Study of Cataract in Relation to Axial Length and Refractivity of the Eye

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Aim: *To ascertain the association between different types and densities of age-related cataract with axial length and refractive state of the eye.*
Methods: *This prospective observational institute-based study enrolled 462 eyes of 450 patients aged 40 years or older. Eyes were classified as myopic (axial length, >25 mm), emmetropic (axial length, 21-25 mm), and hypermetropic (axial length, <21 mm). Refractive error was defined as myopia (spherical equivalent, <-0.5 D) and hypermetropia (spherical equivalent, >+0.5 D). Cataract was categorised as nuclear, cortical, or posterior subcapsular. Nuclear density was measured based on the Emery and Little Classification after slit-lamp biomicroscopy. Student* t *test for unpaired samples and Fisher and Yates tables were used to analyse statistical significance.*
Results: *Emmetropia was the most common condition (417 eyes). The most common cataract combination was nuclear with posterior subcapsular (n = 198; 44%). In the axial myopia group, nuclear cataract was the commonest type, alone or in combination with other types (n = 33; 100%). Most eyes had refractive error of 0 to -5 D. The grade of nuclear cataract increased with increasing age (n = 48 for grade IV nuclear cataract in the 70 to 79 years age group). In all age groups, a higher grade of nuclear sclerosis was significantly associated with axial length (*$t = 2.2$*;* $p < 0.05$*). The relationship was also significant for posterior subcapsular cataract (*$t = 2.7$*;* $p < 0.05$*).*
Conclusions: *Nuclear cataract leads to a myopic shift in refraction. In otherwise healthy eyes, there is a gradual hypermetropic shift. The prevalence and grade of nuclear cataract increases with age. Longer axial length is associated with a higher grade of nuclear and posterior subcapsular cataract.*

Key words: *Axial length, eye, Cataract, Myopia, Refraction, ocular, Ultrasonography*

Asian J Ophthalmol. 2011;12:130-4.

Introduction

There are many risk factors for the development of cataract. High myopia is one such factor that may lead to cataract.[1] However, several studies have resulted in contradictory conclusions about whether a lesser degree of myopia also predisposes to cataractogenesis.[1-5] A study by Perkins found an association for nuclear cataract and myopia.[4]

The refractive power of the eye is determined by the cornea, lens, and axial length. Ametropia may be defined by curvature and or axial length measurements. Some studies in the literature have defined myopia in terms of refractive error.[1,4] It is difficult to discern whether refractive myopia is a risk factor for cataract or whether cataract (nuclear sclerosis) causes refractive myopia in the early stages. Therefore, several studies were conducted that defined myopia in terms of axial length only.[5-8] Various mechanisms of cataractogenesis in myopic eyes have been proposed, but none has been proven. Zonular stress has been found to be increased in myopic eyes,[1,9] and there is more lipid peroxidation by the retina in myopic eyes with cataract than in age-related cataract.[10] It has also been hypothesised that decreased diffusion of metabolites or nutrients to the back of the lens as an effect of longer vitreous cavity may inhibit the oxidative defence mechanism, thereby promoting cataract formation.[3,10,11] Given that virtually no published data are available that address the relationship between axial length and refraction with type of cataract, this study was performed to establish this relationship. An observational institute-based longitudinal study was designed to investigate the prevalence of different types and densities of cataract in relation

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to axial length and spherical equivalent. Ametropia was defined in terms of axial length as well as refractive error. In addition, an association between axial and refractive myopia and type and density of cataract is reported.

Methods

The study was conducted in a tertiary care teaching hospital between February 2008 and November 2009. The study was approved by the institutional ethics committee and was performed according to the principles of the Declaration of Helsinki. Patients aged 40 years or older with unilateral or bilateral primary cataract were included in the study. Exclusion criteria were secondary cataract, use of systemic or topical steroids for >3 months, history of intraocular surgery or trauma, increased intraocular pressure, uveitis, pseudoexfoliation, diabetes mellitus, and previous LASIK, photorefractive keratectomy, prophylactic laser photocoagulation or cryotherapy. Informed consent was taken from all patients.

Eye examination included detailed torch light examination of the patients' eyes, cycloplegic refraction and retinoscopy, slit-lamp biomicroscopy, indirect ophthalmoscopy, and A-scan ultrasonography. Axial length measurement was obtained before dilatation of the pupil. A trained observer recorded the observations and measurements for each eye.

Ocular dimensions, including axial length, were measured by A-scan ultrasonography (Sonomed, New Hyde Park, USA) with high-frequency (10 MHz) and low-energy ultrasonic pulses emitted by the probe. A scan probe tip was applied perpendicular to the cornea. Axial length was determined by the average of 5 acceptable values generated for each eye. The study defined hypermetropia as axial length <21 mm, emmetropia as axial length 21 to 25 mm and myopia as axial length >25 mm. Cycloplegic refraction and retinoscopy were performed after dilatation of the pupil with 1% tropicamide and 2.5% phenylephrine hydrochloride eye drops. A single observer examined the patients to avoid bias and to maintain reliability and consistency. Spherical equivalent was calculated by adding the spherical component of refraction to half of the cylindrical component. Slit-lamp examination (Takagi Model 1208; Takagi, Tokyo, Japan). was done to classify the type of cataract. The type and severity of nuclear sclerosis was measured according to the Emery and Little Classification.[12] The rating scheme for nuclear density was based primarily on the consistency and colour of the nucleus: grade 1, soft; grade 2, semisoft (white, yellowish white, or yellowish green); grade 3, medium (yellow); grade 4, hard nuclei (amber); and grade 5, rock hard (black or brunescent).

The correlations between the age of patients, axial length of the eyeball, and spherical equivalent were analysed by Student *t* test for unpaired samples. The probability of occurrence of nuclear sclerosis and posterior subcapsular cataract associated with axial length and spherical equivalent were tested by Fisher and Yates probability tables. Analysis of the prevalence of different types of cataract according to axial length in patients with myopia only was also done. Thereafter, analysis of the density of nuclear cataract based on axial length was done.

Results

There were 252 women and 198 men (female-male ratio, 1.3:1), with a mean age of 67.8 years (SD, 9.5 years; range 40 to 92 years). The highest number of patients were in the age group 70 to 79 years (40.6%).

The most common type of cataract was nuclear with posterior subcapsular (n = 198) [Table 1], and the least common type was posterior subcapsular alone (n = 3); there were no cortical only cataracts. The most common type of cataract in myopic eyes (n = 33) was nuclear, alone or in combination (nuclear [n = 12], nuclear with posterior subcapsular [n = 12], and nuclear with posterior subcapsular with cortical [n = 9]). The most common age group with axial myopia was 60 to 69 years (n = 15). The prevalence of different grades of nuclear cataract in the different age groups shows a higher grade of nuclear cataract (grade IV) in

Table 1. Prevalence of different types of cataracts in hypermetropic, emmetropic, and myopic eyes by age.

Type of cataract	Age (years)														
	40-49 (n = 12)			50-59 (n = 81)			60-69 (n = 141)			70-79 (n = 192)			>80 (n = 36)		
	H	E	M	H	E	M	H	E	M	H	E	M	H	E	M
Cortical															
Nuclear					24	3	3	36	3	3	48	6		3	
Posterior subcapsular											3				
Cortical with nuclear					6			6							
Nuclear with posterior subcapsular		6			24	3		51	9		84			21	
Cortical with posterior subcapsular		6			3										
Cortical with nuclear with posterior subcapsular					18			30	3	3	45			6	6

Abbreviations: H = hypermetropia (<21 mm); E = emmetropia (21-25 mm); M = myopia (>25 mm).

Table 2. Grading of nuclear sclerosis and axial length or spherical equivalent at the time of cataract surgery.

Grading of nuclear sclerosis*	Axial length (mm) Mean (SD)	Spherical equivalent (D) Mean (SD)
≤2	23.1 (2.1)	-1.45 (1.38)
3-5	23.9 (1.5)	-1.99 (1.44)
t Value	2.2	2.0
p Value	<0.05	<0.05

* Emery-Little Classification.

the 70 to 79 years age group (n = 48). The relationship between high grade of nuclear cataract and increasing age was statistically significant ($t = 4.9$; $p < 0.001$).

Only grade 4 nuclear sclerosis was seen in the 80 to 89 years age group (n = 36). In all age groups, a higher grade of nuclear sclerosis was significantly associated with axial length ($t = 2.2$; $p < 0.05$) and posterior subcapsular cataract was significantly associated with axial length ($t = 2.7$; $p < 0.05$). The relationship between spherical equivalent and nuclear sclerosis (grades 3 to 5) was significant ($t = 2$; $p < 0.05$) [Table 2]. Most patients had refractive error between 0 and - 5 D.

The higher grade of nuclear cataract was associated with negative spherical equivalent ($t = 2$; $p < 0.05$). A positive correlation was found between spherical equivalent and axial length ($r = +0.35$), spherical equivalent and cortical cataract ($r = +0.04$), axial length and nuclear sclerosis ($r = +0.04$), and age and nuclear sclerosis ($r = +0.29$). A negative correlation was found between spherical equivalent and nuclear cataract ($r = -0.18$) and age and spherical equivalent ($r = -0.07$).

Discussion

This study aimed to determine the types of cataract in a defined population. The results highlight the effect of type of cataract on refractive error, as found by Weale[1], Brown and Hill,[2] Panchapakesan et al,[13] Wong et al,[14] and Samarawickrama et al.[15] These studies found that nuclear cataract leads to myopic shift in refraction.

Dandona et al studied 2522 patients of all ages to assess the prevalence, distribution, and demographic associations of refractive error in an urban population in South India.[16] Cycloplegic refraction was done for patients younger than 15 years and non-cycloplegic refraction was done for those older than 15 years, and cataract was classified according to the Lens Opacification Classification System III. Myopia was significantly higher in patients with cataract grade >3.5. Nuclear cataract is thought to cause myopic shift in refraction, and this study found myopic shift in refraction in patients with nuclear sclerosis grades 3 and 4 ($p < 0.05$).

Wensor et al conducted a population-based study (the Visual Impairment Project) of the prevalence and risk factors of myopia in Victoria, Australia, involving 4744 patients.[17] Myopia was defined at 2 levels as worse than -0.5 D and worse than -1.0 D. The prevalence of myopia was significantly related to the level of nuclear opacity, and the level of myopia was significantly higher in people with nuclear opacity >3.0. This study supports the finding that myopic shift occurs with a higher grade of nuclear sclerosis.

The Baltimore Eye Survey found an increase in the prevalence of myopia with age in the black subgroup analysis, with older age showing a positive correlation with nuclear sclerosis ($r = +0.29$; $t = 3.7$) and a negative correlation with spherical equivalent ($r = -0.07$; $t = 0.86$).[18] In this study, spherical equivalent showed a negative correlation with nuclear sclerosis ($r = -0.18$; $t = 2.2$). Thus, a higher grade of nuclear sclerosis seems to be associated with a more negative spherical equivalent. A negative correlation was found between spherical equivalent and nuclear cataract ($r = -0.09$; $t = 1.1$), which directly coincides with the findings of Katz et al. A positive correlation was found between spherical equivalent and cortical cataract ($r = +0.04$; $t = 0.48$), suggesting that cortical cataract shows a hypermetropic change in refractive error.

O'Donnell and Maumenee first described nuclear sclerosis as a cause of visual loss in patients with axial myopia.[19] Praveen et al compared the prevalence of different types and densities of age-related cataract in 800 healthy eyes of Indian people with high myopia (axial length >25 mm) and emmetropia, and concluded that nuclear cataract was strongly associated with high axial myopia ($p < 0.001$).[7] No association was observed between posterior subcapsular or cortical cataract and axial myopia. Posterior subcapsular and mixed cataract were encountered frequently in patients with emmetropia ($p < 0.001$). Perkins conducted a retrospective analysis of 388 patients undergoing cataract surgery, and examined type of cataract in relation to curvatural myopia (better than -1.0 D).[4] However, there was no significant difference in the distribution of the types of cataract between patients with and without myopia. In this study, in the highly myopic eyes, cataract usually presented as posterior subcapsular changes, but the difference was not statistically significant. Axial myopia was significantly associated with nuclear sclerosis and posterior subcapsular cataract ($p < 0.05$). The Blue Mountains Eye study found that long-standing myopia is an independent risk factor for age-related cataract, particularly posterior subcapsular cataract and the cortical and late nuclear types.[20] Wu et al found an association for nuclear cataract and myopia in a population-based study of black adults in Barbados.[21]

The Tanjong Pagar survey conducted by Wong et al showed that greater degrees of nuclear opalescence drive refraction in a minus direction.[22] The relationship of spherical equivalent with age was non-linear. Nuclear cataract was associated with axial myopia ($p < 0.001$), but without any specific biometric component. The study by Kubo et al found a similar result, and concluded that a more negative spherical equivalent is associated with a higher grade of nuclear sclerosis.[23]

A limitation of this study is that as the patients enrolled were attending for surgery, there is potential for bias, and the results should be interpreted carefully. Additionally, a meaningful analysis of cortical, posterior subcapsular, and cortical with posterior subcapsular cataract was not possible because the numbers in each group were too small. The strengths of the study are that the type of cataract is determined in a defined population, along with the effect of cataract on refractive error and the impact of axial length on nuclear sclerosis. This information could be useful for evaluating the potency of anticataract drugs and for longitudinal studies of cataract.

Belkin et al suggested that myopic patients have delayed nuclear sclerosis due to the ultraviolet protection afforded by spectacles.[24] The fact that patients with greater degrees of myopia do not seem to develop lens opacities earlier than patients with lesser degrees of myopia is counterintuitive to the mechanical 'ciliary stress' theory proposed by Fisher.[9] The study investigated lens fibre stress to show that the latently accommodated lens of a hypermetropic eye would be relaxed, whereas in the myopic eye, the lens would be stressed by a continually unrelaxed zonule.

Boscia et al showed by spectrophotometric assay that there is an age-associated increase in lens protein carbonyls and decrease in sulphydryls ($p < 0.01$).[11] A report by Palmquist et al supports the theory of oxidative damage to the lens.[25] Fecondo and Augusteyn showed that decreased glutathione reductase and glutathione peroxidase activity is observed in cataractous lenses.[26] This theory is supported by the study of Spector.[27] Micelli-Ferrari et al concluded that lipid peroxidation may lead to early cataract.[10]

Nuclear cataract appears to be associated with loss of structure of the vitreous body, whether due to surgery,[28] genetics,[29] or the ageing process. The consistency across species that the lens exists in a relatively hypoxic environment supports the hypothesis that low levels of oxygen in the lens may be important to maintain lens transparency.

To conclude, nuclear cataract leads to myopic shift in refraction. In this study, nuclear and posterior subcapsular cataract had a significant relationship with axial length. Thus, type of cataract determines the refractive error of the eye. It remains uncertain whether axial length leads to a particular type of cataract or whether other causative factors leading to ametropia have a role to play.

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