

Intralenticular changes in eyes with mature senile cataract on modified posterior segment optical coherence tomography

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Purpose: To study the morphological changes within mature senile cataracts on modified posterior segment optical coherence tomography (OCT). **Methods:** A cross-sectional observational study recruiting patients of mature cataracts admitted for elective cataract surgery in tertiary eye care. A modified OCT imaging of the lens was done and lenticular findings were noted by a single observer. Corresponding slit-lamp biomicroscopic findings and intraoperative experiences were also noted by a second observer and respective surgeons. **Results:** Forty-four eyes of 44 patients were included. The mean age of patients was 65 ± 5.7 years. The intralenticular findings were uniform in groups of eyes, and they were characterized into three stages. First was a stage of early lamellar separation where small intralenticular clefts were noted superficially. Second was the stage of established lamellar separation where crescentic fluid clefts appeared interspersed between the lens fibers, and the depth increased as a function of severity. Both these stages did not show any distinct slit-lamp or intraoperative findings. A third stage of liquefaction identified as extensive lamellar separation with subcapsular fluid pockets. This was also reflected in slit-lamp biomicroscopy, showing the hydrated cortex with intraoperative challenges. Two cases showed peculiar changes, one of a hyperreflective subcapsular sheath and another of superficial nuclear lamellar separation. **Conclusion:** Mature cataracts may also show graded progression, which could be delineated on lenticular OCT. This could be of immense help in pre-operative planning and optimal management of these high-risk cases.

Key words: Lamellar separation, liquefaction, mature cataract, optical coherence tomography

Cataract is an age-related phenomenon and is inevitable. Cataractogenesis is characterized by alteration in the crystallin composition, relative dehydration, and compaction of lens fibers, all contributing to lenticular opacification.^[1,2] Cataracts evolve, and so were their clinical grading systems.^[3] Nevertheless, mature cataracts have hardly been emphasized, maybe due to the obscured visualization of their details. They demand urgent and skillful management, as they also carry a high risk of complications such as Argentinian flag sign, posterior capsular tear, vitreous loss, nucleus drop, etc. A detailed pre-operative workup and planning may help to circumvent these complications. A clinical assessment could be helpful,^[4] however, cross-sectional imaging may add-on more value to it.

Lens cortex liquefaction is clinically visible on the slit-lamp examination of hypermature Morgagnian cataracts. Of late, optical coherence tomography (OCT) of mature cataracts and mature brown cataracts have also revealed cavitations and fluid pockets within,^[5,6] which could be a reflection of its ongoing pathogenesis and an indication of its process towards hypermaturity. Therefore, this study was designed to observe the intralenticular changes within mature cataracts and shed light on their evolution and progression, thereby adding more

to our current understanding. We also correlate the slit-lamp biomicroscopic picture and the corresponding OCT image and propose an OCT-based staging of these probable graded intralenticular changes.

Methods

This was a cross-sectional observational study where consecutive patients presenting to our in-patient services for elective cataract surgery were screened, and those with mature senile cataract were included. Written informed consent was taken from each participant and the study adhered to the tenets of the declaration of Helsinki.

The patients underwent a detailed preoperative systemic and ocular examination, and biometric work-up as per the routine hospital protocol. During slit-lamp biomicroscopic examination, characteristics of the anterior capsule and subcapsular plane were noted by a single observer, the rest of the interior details was not visible. To note the capsular changes, diffuse and direct focal illuminations were used, and to study the subcapsular plane, a thin direct focal beam with the highest possible illumination was used.

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Table 1: Various stages of mature cataracts and their features

Stage of maturity	OCT features	Slit-lamp features
Stage of vacuolation	Small hyporeflective cavitations in the depth of the lens around 50 microns from an anterior capsule.	Solid cataract. No distinct features visible.
Stage of lamellar separation	Increase in the convexity of anterior capsule. Numerous crescentic hyporeflective spaces interspersed between the lens fibers. Progressive increase in depth of involvement as severity increased up to 1000 microns from anterior capsule	Solid cataract. No distinct features visible.
Stage of liquefaction	Further increase in convexity of anterior capsule. Subcapsular plane showed large irregular cavitations at focal areas. Cortex appearing homogeneous and pultaceous, losing its fibrillar architecture. The lamellar separation was seen up to 1500 microns. In advanced stages, a coalition of the crescentic clefts and loss of integrity of lenticular lamellae.	Subcapsular fluid pockets. Hydrated cortical matter

The patients were then seated in front of a posterior segment OCT machine (RS-3000, OCT RetinaScan Advance, Nidek Inc, California, USA) that was externally fixated with a +20D double aspheric fundus examination lens (Volk Optical Inc, Mentor, Ohio) along its viewing aperture. This modification enabled scanning of the anterior segment structures up to nearly half lens thickness.^[5] Multiline raster macular scanning mode was selected, and the lines were focused onto the phakic lens. The joystick was advanced judiciously to capture the maximum depth of the lens possible. Scans were acquired by a single observer (first author) and were further analyzed one-by-one along the five different raster meridians by two observers. Findings along the anterior capsule, subcapsular plane, anterior cortex, and anterior-most part of the nucleus if visible were noted.

Results

A total of 300 patients were screened for four months, among which 44 cases of mature cataracts were identified and included. The mean age was 65 ± 5.7 years, 19 patients were males and 25 were females. The right eye was studied in 24 patients and left eye in 20 patients. On OCT, varying levels of intralenticular changes were universally seen in all the 44 patients. The depth until which changes were seen was measured by the intrinsic caliper of the machine. These reproducible findings were then graded as per the severity of changes and depth of involvement, and the corresponding slit-lamp biomicroscopic findings were reviewed. The results are presented below.

In one set of mature cataracts, the anterior capsule and the subcapsular plane were uniform and hyper-reflective, but inside the depth of the lens, small hyporeflective clefts were noted, starting from around 50 microns from the anterior capsule. These probably represented early stages of maturity, and this we have termed as the stage of early lamellar separation (16 eyes) [Figs. 1-3]. Slit-lamp examination of these cases had shown a solid white cataract and no other appreciable features.

Further ahead, some cataracts showed a uniform anterior capsule (but more convex than those of the previous stage) but starting from the subcapsular plane, numerous crescentic hyporeflective spaces were noted along the direction of the lens fibers, possibly the enlarged fluid clefts [Fig. 4]. This we termed as the stage of established lamellar separation (8 eyes), as the lenticular fibers appeared to be separated by these clefts. These changes were identified up to 1000 microns depth from anterior capsule probably an indicator of the severity of maturity. Cases showing these OCT features also did not show any distinctive clues on slit-lamp biomicroscopy.

One more step ahead, several cataracts showed an intact, but further convex anterior capsule. The subcapsular plane

showed large irregular cavitations at focal areas, with the cortex appearing homogeneous and pultaceous, losing its fibrillar architecture. Further deeper, there was significant lamellar separation. Moving along the spectrum, few cataracts showed loss of integrity of lenticular lamellae and formation of extensive subcapsular cavities, probably due to coalition of the crescentic clefts, and therefore disruption of the lens fibers [Figs. 5 and 6]. This we call the stage of liquefaction (18 eyes), as these cataracts had exuded liquid cortex on opening the anterior capsule intraoperatively. They varied in depth up to 1500 microns from the anterior capsule as the maturity progressed. These cataracts on slit-lamp examination also showed fluid pockets and hydrated cortical matter [Table 1].

Special circumstances

Among the 44 observations, we noted 2 peculiar variants that did not fit into the above classification. In one case, there was a dense hyperechoic anterior subcapsular layer that hindered the visualization of deeper layers of the lens. Clinically, it showed a solid mature white cataract with few plaque-like foci on the capsule, further details were not perceivable [Fig. 7]. Another case showed subcapsular fluid clefts and homogenization of cortical matter, however, hyporeflective clefts were noted within the anterior part of the nucleus [Fig. 8].

Intraoperative experiences

The surgeries were performed by different surgeons. In the initial two stages, there was less intraoperative extrusion of liquefied cortical matter; however, in the third stage, it was extensive. But optimal precautions were taken by each surgeon to prevent intraoperative inadvertent complications.

Discussion

While early cataracts are pretty easy to handle, advanced cataracts are the priority, as it not only cripples the patient's quality of life but also poses a significant challenge to the treating surgeon. Intraoperative surprises can be minimized by a good preoperative workup and planning. With respect to mature cataracts, cortical liquefaction and raised intralenticular pressure have always been of concern, as they increase the tendency for capsular run-out and Argentinian flag sign.^[4,6] Ironically, clinical examination is of limited help in this scenario.

OCT, on the other hand, can penetrate through a completely opaque lens and provide a detailed cross-sectional illustration. There are very few observations in literature that elaborate on intra lenticular changes happening inside mature cataracts. In a previous observation, we incidentally identified distinct cavitations occurring within mature brown cataracts, however, the features noted were discrete.^[5] Therefore, this study was

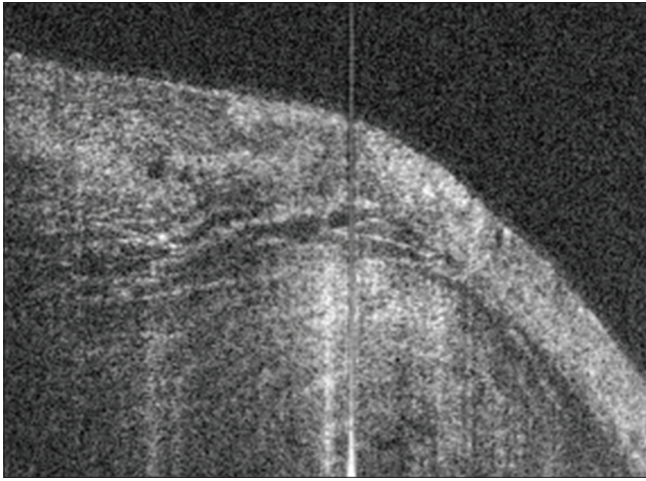


Figure 1: During the early phase of lamellar separation, OCT shows subtle horizontal biconvex empty areas around 50 microns from the anterior surface capsule

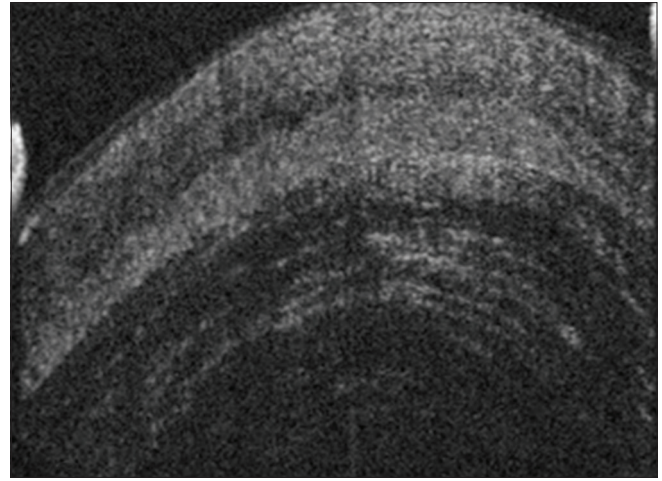


Figure 2: In a slightly advanced phase of the early stage, the biconvex empty areas increased in dimension, with greater extension into the deeper layers and along the equator

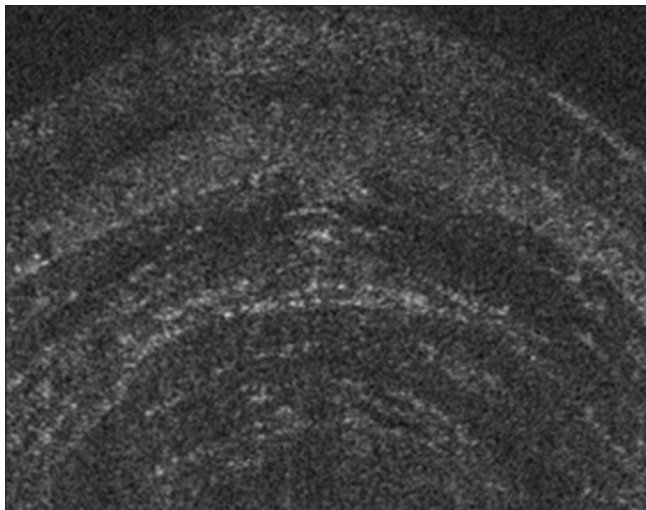


Figure 3: Another example of an early phase of intralenticular separation

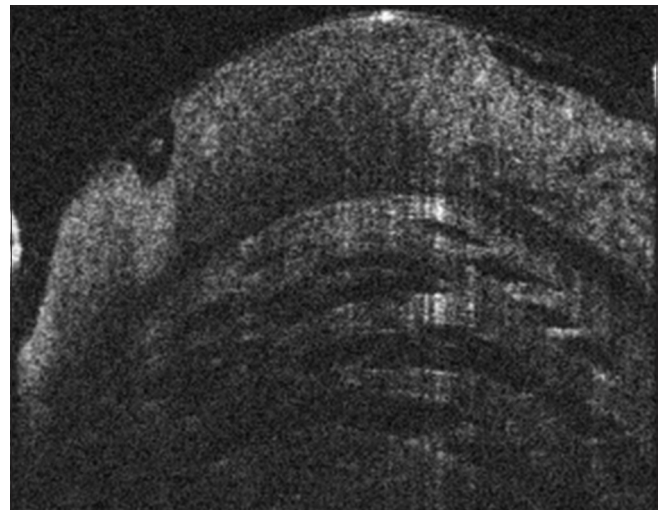


Figure 4: As the lamellar separation along the cortical layers' advanced, well-defined multilayered biconvex areas are evident deeper and wider. This represents the stage of established lamellar separation in mature senile cataracts. Localized small pockets of subcapsular fluid were also seen

undertaken to characterize them in chronological order and to correlate the findings with their respective slit-lamp features. The evolution of a mature cataract and beyond appears to go through sequential stages of cavitation, lamellar separation, and liquefaction. Small hyporeflective defect-like areas and water clefts have been observed even in cataracts of early stages.^[7,8] Probably, these progress onto the bi-convex or crescentic clefts in mature cataracts.^[5] It is well known that as the lens fibers accumulate with age, the inner nucleus gets hardened by compaction and relative dehydration.^[2,9] Therefore, as the nucleus matures as a function of dehydration, superficial fluid clefts arise, which when pronounced, coalesce and disrupt the cortical lens fibers. It is also known that the lens cortex overall exhibits a higher water content than the nucleus.^[10] This process can be compared to the desiccation of soil that happens during extremely dry climatic conditions. However, in the latter situation, the surface water evaporates leaving the land dry, while in this situation, the capsular bag being impermeable, fluid accumulates in the subcapsular region. When advanced, they may progress on to a hypermature Morgagnian type cataract or when leakage occurs, a sclerotic type cataract.

OCT aided the stage-wise progression of a mature cataract is being described by this study for the first time in literature, to the best of our knowledge. Dhama *et al.* showed the importance

of preoperative identification of fluid pockets in mature cataracts before proceeding for phacoemulsification.^[6] While their arm of positive subcapsular fluid had an OCT picture similar to our liquefied stage group, their no-fluid arm also revealed few cleft-like spaces concordant with our stage of lamellar separation, supporting our hypothesis.

By convention, the phakic lens imaged by this modified OCT appeared more convex than the normal lens curvature, as the externally placed +20D biconvex aspheric lens-induced extra-convergence. However, we also noted that as the severity of maturity increased, the anterior capsule became successively more convex. This may be explained by the fact that as the fluid component increases, being an incompressible compartment, the intralenticular pressure raises and manifests as a swollen lens with increased convexity at the anterior pole.^[4] This increased intralenticular pressure may also be the reason for posterior bowing of the disintegrated cortical fibers noted in advanced stages.^[5] Also, the severity of maturity appeared to be directly proportional to the depth of the clefts. In one case (a special circumstance), the clefts were so deep that it appeared to involve even the peripheral nucleus.

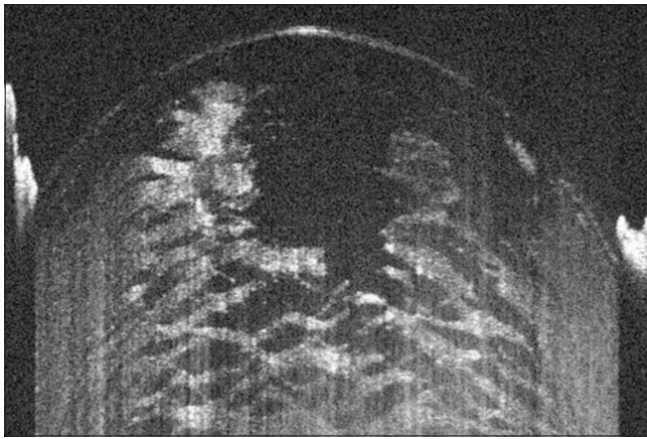


Figure 5: The classical anterior cortical biconvex hypoechoic areas advance in all four directions to create a loosed disintegrated lens framework with an ample amount of liquefied lens matter. These are the eyes that possessed tense anterior capsule intraoperatively with the highest risk for Argentinian flag sign. In addition, because of the raised intra bag pressure with weakened architectural support, the residual cortical fibers showed excessive posterior bowing

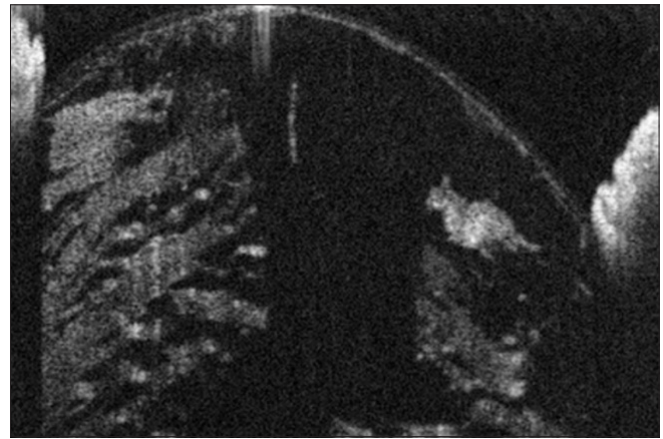


Figure 6: Another example of a case with extensive intralenticular lamellar separation with liquefaction

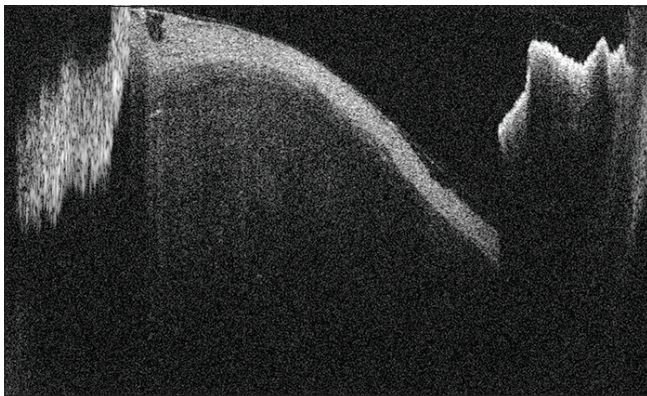


Figure 7: Under some unusual circumstances, the anterior capsule and cortical matter in its vicinity showed excessive hyperreflectivity with less clearly evident deeper changes

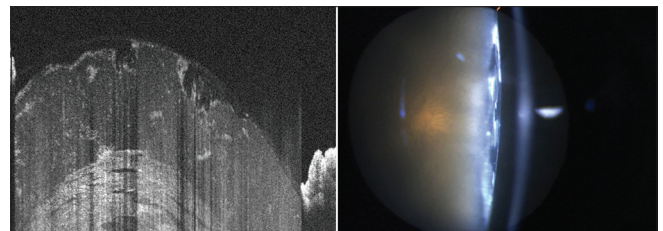


Figure 8: In another mature senile cataract, the anterior cortex did not reveal classical hypoechoic areas but remained homogenous, probably representing a pultaceous cortical matter. However, the anterior part of the nucleus showed the lamellar separation changes

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Conflicts of interest

There are no conflicts of interest.

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The limitations of this study include relatively small patient numbers, its cross-sectional design, and the inability to correlate extensively with the intraoperative surgical experiences. The latter was not possible since the cases were operated by different surgeons and hence their difficulty levels varied. However, understanding this sequence of maturity is important, since intralenticular fluid aspiration and forceps added capsulorhexis can significantly reduce the bag pressure and reduce the risk of radial extensions in cases of subcapsular liquefactions. Another limitation was the ability to visualize only up to 1500 microns of the anterior lens matter. The posterior lens matter may show similar findings or otherwise. Also, there could be some differences in the fluid dynamics between the OCT captured in a sitting position and the surgery done in a supine position. This may be the reason for egression of fluid in one case of Dhami *et al.*'s series where it was pre-operatively not visible.^[6]

Conclusion

To conclude, as early cataracts show changes on the slit-lamp biomicroscopy, mature cataracts may show gradations on the OCT. Therefore, a pre-operative OCT can be crucial before planning surgery for mature cataractous lenses.