LENS HARDNESS IN MATURE CATARACTS

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SUMMARY

A cataract is said to be mature when all the cortical fibres become opaque. Depending on the pathophysiological processes that cause the cortical fibre opacification this phenomenon may be associated with a varying degree of nuclear sclerosis. A relationship between lens hardness and degree of nuclear sclerosis in non-mature cataracts has been demonstrated previously. This study aimed to investigate the relationship between the hardness of mature cataracts and the transmitted nuclear colour, age and rate of progression of the cataract. Thirty-eight patients with mature cataracts were assessed prior to extracapsular cataract surgery. The nuclear colour that was transmitted through the opaque cortex was graded using reference photographs. Age and duration of visual symptoms were recorded and lens hardness was measured by a specially designed lens guillotine. Multivariate analysis of data indicates a relationship between hardness of a mature cataract and the transmitted nuclear colour and age (adjusted $R^2 = 0.59$). There is also a tendency for hardening of the lens as the duration of visual symptoms increases. By considering these clinical markers, the cataract surgeon can estimate the hardness of the lens and therefore its suitability for phacoemulsification.

Hardness of the crystalline lens is a physical property which has not been the subject of much investigation. Lens hardness becomes clinically relevant when the patient is being considered for phacoemulsification. Phacoemulsification is now a well-established technique for the surgical treatment of softer cataracts, hard lenses being considered less suitable. As the procedure becomes more refined, advanced nuclear sclerotic and mature cataracts are being dealt with using this technique. For the surgeon it is desirable to have an idea of how hard the lens is before contemplating surgery. Therefore any clinical markers of lens hardness are useful.

Previous studies involving non-mature cataracts demonstrated a relationship between lens hardness and the

degree of nuclear sclerosis as measured by coloration.^{1,2} Age of the patient was also found to be significantly related to hardness.¹⁻⁵

A mature cataract is the type of cataract in which all of the cortical fibres have become opaque. Although the nucleus in these lenses can not be directly visualised, the nuclear colour is usually transmitted through the white cortex. This transmitted brunescence may be an indicator of the degree of nuclear sclerosis and therefore hardness.

The rate of progression of a cataract is a reflection of the underlying pathology. In cases where there is a long history of visual impairment caused by the cataract, it is likely that the mature cataract is the natural progression of senile nuclear sclerosis and is therefore hard. Conversely, when the mature cataract develops over a short period of time significant pre-existing nuclear sclerosis is less likely and the lens would probably be soft.

This study examines the relationship between the hardness of a mature cataract and the nuclear colour transmitted through the opaque cortex, age and the rate of development of the cataract.

SUBJECTS AND METHODS

Following dilatation of the pupil, 38 patients with mature cataracts underwent slit lamp biomicroscopy pre-operatively. A simple clinical classification using reference photographs was employed in order to grade the nuclear colour that was transmitted through the cortex. The colour was graded from 1 to 4, with 1 being a slight hint of yellow and 4 being brown colour. The age of the patient was also recorded. In order to assess the rate of development of the cataract, patients were asked to categorise the duration of visual symptoms attributable to cataract as (1) less than 2.5 years, (2) between 2.5 and 5 years or (3) over 5 years. Though susceptible to subjective error, this was considered to be the most appropriate estimate of speed of cataract formation in a clinical situation.

An automated lens guillotine was used for assessing lens hardness.^{1,2} This machine incorporated a cutting system that exerted increasing force upon the lens. The system was activated by a switch that started a digital timer. Following extracapsular cataract surgery the

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Fig. 1. Lens hardness in relation to the transmitted nuclear colour.

Table I. The transmitted nuclear colour, lens hardness (force) and age

Colour	Force (N)		Age (yr)		Frequency
	Mean	SD	Mean	SD	
1	0.47	(0.26)	49	(12.9)	6
2	1.06	(0.38)	72.2	(6.9)	15
3	1.53	(0.57)	79.1	(7.4)	10
4	1.89	(0.50)	81.3	(8.6)	7

Table III. Duration and lens hardness

Duration (yr)	Force (N)		Frequency
	Mean	SD	
<2.5	1.15	(0.55)	18
2.5–5	2.05	(0.19)	4
≥5	2.21		2

expressed lens was placed on a bevelled block beneath the cutting blade. The time taken to bisect the lens was measured and the maximum force calculated. This force is taken to represent the hardness.

RESULTS

A total of 38 lenses were investigated. The mean age of the patients was 72.0 years (range 29–93 years) with 5 patients younger than 60 years age. In the young patient group diabetes was present in 4 patients.

Colour

The mean force required to bisect the lens was 0.47 Newtons (N) for grade 1 and 1.06 N for grade 2; it increased to 1.89 N for grade 4. The mean age for each colour group also increased with coloration (Table I, Fig. 1).

Age

With advancing age the lens became progressively harder. For the age group younger than 60 years the mean force was 0.41 N whereas for those over 90 years it was 1.94 N, a fourfold increase (Table II, Fig. 2).

Duration

There is a tendency for increased hardness as duration of

Fig. 2. Lens hardness and age.

Table II. Age and lens hardness

Age (yr)	Force (N)		Frequency
	Mean	SD	
≤60	0.41	(0.25)	5
61–70	1.06	(0.50)	12
71–80	1.23	(0.39)	9
81–90	1.37	(0.49)	9
≥90	1.94	(–)	1

symptoms becomes longer. In the first group the mean force was 1.15 N, which increased to 1.55 N and 1.80 N respectively for groups 2 and 3 (Table III).

Statistical Analysis

Multivariate analysis of data indicates that both colour and age are important variables affecting hardness. The following linear model relating force to colour and age was proposed:

$$\text{Force} = \alpha + (\beta_1 \times \text{Colour}) + (\beta_2 \times \text{Age})$$

where $\alpha = 0.724$ (SE = 0.382), $\beta_1 = +0.305$ (SE = 0.096, $p < 0.03$) and $\beta_2 = +0.017$ (SE = 0.007, $p < 0.02$). The model has an adjusted R^2 value of 0.59, which implies that 59% of the variation of force can be explained by linear variation with colour and age.

Statistical analysis of the variable duration is not possible due to missing data. However, the recorded data do demonstrate a tendency for hardening of the lens as the duration of symptoms increases.

DISCUSSION

When the cortex becomes totally opaque up to the capsule, the cataract is said to be mature. This often follows an intumescent stage when increased inhibition due to the impairment of the capsule and lens fibres cause swelling of the lens. The swelling and the associated biochemical changes lead to the opacification of the cortical fibres. Once the cataract becomes mature, much of the water imbibed during the intumescent stage is lost and the lens returns to its normal size before shrinking further as a

result of loss of water and proteins. This study identifies three factors that indicate hardness of a mature cataract: nuclear colour, age and duration of symptoms.

Nuclear Colour

The lens fibre is normally made up of soluble α -, β -, and γ -crystallins. The crystallins have a slow turnover and are therefore susceptible to various changes due to oxidation, glycation, deamidation and proteolysis. The changes lead to the formation of high-molecular-weight proteins created by the aggregation of crystallins. During this process new cross-linkage of polypeptides involving disulphide bonds occurs. In addition, pigmentation occurs, indicating that modification of proteins involves amino acid residues that lead to colour products.⁶⁻⁸ These changes are closely associated with the progression of nuclear sclerosis. It is possible that the underlying biochemical and structural changes responsible for the development of nuclear coloration also confer hardness upon the lens. This study demonstrates that as far as lens hardness is concerned the colour that is transmitted through the opaque cortex is an accurate representation of the nuclear colour and therefore of the degree of nuclear sclerosis and hardness.

Age

The lens is constantly developing new fibres throughout life, the older fibres being compressed into the centre of the lens forming the adult nucleus. With advancing age this region undergoes increased compression and sclerosis. It is logical that this compaction of nuclear fibres together with the increased ratio of aggregated insoluble proteins is associated with lens hardening. A number of studies have demonstrated hardening of the lens with advancing age¹⁻⁵.

Duration of Symptoms

Different pathophysiological processes may be involved

in the development of mature cataracts. Some are senile in origin representing ageing changes and an advanced stage of cataract formation. This group has significant nuclear sclerosis and a long history of visual symptoms and therefore a hard lens. On the other hand, younger patients, particularly those with diabetes, may develop a mature cataract within a short period. These often have a short history of visual symptoms and little nuclear sclerosis relative to the degree of visual loss, and hence the lens tends to be soft.

In summary, by considering the transmitted nuclear colour, age of the patient and the rate of development of a mature cataract it is possible to estimate the hardness of its nucleus and thus its suitability for phacoemulsification.

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Key words: Age, Duration of cataract, Lens hardness, Mature cataract, Nuclear colour.

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