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Original Research Article

Comparison of nuclear size in mature and hypermature cataract

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ABSTRACT

Introduction: Senile white cataracts are special cases in cataract surgery since they are associated with unique set of complications not seen in immature cataracts. The major drawback while operating on a white cataract is lack of nuclear details like its density or size. This study was conducted to establish nuclear size in mature and hypermature senile cataracts.
Materials and Methods: The study involved intact nucleus obtained during manual small incision cataract surgery. The cases were grouped into mature or hypermature category. The nucleus was measured directly using electronic scale on a smartphone calibrated to measure up to 10 micrometers. The thickness and diameter of nucleus were recorded. These values and ocular parameters obtained by immersion A-scan preoperatively were analyzed.
Results: The mean nuclear thickness in mature cataracts was 3.66 mm (3.17 to 4.38) and in hypermature cataracts was 3.36 mm (2.66 to 3.95). There was significant difference in nuclear thickness and lens thickness between the two groups. The nuclear diameter did not vary significantly between the two groups.
Conclusion: The nucleus in mature cataract is significantly thicker than that of hypermature cataract and occupies most of the lens volume indicating a dense nucleus. During phacoemulsification of mature cataract, it is advisable to increase the machine parameters to tackle this dense nucleus. While in case of hypermature cataract the machine parameters should be lowered as, the nucleus is thinner and less dense.

1. Introduction

The senile cataract presents in various morphological forms and progresses through immature, mature and hypermature stages. As senile immature cataract progresses, it enters into the mature and hypermature stages. The progression to maturity is always due to opacification of the cortical fibers irrespective of the grade of nuclear cataract.[1] Mature cataract is diagnosed when whole of cortex becomes opacified. Hypermature cataract is described when the cortex is liquefied. As the cortical fibers become opaque, the denatured proteins exert more osmotic pressure such that the lens becomes intumescent. These stages of cataract can develop with any grade of nuclear cataract. Progression to maturity and beyond from immature stage depends on the interaction between nuclear and cortical cataracts. The nuclear cataract can progress for considerable time before the cataract matures. Though morphological forms like cortical and subcapsular cataracts are seen along with nuclear cataract, the nuclear size is the most important form determining various surgical factors. A large dense nucleus poses more difficulty as compared to soft nucleus in any method of cataract surgery.

For white cataracts, it is impossible to ascertain the density of nuclear cataract clinically. Various indirect methods like reflected color of nucleus, B-scan or the echo pattern of A-scan during axial length measurement can be used to look at the nuclear density but are not practical for routine use. A reliable clinical method for predicting the size or density of the nucleus in white cataracts is not available till date.

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Different studies across the world estimate the prevalence of white cataract at various levels.[2,3] These advanced forms are more prevalent in the underdeveloped countries where poverty, lack of health care facility or access to health care may result in late presentation of senile cataract. The prevalence can be as low as 0.04% in developed countries and can go as high as 85% in remote areas.[3,4]

The white cataract can be removed using any of the routine techniques like extracapsular cataract extraction [ECCE], manual small incision cataract surgery [MSICS] or phacoemulsification. Both MSICS and phacoemulsification have been found to be safe and give excellent visual outcomes in white cataracts.[5,6]

However, surgery on white cataracts, especially phacoemulsification, is associated with higher complication rates as compared to same technique on immature cataract.[7,8] The most important complications are posterior capsular rent during phacoemulsification and early postoperative corneal edema due to excessive use of phacoemulsification power. Higher effective phaco time [EPT] indicates denser nucleus for the specific emulsification technique. Thus in case of white cataracts, the nuclear density is expected to be higher.

The severity of different forms of cataract can be graded objectively and reliably using the Lens Opacities Classification system (LOCS III) in immature senile cataracts.[9]

Various studies have attempted measuring physical characters of the cataractous nucleus.[8,10–13] Brazitikos et al used A-scan to look at the density of nucleus preoperatively and classify the white cataract into three types based on A-scan acoustic structure of white cataracts.[8] They could identify three types of echo structures for small nucleus, large nucleus and intumescent white cataract. Tabandeh et al in their study attempted to establish relation between the nuclear color in white cataract as seen through the opaque cortex preoperatively and the nuclear hardness measured using a guillotine postoperatively.[10] They graded the nuclear color from 1 to 4 using reference photographs for this purpose. They concluded that hardness of a mature cataract increases with the transmitted nuclear color, age and duration of visual loss.

Studies done in late 20^{th} century by Gullapalli et al, Ayaki et al and Assia et al used different methods to correlate size of nucleus with nuclear color and hardness.[11–13] They used measurement techniques like simple ruler, physical caliper, and electronic caliper to measure the nuclear size. The average nuclear diameter in these studies was 6.51 + 0.75 mm and the average thickness, 2.96 + 0.33 mm. However, till date there has been no study of the nuclear size in white cataracts by direct measurement. In this study, the nuclei taken out in MSICS done for white cataract were measured using an electronic display screen for enhanced accuracy. This study strives to establish data for average thickness and diameter of nucleus in mature and hypermature cataracts.

A smart phone (Micromax Canvas A120) was used at various steps in this study.[14] Use of smartphone makes various aspects of the measurement easy and accurate. This smartphone had touch screen, display size of 5 inches and pixel density of 294 pixels/inch, which works out to 86 microns per pixel. Thus, less than 100 microns accuracy of measurement was possible. With widespread availability of smartphones having high-density display, the pixel size has become smaller. The physical size of a display and pixel density can be used to calculate distance between two pixels on the display to micrometer accuracy. Many applications (apps) are available on Google play website for this purpose. In this study we used an app named "ON rule" version 2.0. This is a free app, and provides two pairs of lines to assess size of physical objects in both dimensions simultaneously (length and breadth).[15] In addition it provides measurement values up to 3 decimal points taking accuracy to micrometer level.

2. Materials and Methods

Ethiccal clearance was obtained from the Institutional ethics committee. This research adhered to the tenets of the Declaration of Helsinki. Removal of the nucleus by MSICS and measurement of the nuclear thickness and diameter were performed by the author. Ophthalmic technician and statistician respectively performed A-scan biometry and data analysis. Successive cases of white cataract undergoing manual cataract extraction were selected for the study. Informed consent was obtained from all individual participants included in the study. All data remained confidential.

The inclusion criteria were patients with senile white cataract opting to undergo MSICS technique, and uneventful surgery. Only cases with intact nuclei after removal were taken up for further evaluation. The study duration was for one year.

Exclusion criteria were set as presence of complications of white cataract, incomplete preoperative workup, like non-availability of slit lamp findings, poor mydriaisis, complicated cataract, chipped or broken nucleus, previous intraocular surgeries. The cases were excluded if measurement of nuclear size was not carried out within two hours of removal of nucleus.

Preoperatively, after dilating the pupil the type of white cataract was evaluated by noting following factors in slit lamp: Color of the lens, depth of the anterior chamber, bulging of anterior lens capsule into pupillary plane, presence of sunken nucleus, phacodonesis. The cataract was classified as mature or hypermature depending on the findings. Intumescent white cataract was considered as a type of mature cataract for this study. The diagnosis had to be modified during surgery in a few cases as presumptive mature cataracts turned out to have liquefied cortex as major component.

The ocular dimensions were measured using immersion biometry during preoperative intraocular lens calculation. Alcon Ocuscan RxP A-scan machine in immersion technique mode was used for this purpose. Mean of ten readings was taken and the standard deviation was kept less than 0.05 for accepting the readings. Axial length (AL), anterior chamber depth (ACD) and lens thickness (LT) were thus obtained. The central corneal thickness (CCT) was recorded using same machine by ultrasound pachymetry.

The cataract surgery was performed using phacosandwich technique for MSICS as described previously to obtain an intact nucleus [16].[@12].

In this study we used an app named " ON ruler " version 2.0 (the App) to measure the nuclear dimensions. This is a free app, and provides two pairs of lines to assess length and breadth of physical objects simultaneously in millimeters.[15] The app provides measurement values up to three decimal points taking accuracy to micrometer level. The app has to be calibrated once by comparing against a known length. A 2.2 mm keratome (Alcon labs) was used for this purpose and measurement unit of one millimeter was calibrated. This setting was used throughout the experiment. The same procedure was carried out before every measurement.

A simple method was developed to measure the dimensions of the nucleus. After wiping loose lens fibers from surface of the nucleus with gauze piece, the nucleus was rinsed and wiped once more. Measurements were carried out on this relatively dry nucleus.

Measurement of diameter: The microscope was set at 0.6x magnification with 10x ocular without switching on light. The background illumination of smartphone was set to maximum. The App was launched and four-crosshair option was selected.(Figure 1) The nucleus was placed in the center of the screen with anterior surface (flatter surface) in contact with the screen. The vertical (Y-axis) and horizontal (X-axis) pairs of lines were adjusted while observing under microscope with mono-ocular view. Right ocular was used throughout the study to maintain uniformity and to avoid parallax error. Values along x and y-axes were recorded up to three decimal points. The procedure was repeated 3 times and average was taken as final value (Figure 2). The nucleus was skewered adjacent to its center using a 26G needle on 10cc syringe holding the syringe vertically. This nucleus mounted on 26G needle was placed with its equatorial edge touching the screen so that its thickness could be measured. The measurement was taken similar to measuring diameter but only in one axis. The syringe was rotated 90^0 on its axis and thickness of nucleus was measured again. Average of these two measurements was taken as thickness of the nucleus.

2.1. Statistical analysis

The data thus obtained was entered into SPSS software (version 21.0, IBM Inc. Chicago, Illinois) for analysis. Descriptive statistics were presented as mean and standard deviations. Unpaired T-Test was used for comparison of between group variations. The level of significance was set at $P<0.05$ across all parameters.

3. Observations and Results

In this prospective observational study, eighteen mature and sixteen hypermature senile cataracts were analyzed over six months period. In the mature cataract group, the mean age was 62.17 + 10.39(range of 45 to 80 years) ; the sex ratio was equal. In the hypermature cataract group mean age was 64.7 + 13.0 years (range 45 to 87 years); 11 out of 16 patients were female (69%).

The ocular parameters for the two study groups are listed in Table 1. The mean axial length (22.95mm + 0.67 in mature and 23.04 + 0.95 mm in hypermature group), central corneal thickness (518.8 + 47 vs. 518.1 + 19) and AC depth (3.13 + 0.58 vs. 3.03 + 0.49) in both the groups were comparable. Average lens thickness in mature cataract group was 4.41mm (+ 0.55, range 3.38-5.38) while in the hypermature group it was 3.81mm (+ 0.31, range 3.12-4.33). The average lens thickness differed significantly between the two groups (p= Table 2). The average nuclear thickness was 3.66 mm (+ 0.39, range 3.17-4.38) in mature vs. 3.36 mm (+ 0.32, range 2.66- 3.95) in the hypermature group. This difference was statistically significant (p=). The average nuclear diameter in mature group was 7.55mm (+ 0.54, range 6.56-8.49) and in hypermature group was 7.36 mm (+ 0.44, range 6.35-8.07). The nuclear diameter did not differ significantly between two groups (p=). The ratio between nuclear thickness and lens thickness was similar in both groups (0.84 in mature and 0.89 in hypermature group). The thickness to diameter ratio of nucleus also was similar in both the groups (0.48 + 0.04 in mature and 0.46 + 0.04 in hypermature). Significance levels for different parameters between the two groups are listed in Table 2.

4. Discussion

The present work takes a new approach in direct measurement of the dimensions of nucleus by utilizing an electronic display. This has various advantages like easy calibration, good repeatability, ease of access, low technical knowledge required for the observer and possibility of using it under operating microscope to improve the accuracy of measurement. This also has high accuracy of up to three decimal points of a millimeter. An exhaustive search on internet did not reveal any previous studies directly measuring the nuclear size in white cataracts.

It is difficult assessing the density and size of nucleus in white cataract. Conventionally it is believed that

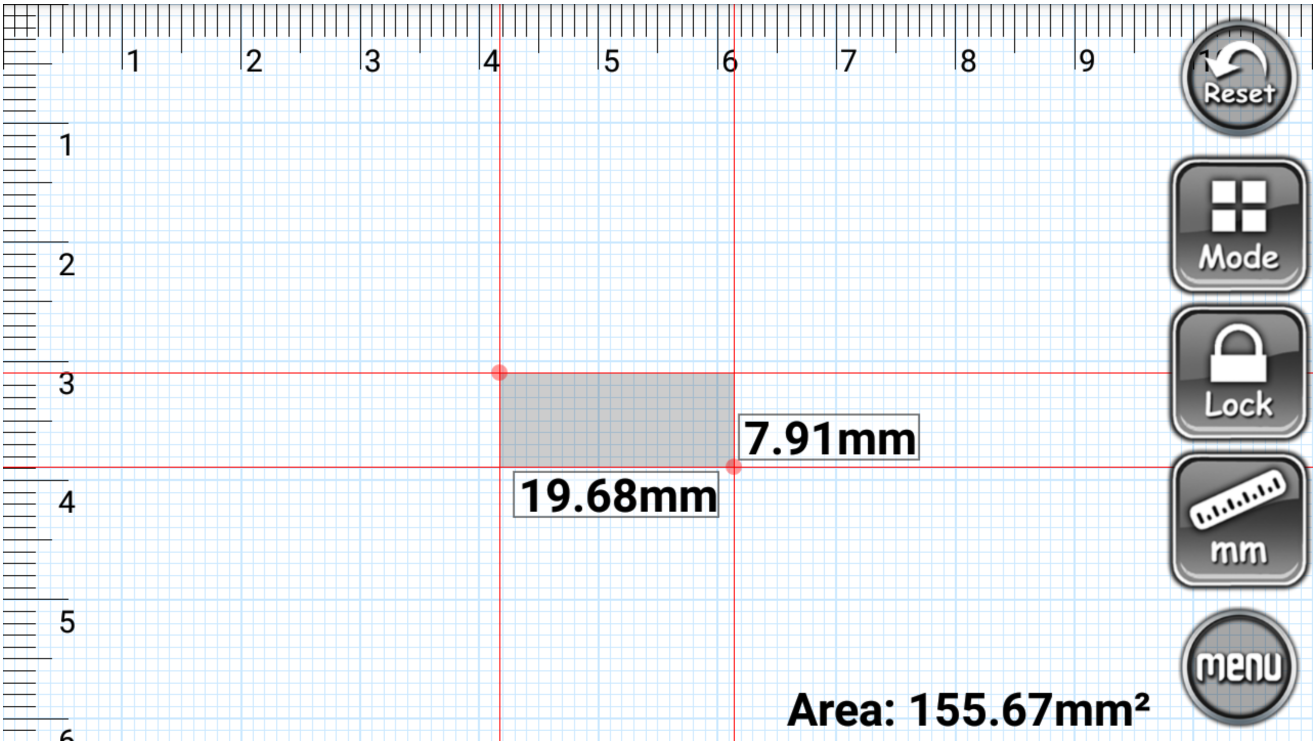

Fig. 1: “ON ruler” app screen showing cross hairs fo r measuring length and breadth simultaneously

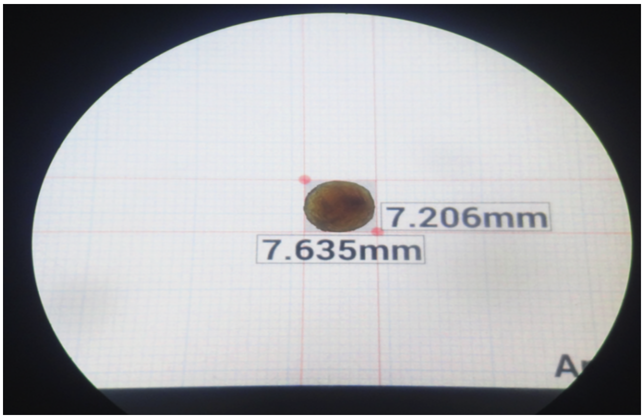

Fig. 2: Nuclear size measured through operating microscope

Table 1: Comparison of Ocular parameters between mature and hypermature group

	Mature cataract				**Hypermature cataract**			
Measurement (mm)	**Mean**	**Std. Dev**	**Min**	**Max**	**Mean**	**Std. Dev**	**Min**	**Max**
Axial length	22.96	0.67	22	24.1	23.04	0.95	22.09	25.84
CCT	518.8	46.6	452	627	518.1	18.6	482	546
AC depth	3.13	0.58	2.16	3.98	3.03	0.49	2.25	3.82
Lens_thickness	4.41	0.55	3.38	5.38	3.81	0.31	3.21	4.33
Nuclear thickness	3.66	0.39	3.17	4.38	3.36	0.32	2.66	3.95
Nuclear diameter	7.55	0.54	6.56	8.49	7.36	0.44	6.35	8.07
Nucleus/Lens thickness	0.84	0.13	0.61	1.0	0.89	0.10	0.68	1.0
Thickness/ diameter of nucleus	0.48	0.04	0.40	0.56	0.46	0.04	0.36	0.53

Table 2: Comparison between mature and hypermature groups (unpaired T-Test)

Mature vs. Hypermature cataract	p value
Age	0.54
Avg_Axial length	0.77
Lens_thickness	0.0004
Nuclear thickness	0.02
Nuclear diameter	0.29
Nuclear thickness / Lens thickness	0.26

hypermature stage follows mature stage. Cases with significant cortical component progress to hypermaturity. In the present study two factors were noticeable. The nuclear thickness was significantly more in mature than hypermature cataracts while nuclear diameter was similar. The lens thickness was significantly more in mature cataract than hypermature cataract but the nuclear to lens thickness ratio did not differ significantly between the two groups. A thick nucleus with significantly thicker lens thus could be seen in mature cataract as compared to hypermature cataract. Thicker lens and thicker nucleus in presence of similar nuclear diameter and comparable nucleus lens ratio is suggestive of the nucleus of mature cataract occupying larger volume. In hypermature cataract one can expect more of liquefied cortex than a large nucleus. These findings are in line with conventional view that cortical cataracts progress more commonly to hypermaturity than nuclear cataracts.

However, the nuclear thickness differs significantly between mature and hypermature cataracts, the nuclear diameter remain same in the two groups. Thus there seems to be increase in nuclear thickness than diameter as cataract advances to late stages.

Among the three types described by Brazitikos et al in their study, type I with liquefied cortex and type III with fibrosed shrunken capsule would fit into clinical definition of hypermature cataract.[8] Type II was described with " voluminous " nucleus and solid cortex, and would fit into definition of mature cataract. In this study though the two clinical types of mature and hypermature cataract were used. The finding of larger nuclear and lens thickness in mature cataract than hypermature cataract agrees with the findings of Brazitikos et al. They also noted higher mean phacoemulsification time and energy in type II and type III white cataracts. Thus it is logical to conclude that the larger nucleus seen in mature cataract usually is denser and can have more chances of complications in phacoemulsification. A preoperative knowledge of the nuclear thickness would be helpful to surgeon to plan proper technique and fluidics parameter to use for these difficult cases. Some cases always end up in the other group than the preoperative diagnosis. Thus it is better to prepare for phacoemulsification of mature cataracts in case of white cataracts, as mature cataract would have thicker and denser nucleus and minimal epinuclear support. It should also be noted that the nucleus in hypermature cataract can be quite thin (lowest value of 2.66 mm in present study) and emulsification parameters adjusted accordingly.

Day et al study covering 180 thousand eyes from 28 centers in the United Kingdom concluded that white cataracts are more common at extremes of age. But in our study the mean axial length in both groups was in normal range with all the eyes within 22-26 mm range. The possible reason for this disparity could be small sample size of present study and higher prevalence of white cataract in India.[2,3]

The limitations of this study include small sample size, single surgeon handling both surgery and recording of data. A larger sample size is required to create normative data for nuclear size in white cataracts.

5. Conclusions

Though it is easy to diagnose a white cataract, these cases pose special challenges during surgical removal. In case of mature cataract, the nuclear thickness can be about 3.2 mm to 4.4 mm and in hypermature cataract it is between 2.7 mm to 4 mm. The lens and nucleus in mature cataract are thicker than hypermature cataract thus indicating need to use higher machine parameters. On the other hand the lens and nucleus are thinner in hypermature cataract. This requires lower setting of parameters during phacoemulsification. As there is a thin nucleus with liquefied cortex, all intraocular manipulations should be gentle in such cases. Only definitive way to confirm the hypermature stage is at the time of capsulorhexis when liquefied cortical matter egresses form the lens.

6. Source of Funding

None.

7. Conflict of Interest

None.

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