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

Chidanand Kulkarni

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
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. 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.

For objective grading of lenticular opacities, three methods have been used: Scheimpflug imaging, anterior segment optical coherence tomography, and spectral fundus reflectometry (SFR). 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.

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.

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. This confirms similar observations by other studies conducted previously.

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. 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. 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.

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. 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. 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. \cite{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. \cite{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].

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. \cite{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 $65.6 \pm 10.2$ years. The mean LOCS III grade of the groups was $4.4 \pm 1.4$, 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

---

*Figures 2a, 2b, 2c, 2d, 2e, 2f: Study variables at different grades of 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,
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 nucleus 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

| 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        | 2.65-3.3               | 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                  | 5.665-7.85         | 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

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.\(^{[19,29]}\) 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
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.\(^{[10,29]}\) 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.
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.

Financial support and sponsorship

Nil.

Conflicts of interest

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

References

1. Klein BE, Klein R, Lee KE. Incidence of age-related cataract over a 10-year interval: The beaver dam eye study. Ophthalmology 2002;109:2052-7.
2. Vashist P, Talwar B, Gogoi M, Maraini G, Camparini M, Ravindran RD, et al. Prevalence of cataract in an older population in India: The India study of age-related eye disease. Ophthalmology 2011;118:272-80.
3. Chylack LT Jr., Wolfe JK, Singer DM, Leske MC, Bullimore MA, Bailey IL, et al. The lens opacity classification system III. The longitudinal study of cataract study group. Arch Ophthalmol 1993;111:831-6.
4. Nixon DR. Preoperative cataract grading by Scheimpflug imaging and effect on operative fluids and phacoemulsification energy. J Cataract Refract Surg 2010;36:242-6.
5. Lim DH, Kim TH, Chung ES, Chung TY. Measurement of lens density using Scheimpflug imaging system as a screening test in the field of health examination for age-related cataract. Br J Ophthalmol 2015;99:184-91.
6. Wong AL, Leung CK, Weinreb RN, Cheng AK, Cheung CY, Lam PT, et al. Quantitative assessment of lens opacities with anterior segment optical coherence tomography. Br J Ophthalmol 2009;93:61-5.
7. van de Kraats J, Berendschot TT, Valen S, van Norren D. Fast colour of the nucleus as a marker of nuclear hardness, diameter and central thickness. Indian J Ophthalmol 1995;43:181-4.
8. Ayaki M, Ohde H, Yokoyama N. Size of the lens nucleus separated by hydrodissection. Ophthalmic Surg 1993;24:492-3.
9. Smith JM, El-Brawany M, Nassiri D, Tabandeh H, Thompson GM. The relationship between nuclear colour and opalescence on the LOCSIII scale and physical characteristics of cataract nuclei. Eye (Lond) 2002;16:543-51.
10. Heyworth J, Thompson GM, Tabandeh H, McGuigan S. The relationship between clinical classification of cataract and lens hardness. Eye (Lond) 1993;7 (Pt 6):726-30.
11. Tabandeh H, Thompson GM, Heyworth J. Lens hardness in mature cataracts. Eye (Lond) 1994;8 (Pt 4):453-5.
12. Assia EI, Medan I, Rosner M. Correlation between clinical, physical and histopathological characteristics of the cataractous lens. Graefes Arch Clin Exp Ophthalmol 1997;235:745-8.
13. Czygan G, Hartung C. On the correlation of mechanical and optical properties of cataractous eye lens nuclei. Biomed Tech (Berl) 1997;42:2-6.
14. Davison JA, Chylack LT. Clinical application of the lens opacities classification system III in the performance of phacoemulsification. J Cataract Refract Surg 2003;29:138-45.
15. Storr-Paulsen A, Norregaard JC, Ahmed S, Storr-Paulsen T, Pedersen TH. Endothelial cell damage after cataract surgery: Divide-and-conquer versus phaco-chop technique. J Cataract Refract Surg 2008;34:996-1000.
16. Abell RG, Kerr NM, Vote BJ. Toward zero effective phacoemulsification time using femtosecond laser pretreatment. Ophthalmology 2013;120:942-8.
17. Nagy Z, Takaes A, Filkorn T, Sarayba M. Initial clinical evaluation of an intraocular femtosecond laser in cataract surgery. J Refract Surg 2009;25:1053-60.
18. Khanna RC, Kaza S, Palamaner Subash Shantha G, Sangwan VS. Comparative outcomes of manual small incision cataract surgery and phacoemulsification performed by ophthalmology trainees in a tertiary eye care hospital in India: A retrospective cohort design. BMJ Open 2012;2. pii: e001035.
19. Hamzeh N, Moghimi S, Latifi G, Mohammadi M, Khatibi N. Incidence of cataract in an older population in India: The India study of age-related eye disease. BMJ Open 2012;2: pii: e001035.
20. Gsmarena. Micromax A120 Canvas 2 Colors; 2014. Available from: https://www.gsmarena.com/micromax_a120_canvas_2_colours-6363.php. [Last accessed on 2017 Oct 01].
21. PotatotreeSoft. On Ruler; 2013. Available from: https://play.google.com/store/apps/details?id=com.potatotree.onruler. [Last accessed on 2015 Jun 07].
22. Kulkarni C, Vivekananda U. Extra large temporal tunnel cataract extraction [ETCE]. J Clin Diagn Res 2014;8:VC01-4.
23. Makhotkina NY, Berendschot TT, van den Biggelaar FJ, Weik AR, Nuijts RM. Comparability of subjective and objective measurements of nuclear density in cataract patients. Acta Ophthalmol 2018;96:356-63.
24. Simnel HV. Divide and conquer nucleofractis phacoemulsification: Development and variations. J Cataract Refract Surg 1991;17:281-91.
25. Koch PS, Katzen LE. Stop and chop phacoemulsification. J Cataract Refract Surg 1994;20:566-70.
26. Kurian M, Das S, Nararani B, Nagappa S, Shetty R, Shetty BK, et al. Y sign: Clinical indicator to stop trenching and start cracking. J Cataract Refract Surg 2013;39:493-6.
27. Akahoshi T. Phaco prechop: Manual nucleofractis prior to phacoemulsification. Oper Tech Cataract Refract Surg 1998;1:69-91.
28. Chang DF, editor. Why learn chopping? In: Phaco Chop: Mastering Techniques, Optimizing Technology, and Avoiding Complications. Thorofare, NJ: Slack; 2004. p. 3-12.
29. Tabin G, Chen M, Espandar L. Cataract surgery for the developing world. Curr Opin Ophthalmol 2008;19:55-9.
30. Mezra A, Ramanathan S, Bidgood P, Horgan S. Visual outcome in cataract surgery complicated by vitreous loss in a district general hospital. Int Ophthalmol 2009;29:157-60.
31. Hamzeh N, Moghimi S, Latifi G, Mohammad M, Khatibi N, Lin SC. Lens thickness assessment: Anterior segment optical coherence tomography versus A-scan ultrasonography. Int J Ophthalmol 2015;8:1151-5.