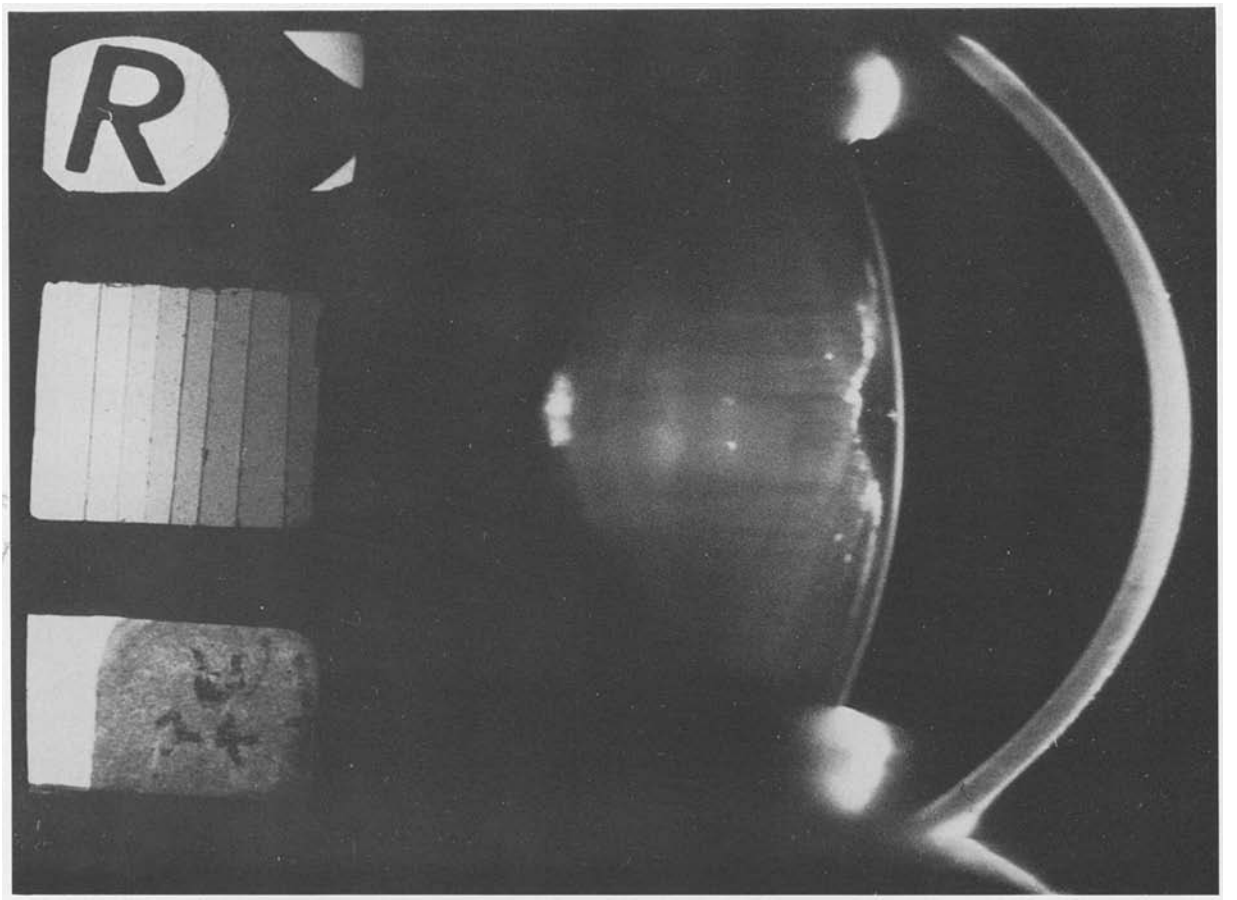


Fig. 8. An example of a Watercleft.

(12 to 36 retro-dots.)
Grade 4: >3rd; < or = 4th diagram.
(37 to 121 retro-dots.)
Grade 5: >4th diagram.
(>122 retro-dots.)

Posterior sub-capsular opacities are typically circular, and like anterior sub-capsular opacities, are graded by diameter. When an opacity is not circular, or is off centre, a corrective mental adjustment is made. The concentric circles used in grading this feature, produce a linear grade with regard to diameter. (Fig. 6)

Grade 0: feature absent.
Grade 1: >0; < or = 1st circle.
(>0% to 20% of diameter.)
Grade 2: >1st; < or = 2nd circle.
(>20% to 40% of diameter.)
Grade 3: >2nd; < or = 3rd circle.
(>40% to 60% of diameter.)
Grade 4: >3rd; < or = 4th circle.
(>60% to 80% of diameter.)
Grade 5: >4th circle.
(>80% to 100% of diameter.)

Focal-dots appear distributed with increasing frequency towards the periphery of the lens. For this reason a standard 'grading patch' is chosen, and all lenses are graded in this specific region. Practical considerations have determined the 'grading patch' as follows: The slit beam is directed into the lens from the nasal side, at 45 degrees to the optic axis. The slit beam height is set at 2 mm and the width at 0.7 mm. (Number 14 on the Haag-Streit slit-lamp width setting.) The 'grading patch' is located temporally in zone C2A, 3 mm temporal to the optic axis. The standard diagrams represent this rec-

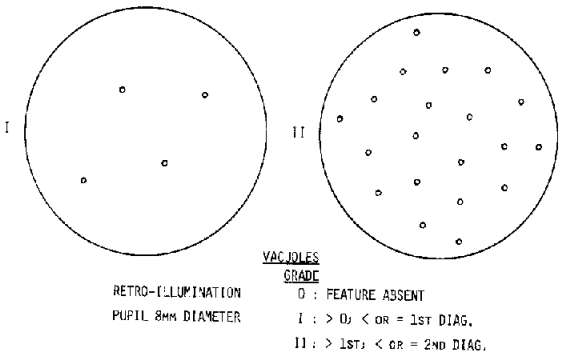


Fig. 9A. The 'Vacuole' reference standards. (Lower grades.)

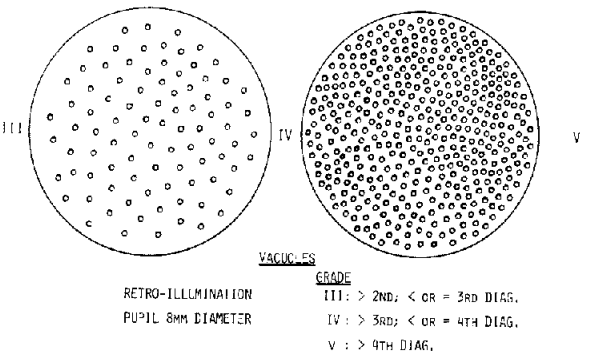


Fig. 9B. The 'Vacuole' reference standards. (Higher grades.)

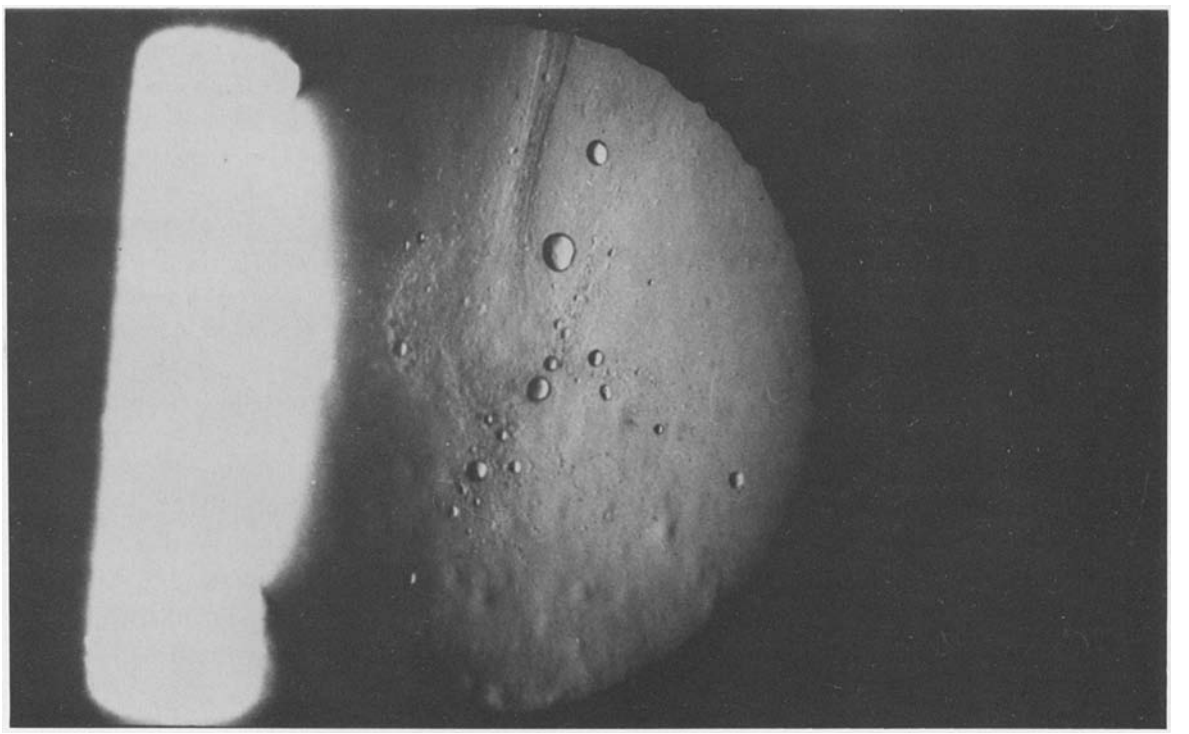


Fig. 9C. An example of Grade 2 vacuoles.

tangular 'grading patch'. When opacification makes it impossible to grade a temporal patch, a similar nasal patch is chosen, and this is noted on the recording sheet. The diagrams were derived by filling an appropriately magnified 'grading patch' with 'focal dots', and then calculating from this 'maximum number possible', equal interval logarithmic intervals. (Fig. 11). The diagrams represent borders between grades.

Grade 0: feature absent.
Grade 1: >0; < or = 1st diagram.
(1 to 3 focal-dots.)
Grade 2: >1st; < or = 2nd diagram.
(4 to 9 focal-dots.)
Grade 3: >2nd; < or = 3rd diagram.
(10 to 27 focal-dots.)
Grade 4: >3rd; < or = 4th diagram.
(28 to 81 focal-dots.)
Grade 5: >4th diagram. (>82 focal-dots.)

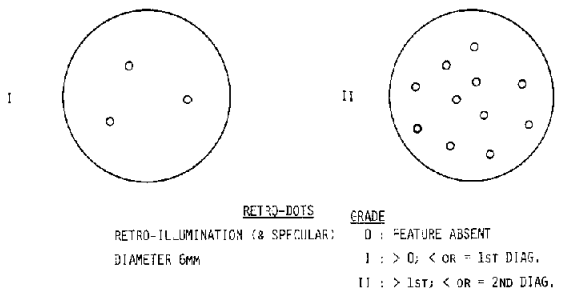


Fig. 10A. The 'Retro-dot' reference standards. (Lower grades.)

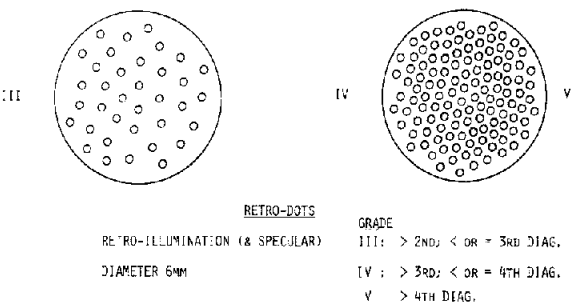


Fig. 10B. The 'Retro-dot' reference standards. (Higher grades.)

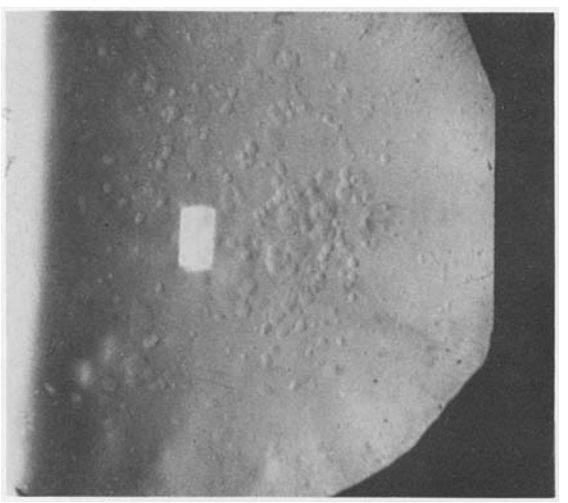


Fig. 10C. An example of Grade 4 retro-dots.

Nuclear features

Nuclear brunescence is graded by comparison with standard Munsell colour samples. (52) The colours used were selected by making multiple colour matches on lenses with nuclear brunescence, following which evenly spaced representative colours were chosen. (60) (Fig. 12A). The grading principle adopted for brunescence differs from that of the cortical features in that here the colours are a representative example of the grade, rather than a border between grades. The grade is selected according to the closest available match between the nucleus and the colour samples. (Fig. 12) Although an attempt has been made to place similar steps between the grades in Munsell colour space, no more than an ordinal scale of measurement is considered possible. The basic feature being assessed is the presence of a yellow or brown pigment in the nucleus. The colour matches are made in a specific region of the nucleus to maintain consistency. The region chosen is the posterior part of the nucleus, just anterior to the posterior nuclear shell, axially. The slit beam is adjusted to enter the lens at 45 degrees to the optic axis, with a beam width of 0.3 mm, (number 12 on the Haag-Streit slit-lamp width setting), and illumination on full power. For accurate matching, the standard colour samples should be viewed in a light with the same spectral characteristics as the slit-lamp light source. This is easily achieved by mounting a slit-lamp bulb in a convenient position adjacent to the slit-lamp. (Fig. 4) When no yellow colour is detectable in the nucleus, this is regarded as 'Grade 0', and the nuclear colour matches the 'Grade 0' colour sample.

Colour	Munsell notation
Grade 0: No yellow detectable	(5GY 6/1)
Grade 1: Yellow just detectable	(5Y 7/4)
Grade 2: Definate yellow	(2.5Y 7/8)
Grade 3: Orange yellow	(7.5YR 6/8)
Grade 4: Reddish brown	(5YR 4/6)
Grade 5: Blackish brown	(2.5YR 2.5/2)

White nuclear scatter is obvious when it occurs in isolation. (Fig. 13B) More commonly however nuclear brunescence coexists with white nuclear scatter in a nuclear cataract, (Fig. 12B), which complicates the assessment slightly. The feature being assessed is the amount of white light being scattered back to the observer by the lens nucleus. Grading is accomplished by comparison with Mun-

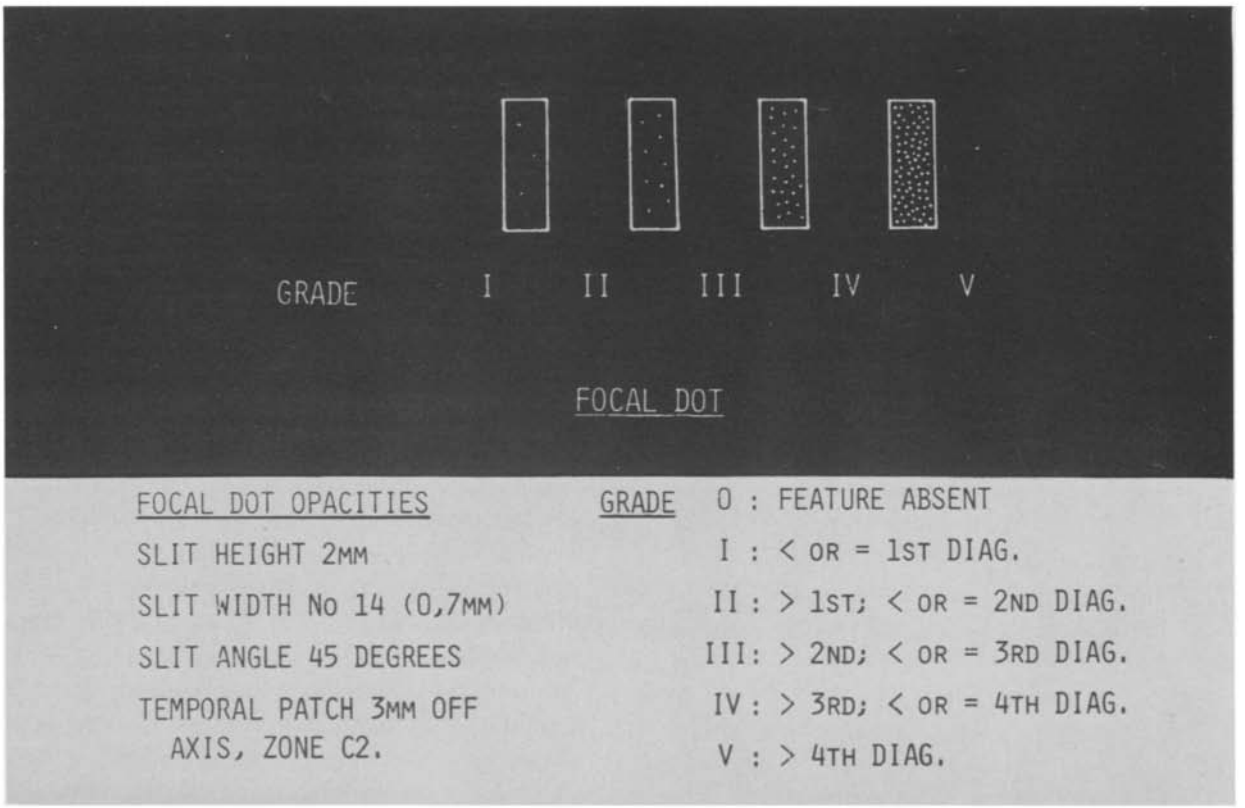


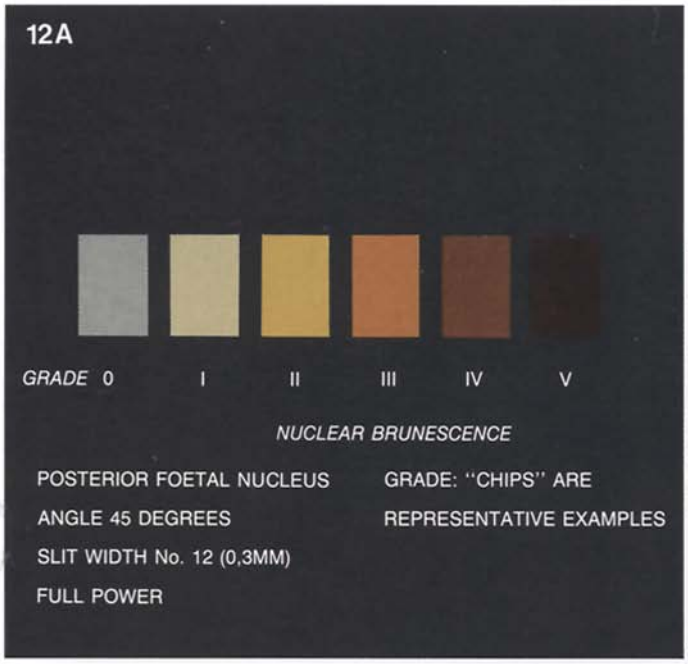
Fig. 11. The 'Focal dot' reference standards.

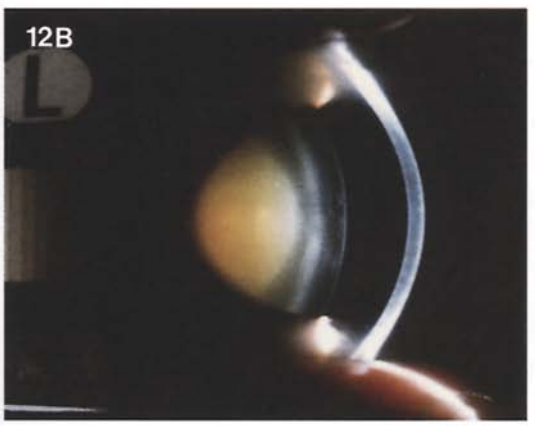
sell neutral density grey scale samples. (Fig. 13). The neutral grey samples are representative examples of each grade, and as with the colours, grading is performed by selection of the best available match. The lightness range was determined by performing multiple matches on patients with all degrees of white nuclear scatter, using the complete 32 step Munsell neutral density grey scale range. The grades were chosen with equal visually discernable steps along the Munsell grey scale, and are linear with regard to this interval scale. In order to reduce the confusing effects of coexistent brunescence on white scatter grading, a pair of spectacles containing a yellow filter (Wratten No. 12) is employed. Both the lens being graded, and the neutral density grey scale samples are viewed through the yellow filters. Grading white scatter without the filters is possible, but it is less accurate and requires a considerable amount of practise. Assessment is made in the anterior nucleus, axially, and observations are made with the same slit-lamp settings and illumination as for the colour grading. There is some white scatter in every nucleus, (if not the nucleus would appear black), and for this reason Grade 1 is considered to be inclusive of normality, and no 'Grade 0' is recognised.

Munsell notation	*(% Reflectance)*
Grade 1: N5	(19.8%r)
Grade 2: N6	(30.0%r)
Grade 3: N7	(43.1%r)
Grade 4: N8	(59.1%r)
Grade 5: N9	(78.7%r)

The percentage reflectance values quoted are those specified by the manufacturers. (51)

Each of the above features is graded and the matrix filled in for the appropriate zone. Absence of a particular feature is indicated as 'grade 0', except for anterior clear zone thickness, and white nuclear scatter, as indicated above. When a feature





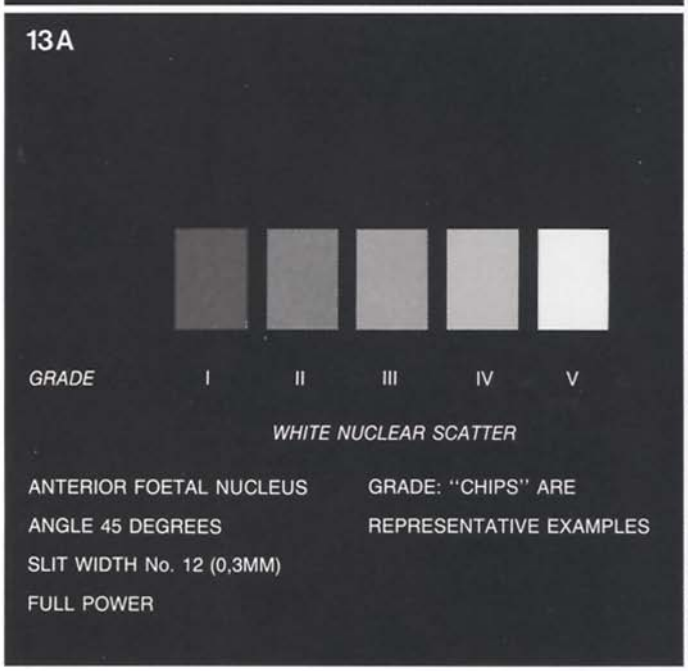


Fig. 12A. The 'Nuclear brunescence' reference standards. (It should be noted that photographic reproductions in colour are inaccurate, and that these representations are for demonstration purposes only.)

Fig. 12B. An example of Grade 3 nuclear brunescence. (It should be noted that photographic reproductions in colour are inaccurate, and that these representations are for demonstration purposes only.)

Fig. 13A. The 'White nuclear scatter' reference standards. (It should be noted that photographic reproductions in colour are inaccurate, and that these representations are for demonstration purposes only.)

Fig. 13B. An example of Grade 5 white nuclear scatter. (It should be noted that 'grey scale' photographic reproductions are inaccurate, and that these representations are for demonstration purposes only.)

cannot be graded for some reason, a '?' sign is used to indicate this. Such a situation may arise, for example, when a posterior feature is obscured by an anterior opacity.

Other features

Any other features present are annotated individually and are not graded.

The major cataract features are now summarized in the section headed 'cataract type', and the grading is completed with a comment on the lens status. (ie. immature, mature, [table 2].) The lens status should not be regarded as a ranking scale, but rather as a nominal scale. The lens status assumes overriding importance when a cataract is mature, because in this situation most of the graded features become invisible.

Finally, the examiner signs the grading chart.

Discussion

The need for a standardised classification of cataract is well recognised. (2, 12–14, 22, 26–28, 39, 40, 45, 48, 49, 55, 59) Different systems have evolved to serve the needs of workers in various settings. Early classifications were mainly designed for use in laboratories on extracted lenses, (12, 13, 17–19, 26, 50, 55) although more recently systems have evolved, or been modified for use in vivo. (2, 10, 15, 20, 22, 23, 36, 45) Photography has been used to quantify lens opacities; the two most important in vivo techniques are Scheimpflug slit-image photography, (4, 5, 7–9, 34, 37, 53, 56, 57) and retro-illumination photography. (9, 16, 29, 41, 49) These images may be subjected to various forms of analysis, which provide reproducibile 'hard data'. (5, 8, 9, 16, 32, 37, 42, 43, 47, 49, 58) The photographic techniques have their merits, but they all require sophisticated equipment, and although they offer an excellent means of quantification, they do not provide a comprehensive approach to classification.

Table 2. Descriptors of lens status

Clear
Immature
Mature
Hypermature
Morgagnian
Intumescent
Subluxed
Dislocated
Altered shape, eg lenticonus
Aphakic

The Oxford Clinical Cataract Classification Grading System is intended as a clinical tool. Its strengths lie in its availability, standardisation, and ease of use. The time taken to grade a cataract by an examiner who is familiar with the system, varies from 2 to 7 minutes, depending on the complexity of the opacities. The average time required is under 5 minutes. The system is well suited to epidemiological surveys, clinical trials of anti-cataract drugs, toxicological and natural history studies, and routine clinical assessment. In order to place the Oxford system on a firm theoretical foundation, grades have included, whenever possible, the use of interval scales with linear relationships providing equal interval category steps. (ASC, PSC, spokes, waterclefts, white nuclear scatter and anterior clear zone thickness.) Logarithmic conversions have been used for features when linear scales are unrealistic. (Vacuoles, retro-dots and focal dots.) This detailed attention to measurement theory is new to cataract grading, and has been introduced in order to strengthen the theoretical basis of the grading, and to facilitate statistical analysis. Interval measurement is not possible for nuclear colour grading.

Difficulties arise when direct comparisons are attempted between studies from different centres, as a result of varying methods of examination and classification. It may be informative to compare the Oxford system with certain other systems of lens classification, which have been used in studies elsewhere. Clayton et al use a clinical classification scheme based on slit lamp appearances of cortical features and nuclear colour. Their cortical features are: Clefts, vacuoles, granules, and iridescence. (20) Leibowitz et al describe their system in the 'Framingham Eye Study' monograph, (45) in which features are divided into 'early' and 'late'

senile lens changes, again according to their slit-lamp appearances. Early features include: Vacuoles, waterclefts, spokes, and lamellar separations. Pseudoexfoliation, cortical cuneiform, decreased nuclear 'lucency', posterior subcapsular, and 'other' classes exist for late features. (45) The American Cooperative Cataract Research Group (CCRG) method of cataract classification has been well described by Chylack. The system was initially developed for use in vitro, (13, 17–19) and has been modified for use in vivo. (15) Assessments are based on photographs and the cortical zoning is considerably different from that in the Oxford system. Nuclear colour is divided into 8 categories. (15, 18)

A gradation of nuclear brunescent colour from yellow, through 'hazel brown' to 'deep brown', was first described by Pirie as an in vitro cataract classification system. (55) This gradation of colour has been correlated by a number of researchers with biochemical changes in the human lens. As brunescence increases, water insoluble and urea insoluble protein, protein fluorescence, and high molecular weight aggregates increase; while wet and dry weight, protein thiol and glutathionine decrease; to name but a few of the correlated biochemical parameters. (31) Although moderate degrees of nuclear brunescence do not disturb vision significantly, the higher grades of brunescence, particularly when associated with increased scattering or perinuclear encroachment, may do so. It is therefore important to maintain a grading of nuclear brunescence in any system of cataract classification. The colour grades in the Oxford clinical system correlate approximately with those of Pirie as follows:

Oxford Clinical Grade	*Pirie's in vitro Grade*
Grades 0, 1 & 2	Grade 1
Grade 3	Grade 2
Grade 4	Grade 3
Grade 5	Grade 4

Such comparisons however, should not be taken too far. Not only does the nomenclature of the systems vary, but the same terms may represent different features in the various systems. An example of this is evident when comparing the Oxford Clinical System with the Framingham method, with regard to spokes and cuneiform opacities. (45) In the Oxford system spokes and cuneiform opacities are terms which are used interchangably, whereas in the Framingham method these terms denote separate entities.

The Oxford Clinical Cataract Classification and Grading System is a useful clinical tool in cataract assessment in vivo. The system can be used in conjunction with photographic methods where these are available, and is compatible with the in vitro Pirie classification. Validation of the system will be presented in a separate publication.

Acknowledgement

We are grateful to Mr. Don Barbour for his indespensible and expert photographic assistance in the preparation of the diagrams and photographs.

References

1. Berliner ML: Biomicroscopy of the Eye. Vol 2. p 1115. Medical Book Department, Harper and Brothers, New York, 1949
2. Bron AJ, Brown NAP: Classification, grading and prevention of cataract. IBID 4(1): 21–47, 1983
3. Bron AJ, Brown N: Retro-dots. In preparation
4. Brown N: Slit image photography. Trans Ophthal Soc UK 89: 397–408, 1968
5. Brown N: Quantitative slit image photography of the lens. Trans Ophthal Soc UK 92: 303–317, 1972
6. Brown N: Visibility of transparent objects in the eye by retro-illumination. Brit J Ophthalmol 55: 517–524, 1971
7. Brown N: An advanced slit-image camera. Trans Ophthal Soc UK 56: 624–631, 1972
8. Brown N: Lens change with age and cataract; slit image photography. (General discussion 1.) In: The human lens in relation to cataract. CIBA Found. symp. 19 (Ed: Elliott K, Fitzsimons DW) p 65–78, 1973
9. Brown NAP, Bailey K, Ayliffe W, Sparrow JM, Bron AJ: Photographic evaluation of cataract. In preparation, presented at the CCRG meeting, Hawaii. (December 1985)
10. Brown N, Gardner RJM: Lowe Syndrome: Identification of the carrier state. In: The eye and inborn errors of metabolism. (Ed: Bergsma D, Bron AJ, Cotlier E) p 579–591, 1976

11. Brown N, Tripathi R: The loss of the anterior sub-capsular clear zone of the lens. Prognostic significance in cataract formation. Trans Ophthal Soc UK 94: 29–45, 1984
12. Cicchetti DV, Sharma Y, Cotlier E: Assessment of observer variability in the classification of human cataracts. The Yale J of Biol and Med 55: 81–88, 1982
13. Chylack LT: Classification of human cataracts. Arch Ophthalmol 96: 888–892, 1978
14. Chylack LT, Editorial: The co-operative cataract research group. Invest Ophthalmol 17(12): 1131–34, 1978
15. Chylack LT: Classification of human cataractous change by the American co-operative cataract research group method. In: Human cataract formation. (Ed: Nugent J, Whelan J.) Pitman, London. (CIBA Foundation Symposium, 106.) p: 3–24, 1984
16. Chylack LT, Cheng HM, White O: Retro-illumination and Topcon SL-45 photography of cataracts *in vivo*: A Quantatative study of the varieneces of these techniques with computerized image analysis. ARVO Abst Sarasota suppl, Invest Ophthalmol 25: 270, 1984
17. Chylack LT, Lee MR, Tung WH, Cheng HM: Classification of human senile cataractous change by the American co-operative cataract research group method. 1. Instrumentation and technique. Invest Ophthalmol 24: 424–431, 1983
18. Chylack LT, Ransil BJ, White O: Classification of human senile cataractous change by the American co-operative cataract research group method. 3. The association of nuclear colour (sclerosis) with extent of cataract formation, age and visual acuity. Invest Ophthalmol 25: 174–180, 1984
19. Chylack LT, White O, Tung WH: Classification of human cataractous change by the American co-operative cataract research group method. 2. Staged simplification of cataract classification. Invest Ophthalmol 25: 166–173, 1984
20. Clayton RM, Cuthbert J, Phillips CI, Bartholomew RS, Stokoe NL, Ffytche T, McK Reid J, Duffy J, Seth J, Alexander M: Analysis of individual cataract patients and their lenses: A progress report. Exp Eye Res 31: 553–566, 1980
21. Cotlier E: Senile cataracts: Evidence for acceleration by diabetes and deceleration by salicylate. Can J Ophthalmol 16: 113–118, 1981
22. Cotlier E, Fagadau W, Cicchetti DV: Methods for evaluation of medical therapy of senile and diabetic cataracts. Trans Ophthal Soc UK 102: 416–422, 1982
23. Crews SJ: Posterior subcapsular lens opacities in patients on long term corticosteroid therapy. Brit Med J (22nd June): 1644–46, 1963
24. Cuthbert J, Clayton RM, Truman DES, Phillips CI, Bartholomew RS: Analysis of the crystallin composition of individual human lenses: Characteristic modification associated with different cataracts. Interdiscipl Topics Geront 13: 183–192, 1978
25. Duke-Elder S: System of Ophthalmology, Vol 2, The anatomy of the visual system. Henry Kimpton, London, p 312, 1960
26. Duncan G: On classifying human cataractous lenses. In: Mechanisms of cataract formation in the human lens. (Ed: Duncan G) Academic press, London, p 1–5, 1981
27. Duncan G, Bushell AR: Relationships between colour, sodium and protein content of individual senile human cataractous lenses. Ophthal Res 11: 397–404, 1979
28. Ederer F, Hiller R, Taylor HR: Senile lens changes and diabetes in two population studies. Am J Ophthalmol 91: 381–395, 1981
29. Fincham EF: Photographic recording of opacities of the ocular media. Brit J Ophthalmol 39: 85–89, 1955
30. Goldman H, Niesel P: Ophthalmologica 147: 134, 1964
31. Harding JJ: Changes in lens proteins in cataract, In: Molecular and cellular biology of the eye lens. (Ed: Bloemendal H) John Wiley, New York p 327–365, 1981
32. Helve J, Nieminen H: Autofluorescence of the human diabetic lens in vivo. Am J Ophthalmol 81: 491–494, 1976
33. Hockwin O, Dragomirescu V: Die Scheimpflug-photographie des vorderen augenabschnittes. Z prakt Augenheilkd 2: 129–136, 1981
34. Hockwin O, Dragomirescu V, Koch HR: Photographic documentation of disturbances of the lens transparency during ageing, with a Scheimpflug camera system. Ophthal Res 11: 405–410, 1979
35. Hockwin O, Dragomirescu V, Laser H: Measurements of lens transparency or its disturbances by densitometric image analysis of Scheimpflug photographs. Graefe's Arch Clin Exp Ophthalmol 219: 255–262, 1982
36. Hockwin O, Eckerskorn U, Schmidtmann W, Dragomirescu V, Korte J, Laser H: Epidemiological study of the association between lens cataract and case history, blood composition, and enzymes involved in lens carbohydrate metabolism. Lens Res 2(1): 23–41, 1984
37. Hockwin O, Lerman S, Ohrloff C: Investigations on lens transparency and its disturbances by micro-densitometric analysis of Scheimpflug photographs. Curr Eye Res 3(1): 15–22, 1984
38. Hockwin O, Weigelin E, Laser H, Dragomirescu V: Biometry of the anterior eye segment by Scheimpflug photography. Ophthalmic Res 15: 102–108, 1983
39. Kahn HA, Leibowitz H, Ganley PJ, Kini M, Colton T, Nickerson R, Dawber TR: Standardizing diagnostic proceedures. Am J Ophthalmol 79(5): 768–775, 1975
40. Kahn HA, Leibowitz HM, Ganley JP, Kini MM, Colton T, Nickerson RS, Dawber TR: The Framingham Eye Study. 1. Outline and major prevalence findings. Am J Epidemiol 106(1): 17–32, 1977
41. Kawara T, Obazawa H: A new method for retroillumination photography of cataractous lens opacities. Am J Ophthalmol 90: 186–189, 1980
42. Kawara T, Obazawa H, Nakano R, Sasaki M, Sakata T: Quantatative evaluation of cataractous lens opacities with retro-illumination photography. Jpn J Ophthalmol (Rinsho Ganka.) 33: 21–26, 1979
43. Koch HR, Schnell G: Intrinsic yellow fluorescence of human lenses. Ophthal Res Suppl 16: 209, 1984
44. Leibowitz H, Bussey T, McGuire P: Shape and size constancy in photographic reproductions. J Opt Soc Amer 47: 658–661, 1957

45. Leibowitz HM, Krueger DE, Maunder LR, Milton RC, Kini MM, Kahn HA, Nickerson RJ, Pool J, Colton TL, Ganley JP, Lowenstein JI, Dawber TR: The Framingham Eye Study. Monograph Surv Ophthalmol Suppl 24: 350–364, 1980
46. Lerman S: An experimental and clinical evaluation of lens transparency and ageing. J Geront 38: 293–301, 1983
47. Lerman S, Hockwin O: Ultraviolet-visible slit lamp densitography of the human eye. Exp Eye Res 33: 587–596, 1981
48. Leske MC, Sperduto RD: Epidemiology of senile cataracts: A review. Am J Epidemiol 118(2): 152–165, 1983
49. Maclean H, Taylor CJ: An objective staging for cortical cataract in vivo aided by pattern-analysing computer. Exp Eye Res 33: 597–602, 1981
50. Marcantonio JM, Duncan G, Davies PD, Bushell AR: Classification of human senile cataracts by nuclear colour and sodium content. Exp Eye Res 31: 227–237, 1980
51. Munsell Colour, Macbeth Division of Kollmorgen Corporation, 2441 N. Calvert street, Baltimore, Maryland. 21218
52. Newhall SM, Nickerson D, Judd DB: Final report of the O.S.A. Subcommittee on the spacing of the Munsell colours. J Opt Soc Am 33: 385–418, 1943
53. Niesel P: Visible changes of the lens with age. Trans Ophthal Soc UK 102: 327–330, 1982
54. Peckar CO, M.Sc. Thesis, Linacre College, University of Oxford p 46–50, 1982
55. Piric A: Colour and solubility of the proteins of human cataracts. Invest Ophthalmol 7(6): 634–650, 1968
56. Sasaki K, Oishi T, Yamaaki H, Nakamura F: Documentation of human lens by rotating photoslit-lamp. Clinical applications and examinations for the reproducibility of obtained photographs. Jpn J Ophthal 33: 621–627, 1979
57. Shibata T, Hockwin O, Weigelin E, Kleifeld O, Dragomirescu V: Lens biometry according to age and cataract morphology. Evaluation of Scheimpflug photographs of the anterior segment. Klin Mbl Augenheilk 185: 35–42, 1984
58. Shibata T, Sasaki K: Observation of ageing changes of lens transparency – Analysis of 541 eyes from colour images. Nippon Ganka Gakkai Zasshi 86: 1701–8, 1982
59. Sommer A: Cataracts as an epidemiologic problem. Am J Ophthalmol 83(3): 334–339, 1977
60. Sparrow JM, Aylffe W, Hill A: In preparation