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Evaluation of the relation between Lens Opacities Classification System III grading and nuclear size by direct measurement

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Abstract:

CONTEXT: Although relation between Lens Opacities Classification System III (LOCS III) and nuclear density is established, no data are available about nuclear size at different LOCS III grades.

AIMS: The aim of this study is to evaluate the relation between LOCS III grading of nuclear opacity obtained preoperatively and the size of the nucleus obtained during cataract surgery.

SETTINGS AND DESIGN: This was a prospective observational study carried out in a hospital attached to medical college.

MATERIALS AND METHODS: Patients who underwent manual small-incision cataract surgery or extra-large temporal tunnel cataract extraction and gave consent were included in this study. Institutional Ethics Committee clearance was taken for the study. Preoperative LOCS III grading was obtained at slit-lamp biomicroscope. Ocular dimensions were obtained by preoperative immersion biometry. The thickness and diameter of the nucleus obtained by extraction were measured up to 10 μ accuracy. Data were analyzed for the change in nuclear thickness, nuclear diameter, age, lens thickness, and anterior chamber depth in relation to the LOCS III grade of the nucleus.

STATISTICAL ANALYSIS USED: Statistical analysis used in this study was one-way ANOVA, mean, and range.

RESULTS: There was a significant increase ($P < 0.05$) in nuclear thickness, nuclear diameter, and age with increasing LOCS III grade of the nucleus. The change in nuclear size was linear between Grades 1 and 4. The nuclear size did not increase between Grades 4 and 5. It increased steeply from Grade 5 to Grade 6.9.

CONCLUSION: LOCS III grading of the nucleus can be utilized for determining the nuclear thickness and diameter preoperatively. These data can be helpful in adjusting machine parameters during phacoemulsification.

Keywords:

Cataract/classification, cataract/diagnosis, lens nucleus

Introduction

Nuclear cataract is the most common morphological form of age-related cataract worldwide.[1,2] It is also the most important category among the morphological types of senile cataract. The present-day techniques of extracapsular cataract extraction (ECCE) mainly aim at removing the nucleus with as small an incision size as possible. Conventional phacoemulsification technique attempts to remove the nucleus using ultrasound energy, whereas femto second laser-assisted cataract surgery (FLACS) does this using laser energy. Manual small-incision cataract surgery (MSICS) takes the approach of creating a sclerocorneal tunnel to reduce

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incision size. Thus, assessing the nuclear characters such as density and size preoperatively is imperative for any of these surgical techniques.

The Lens Opacities Classification System III (LOCS III) was introduced in 1993 as a subjective grading system for cataract using slit lamp, with accuracy comparable to objective methods.[3] It established a better grading system for age-related cataract as compared to LOCS II. It is strongly consistent between users and during follow-up comparison. It is common to use nuclear opacity (NO) for grading nuclear cataract in routine clinical practice. The NO is graded from 0.1 to 6.9 from clear lens to very opaque or brunescent nuclear cataract.[3]

For objective grading of lenticular opacities, three methods have been used: Scheimpflug imaging, anterior segment optical coherence tomography, and spectral fundus reflectometry (SFR).[4-7] All three methods estimate the nuclear density using imaging of the lens directly. They grade the density of the lenticular opacity based on pixel intensity in the image. These objective methods can estimate the thickness of lens, but for estimating nuclear thickness, an observer has to define the nuclear dimensions, introducing subjective variation. These are also limited by the area available for imaging and thus may not allow estimation of the nuclear diameter. Thus, the best possible way of estimating both thickness and diameter of the nucleus would be measuring them in the intact nucleus removed during cataract surgery.

Gullapalli *et al*. compared the color of the nucleus with its hardness and size in nuclei removed during conventional ECCE. They demonstrated that darker nuclei are larger and harder than light-colored nuclei.[8]

Ayaki *et al*. studied the thickness and diameter of the nucleus extracted by conventional ECCE. They found that the mean nuclear diameter was 6.51 ± 0.75 mm and the mean thickness was 2.96 ± 0.33 mm.[9]

Smith *et al*. in a small set of patients studied compression characters of nuclei extracted by ECCE (n = 16) and observed that there was a significant inverse correlation between NO and anteroposterior linear compressibility of the nucleus. They concluded that the LOCS III grade correlates well with hardness of the nucleus.[10] This confirms similar observations by other studies conducted previously.[11-14]

In conventional phacoemulsification, almost all the energy delivered during the procedure is spent on emulsification of the nucleus. Increase in grade of nuclear cataract is associated with excessive use of energy for emulsification of the nucleus and hence more complications.[15-17] Although advanced technique such as direct chop reduces the need for energy as compared to divide and conquer, the energy utilization increases exponentially with increased LOCS III grade of the nucleus.

FLACS introduced less than a decade back allows for precision in size and shape in steps such as corneal incision, capsulorhexis, and side port.[18] This system tackles nuclear cataract by creating a grid pattern of laser spots applied from posterior to anterior part of the nucleus to separate the lenticular fibers and facilitate emulsification by ultrasound. This technique can be used for the nucleus from Grade 1 to Grade 5 of LOCS III classification. Again similar to conventional phacoemulsification, the overall energy used increases with increasing LOCS III grade of the nucleus.[17,19]

Our study was planned to evaluate whether nuclear thickness and diameter increase significantly with LOCS III grades of nuclear opacity. In the present study, the measurement technique for nuclear size was the same for both thickness and diameter.

An android smartphone (Micromax Canvas A120) was used at various steps in this study.[20] This smartphone had touchscreen, display size of 5 inches, and pixel density of 294 pixels/inch which works out to 86 μ per pixel. Thus, <100 μ accuracy of measurement was possible. The physical size of a display and pixel density can be used to calculate the 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 Ruler" version 2.0. This is a free app and provides two pairs of crosshairs to assess the size of objects in both dimensions (length and breadth) simultaneously.[21] In addition, it provides measurement values up to three decimal points taking accuracy to micrometer level.

Materials and Methods

Ethics approval for this research was obtained from the Institutional Ethics Committee (Institutional Ethics Committee, Kasturba Hospital, Manipal. Approval No: IEC 396/2016 Approval Date: 15/01/2016). This research adhered to the tenets of the Declaration of Helsinki. One hundred successive patients with immature senile cataract giving consent for manual cataract extraction were selected for the study. All data remained confidential.

The inclusion criteria were senile cataract undergoing MSICS or extra-large temporal tunnel cataract extraction (ETCE) technique and uneventful surgery. ETCE as described by the authors facilitates safe removal of very large nucleus intact.[22] This technique was used when the NO grade was 5 or more since we assumed that removal of denser nucleus intact requires larger tunnel size. Cases with intact nuclei after removal were taken up for further evaluation.

Exclusion criteria were set as nonavailability of LOCS III grading or biometry values, poor mydriasis, complicated cataract, chipped or broken nucleus, previous intraocular surgeries, and incomplete hydrodelineation, if measurement of nuclear size was not carried out within 2 h of removal of the nucleus.

The nuclear opacity in immature cataracts was assessed as described in the original article by comparing slit lamp finding to the standard image.[3] For this study, the grading was rounded off to the nearest integer. For example, if NO was found to be 2.2, it was graded as NO2, whereas if it was 2.5 or more, it was graded NO3 and so on. Grades from 6.5 to 6.9 were kept as a separate category of 6.9. Thus, from Grade 1 to Grade 6.9, we had seven groups of nuclear densities.

The ocular dimensions were measured as per standard protocol using immersion biometry during preoperative intraocular lens calculation. OcuScan RxP immersion A-scan machine (Alcon Laboratories, USA) was used for this purpose. Axial length, anterior chamber depth, and lens thickness (LT) were thus obtained. The central corneal thickness was recorded using the same machine by pachymetry.

Nuclear dimensions

The app "ON Ruler" provides two pairs of lines to assess the length and breadth of physical objects simultaneously up to three decimal points of a millimeter taking accuracy to micrometer level [Figure 1].

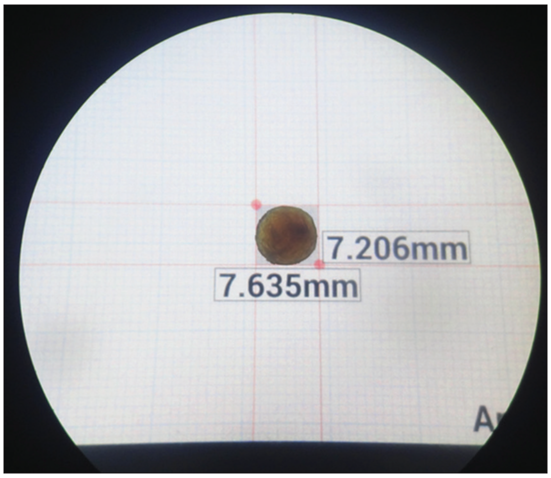

Figure 1: Operating microscope ocular at × 6, view of "ON Ruler" screen with double crosshairs adjusted to nuclear diameter

The app has to be calibrated once by comparing against a known length. A 2.2 mm wide keratome (Alcon Labs) was used for this purpose, and measurement unit of 1 mm was calibrated. This setting was used throughout the experiment. All the surgeries were performed, and measurements were carried out by the first author. The measurements were recorded within 2 h of removal of the nucleus as has been advised by Smith *et al*. in a previous study.[10] The nucleus was rinsed and loose lens fibers were wiped from its surface using a gauze piece. The relatively dry nucleus was used for measuring diameter and thickness.

Measurement of diameter

The microscope was set at ×0.6 magnification with ×10 ocular without switching on illumination light. The background illumination of smartphone was set to maximum. The App was launched and four crosshair options were selected. The nucleus was placed in the center of the screen with anterior 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. The 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 three times and average was taken as the final value.

Measurement of thickness

The nucleus was pierced adjacent to its center using a 26G needle on 10cc syringe perpendicular to the surface. 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. The syringe was rotated 90° on its axis, and the thickness of the nucleus was measured again. Average of these two measurements was taken as the thickness of the nucleus. Repeatability of this method was confirmed in a small set of patients before starting this study.

Statistical analysis

Statistical analysis was performed using SPSS software (version 21.0, IBM Inc. Chicago, Illinois, USA). The normality of data was tested using histogram method and Kolmogorov–Smirnov Test. Descriptive statistics were presented as range, mean, and standard deviations. For comparison of between-group variations, one-way ANOVA was used. The level of significance was set at $P < 0.05$ across all parameters.

Results

The study enrolled 100 eyes from 100 consecutive patients undergoing MSICS or ETCE over a 9-month period. Table 1 summarizes the study population characteristics.

Mean age of the patients was 65.6 ± 10.2 years. The mean LOCS III grade of the groups was 4.4 ± 1.4, confirming that most of the patients had a denser nuclear cataract. Mean LT was 4.2 mm, with a range of 3.2–5.6. The mean nuclear thickness in this study group was 3.31 mm (range: 2.57–4.20). The mean nuclear diameter in this study group was 7.29 mm (range: 5.15–9.48).

The outcomes of one-way ANOVA test for different study parameters at various grades of LOCS III are summarized in Table 2.

Nuclear thickness at various grades of LOCS III showed highly significant ($P < 0.001$) difference between the LOCS III grades from Grade 1 to Grade 6.9 [Figure 2a]. There was highly significant ($P < 0.001$) difference in nuclear diameter between the LOCS III grades [Figure 2b]. Similarly, test for age in different grades of LOCS III indicated that there were significantly older patients ($P < 0.001$) as the nuclear grade increased [Figure 2c]. There was a significant change in nuclear thickness-to-LT ratio between the LOCS III grades ($P = 0.025$). However, the variation in LT and AC depth between LOCS III grades was not significant ($P = 0.2$ and $P = 0.7$, respectively).

The average nuclear thickness and diameter at various LOCS III grades are recorded in Table 3. The thickness ranges from 2.7 to 3.9, whereas the diameter range was from 5.98 to 8.2 mm.

Discussion

These findings reaffirm the fact that with advancing age, the nuclear cataract progresses. As both diameter and thickness increase with LOCS III grade, nuclear size (volume) increases as LOCS III grade increases. When the mean nuclear thickness was compared between groups, there was a progressive increase in thickness from Grade 1 to Grade 4 [Figure 2a]. The thickness reduced between Grades 4 and 5, whereas it increased steeply from Grade 5 to 6.9. The mean nuclear diameter likewise reduced between Grades 4 and 5 [Figure 2b]. This indicates that there is a period in progression of nuclear cataract after Grade 4 during which its density increases without an appreciable increase in its size. A similar comparison of means for age at different LOCS III grades shows increasing age with LOCS III grade [Figure 2c]. Nucleus/LT ratios increased linearly with LOCS III grade except at Grade 5, indicating

Table 1: Demographic and ocular profile of the study group

Parameter	Range	Mean±SD
Male:female ratio	46:54	
Age (years)	40-90	65.6±10.2
LOCS III grade	1-6.9	4.4±1.4
AC depth (mm)	2.34-4.02	3.3±0.4
Lens thickness (mm)	3.18-5.58	4.2±0.5
Nuclear thickness (mm)	2.57-4.2	3.3±0.4
Nuclear diameter (mm)	5.15-9.48	7.3±0.6
Nuclear/lens thickness (%)	55-100	79±10

LOCS III=Lens Opacities Classification System III, AC=Anterior chamber, SD=Standard deviation

Table 2: Correlation between Lens Opacities Classification System III and different parameters

Parameter	*F*	*P*
Age	7.064	<0.001
Lens thickness	1.423	0.214
Nuclear thickness	6.766	<0.001
Nuclear diameter	6.875	<0.001
AC depth	0.636	0.701
Nuclear/lens thickness (%)	2.538	0.025

AC=Anterior chamber

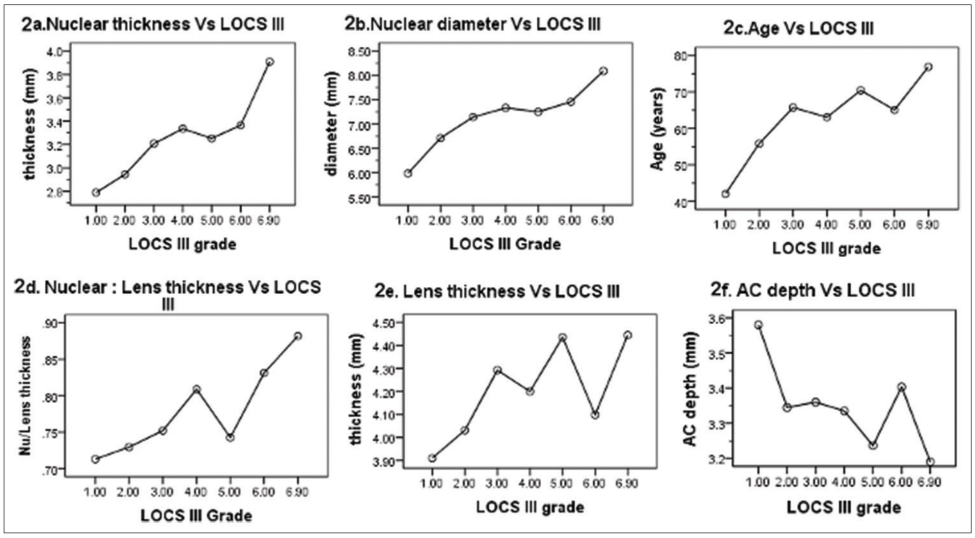

Figure 2: Study variables at different grades of Lens Opacities Classification System III

Table 3: Nuclear thickness and diameter at different Lens Opacities Classification System III grades

LOCS III	Nuclear thickness (mm)		Nuclear diameter (mm)	
	Range	Mean	Range	Mean
1	2.74-2.83	2.79	5.15-6.82	5.98
2	2.65-3.5	2.94	5.4-7.29	6.71
3	2.57-3.52	3.21	3.39-7.94	7.21
4	2.75-4.0	3.34	4.92-8.06	7.06
5	2.66-3.95	3.25	6.865-7.85	7.27
6	2.75-4.12	3.36	7.205-8.13	7.72
6.9	3.69-4.2	3.9	7.51-9.48	8.20

LOCS III=Lens Opacities Classification System III

that there is an enlargement of lens out of proportion to the nucleus in such cataracts [Figure 2d]. Both LT and AC depth did not show a significant association with the nuclear grade [Figure 2e and f].

In a recent study, Makhotkina *et al*. evaluated the relationship between subjective and objective measurements of lens density and the energy of phacoemulsification. In this study, they found that LOCS III grading of the nucleus was a better predictor for the use of phacoemulsification energy than objective methods such as Scheimpflug imaging, anterior segment optical coherence tomography, and SFR.[23] The phacoemulsification energy depends on the density and size of the nucleus. By predicting nuclear density, thickness, and diameter, LOCS III would be an ideal tool to predict average phacoemulsification energy for the group.

The size of the nucleus is also a determinant factor for deciding type of surgical method, incision size, the amount of energy used, and the complication rates. It has been common experience to find nuclear size increasing with nuclear density. Establishing a relation between LOCS III and nuclear size by direct measurement makes it possible to consistently predict the nuclear size preoperatively. This would help the cataract surgeon take better decisions pre- and peroperatively.

The range of thickness between different NO grades in this study varies from 2.57 to 4.20 mm. We can decide the safe zone of nuclear emulsification depending on this information and LOCS III grade. In nucleus removal by various trenching techniques, depth of trenching is decided upon various indirect factors such as the visibility of glow and depth in relation to tip diameter.[24-26] Since the nuclear thickness increases in proportion to NO, estimation of NO can be used as a guide to thickness of the nucleus preoperatively. Thus, the trench depth can be decided preoperatively by knowing LOCS III grading for the case, as recorded in Table 3.

During phaco chop technique of nuclear removal, a chopper with sharp edge is used for chopping. Due to concerns of chopper damaging posterior capsule, the usual length of sharp chopper is kept at 1–1.5 mm.[27,28] However, with additional safety of 1.5 mm in case of denser cataracts, the chopper length needs not to be uniform for all grades of NO. While a Grade 3–4 nucleus can be chopped by a short chopper, even 2–2.5 mm chopper may be safe in denser NO cases without compromising safety. Longer tip designs may be helpful in harder cataracts and can make the separation of posterior nuclear fibers more convenient.

In developing countries where bulk of the cataract load exists, MSICS has become quite popular.[19,29] This surgery is fast, effective, and safe. However, for denser cataracts, the intraoperative complication rate increases while removing the nucleus.[30] The major hurdle is removing the nucleus through a smaller tunnel and may cause complications such as endothelial damage, stretching of tunnel, and bleeding from tunnel. Knowledge of nuclear diameter as indicated by LOCS III grading can guide the decision about the tunnel length and make the nuclear removal safer even in Grade 6–6.9 nuclei.

In FLACS technique of cataract removal, femtosecond-pulsed laser is applied in a grid of laser spots to create the separation of nuclear fibers to facilitate later removal with or without emulsification. The grid pattern leaves a safe margin of 500–800 μ from anterior and posterior capsules of lens to prevent damage to the capsule (the anterior/posterior capsule safety zone). As LOCS III grading is routinely done before surgery, this can guide the creation of grid by predicting the nuclear size in addition to intraoperative OCT. This safety zone can be larger in lower nuclear grades and can be reduced with progress in LOCS III grade as nuclear thickness increases. NO grade thus can be utilized for adjusting grid volume, making it more flexible so that both laser energy delivery and efficiency of the procedure can be improved for optimal performance. Further studies are necessary in this regard.

An unexpected outcome in this study was the relatively similar thickness and diameter of NO Grades 4 and 5. A study by Hamzeh *et al*. comparing LT assessment using OCT and A-scan has reported a high degree of correlation between the two techniques in all LOCS III grades of the nucleus except for Grade 5.[31] A possible explanation for this observation could be increased in the density of the nucleus without change in nuclear thickness seen in our study. Change in density and opacity of medium can affect the transmission of sound and light differently.

An important shortcoming of this study is that the surgeon was not blinded to LOCS III grading. Another shortcoming is that estimation of the nuclear size manually is prone to observer bias. A larger number of cases, finer grading of the NO, and objective estimation of nuclear size using an imaging software can be utilized to eliminate these shortcomings. Establishing a normative database for different grades of NO is possible with this technique. This will help to automate various decision-making processes by the machine itself: setting the phacoemulsification parameters, the posterior safe zone, grid pattern/size, and number of laser spots in case of FLACS being important examples.

Conclusion

Our study provides evidence based support to the hypothesis that the nuclear thickness and diameter increase with increasing LOCS III grade of nuclear cataract. This knowledge can be utilized to improve and adjust the finer aspects of various surgical techniques.

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Nil.

Conflicts of interest

The author declares that there are no conflicts of interests of this paper.

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