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A study of anterior chamber morphology using UBM (Ultrasound Biomicroscopy) in cases with corneal pathology undergoing penetrating keratoplasty

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Abstract
Introduction/Purpose: Corneal pathologies are one of the leading causes of blindness. Optical rehabilitation for total corneal opacities requires penetrating keratoplasty (PK). It is necessary to understand the associated pathologies of anterior segment before surgery. UBM (Ultrasound biomicroscopy) being the only modality which works on principle of ultrasound waves and can easily peep into the anterior segment via opaque cornea.
Method: 37 eyes of 37 patients with corneal opacities due to various reasons that underwent penetrating keratoplasty were evaluated preoperatively by performing UBM in all meridians 360 degrees. Depth and extent of these lesions, thickness of cornea, anterior chamber depth, position, extent and spread of synechiae, fibrous membrane formation and status of lens were noted.
Results: 37 patients were grouped into corneal opacities, adherent leucoma and anterior staphylomas. Penetrating keratoplasty was planned along with certain modifications like iris reconstruction, membranectomy, synechiolysis, cataract extraction and IOL implantation or replacement. In 83.33% cases prediction of preoperative UBM findings and surgical modification were found to be accurate.
Conclusion: In patients with corneal pathologies, UBM helps to evaluate the morphology of anterior-segment structures and thus in preplanning of surgical strategies and intraoperative modifications.

Keywords: ultrasound bio-microscopy, corneal opacities, adherent leucoma, anterior staphyloma, penetrating keratoplasty

1. Introduction

Penetrating keratoplasty is indicated in various full thickness corneal pathology. These pathologies obscure the visualization of anterior segment as they affect central part of cornea including variable peripheral part. While performing penetrating keratoplasty consideration of associated anterior segment co-morbidities is important factor to get optimised results [1], [2]. In such a situation, strategizing a reconstructive surgery of the anterior segment in the presence of an opaque cornea can be a surgical challenge [3]. Therefore, understanding architecture of anterior segment pre-operatively is essential for right diagnosis, planning of surgery to overcome intra-operative complications. To visualize the anterior segment, we have various imaging modalities such as rotating Scheimpflug imaging (Pentacam-Scheimpflug), anterior segment optical coherence tomography (Visante OCT and Slit-Lamp OCT) which are based on light rays. These modalities cannot penetrate through opaque media. Ultrasound bio-microscopy works on the principle of ultrasound waves which penetrate deeper through opaque media easily. [4, 5] Therefore, this study was undertaken to evaluate the role of UBM in planning of penetrating keratoplasty in corneal pathologies of various types, grades and depth of involvement along with the associated anterior segment comorbidities.

2. Materials and Methods

After approval from the institutional ethical committee (IEC) of Sri Aurobindo medical college and postgraduation institute (SAMC & PGI, Indore) [IEC No. SAIMS/IEC/2019/38] and in accordance to the health Helsinki law, this observational study was conducted with 37 eyes of 37 patients with corneal opacities who were planned for penetrating keratoplasty were divided in three groups, 1. Corneal Opacity 2. Adherent Leucoma 3. Anterior staphyloma. They were evaluated preoperatively with the help of UBM to know the morphology of anterior segment.

Inclusion Criteria

1. Patients with full thickness corneal lesions of non-infective aetiology.
2. Accurate perception of light and projection of rays.
3. No posterior segment involvement.
4. Patients giving informed written consent for the study.

Exclusion Criteria

1. Patients with extensive scleral pathology.
2. Patients with perforated cornea.
3. Patients with Infective etiology.

Informed written consent was taken from all the patients willing to participate in the study. A detailed history was recorded to Know the course of the disease which included both ocular as well as systemic diseases, including treatment received (both medical and surgical) to understand the underlying etio-pathogenesis. Complete ocular examination was carried out including visual acuity in both eyes, anterior segment details by slit-lamp microscope. B scan was done to rule out posterior segment involvement. After taking consent from the patient, ultrasound bio-microscopy (UBM) was performed using a commercially available system (Optos OTI scan 3000) with a 50-MHz transducer for detailed analysis of the anterior segment.

Scanning was performed by an ophthalmologist with the patient lying in the supine position. After topical anesthesia, a silicone rubber eyecup of the appropriate size was inserted between the lids. This cup contained distilled water or normal saline as coupling medium. All scans were performed with standard settings. All 360-degree meridians were scanned by placing the probe in appropriate position. Parameters with comorbidities describing their severity, extent, depth and location were noted down. Pre-operatively clinical photographs, UBM findings were recorded for documentation. All findings such as the corneal depth, extent, oedema and thickness along with anterior chamber depth, position of angle, anterior and posterior synechiae, iris details, lens and zonular status were taken into consideration by the operating surgeon preoperatively before performing penetrating keratoplasty and similar findings were then rectified intraoperatively. We have divided UBM findings into 3 groups just to understand modification of surgical steps in a better way – 1.) Status of cornea 2) Status of anterior chamber (AC) and iris synechiae 3) Status of lens and zonules.

3. Results and discussion

3.1 Result

37 patients with opaque corneal pathologies as shown in Figure 1 were evaluated in this study which were divided into 3 groups consisting of corneal opacities (12), adherent leucoma (13) and anterior staphyloma (12). Details of the grouping are depicted in table 1. Corneal opacities were found to be 12 in number. As shown in various corneal parameters in table 2, maximum cases (83.33%), full central corneal involvement and increased corneal thickness was found. Half stroma with scarring was seen only in 2 (16.66%) cases of bullous keratopathy. Corneal edema was present more in pseudophakic bullous keratopathy and graft failure cases. 13 cases of adherent leucoma were examined where all the cases showed full thickness involvement (100%) along with an increase in the thickness of the cornea. Maximum cases showed horizontal corneal extent which was central (3-8mm) and nasal in only 2 cases. We included 12 anterior staphylomas in our study who had full thickness corneal involvement and extent from white to white. Table 3 elaborates on the status of anterior chamber on UBM findings. Out of the 12 cases of corneal opacities, only 1 (8.33%) case showed a shallow AC as shown in figure 2 and 1 showed a variable AC (8.33%). ACD (anterior chamber depth) was variable in all the cases (100%) of adherent leucoma due to anterior adherence or posterior synechiae as shown in figure 3. 2 cases (15.38%) had closed angles due to membrane formation and 1 showed a receding angle (7.69%). 8 (66.66%) anterior staphyloma cases showed a shallow AC and 4 (33.33%) showed a variable AC with normal angle position (100%) as depicted in figure 2. Table 4 describes the lens and zonular status in this series. 12 cases of corneal opacities were found to be phakic with intact zonules with 1 case of pseudophakia and 1 case of iris claw. Most of the cases in adherent leucoma and anterior staphyloma had phakic lens with intact zonules. Site of zonular dehiscence or dialysis could be evaluated on UBM as shown in figure 5. Intraoperative confirmation of preoperative predictability of corneal findings on UBM has been represented in table 5**.** For corneal findings of the UBM, predictability was evaluated in form of graft size, depth of trephination, AC depth and entry into AC. We could 100% predict the size of the graft based on extent of corneal pathology and depth of trephination based on thickness of the pathology. Entry into AC was decided based on available adequate depth of AC which was better corelated in adherent leucoma (92.30%), corneal opacities (91.66%) better than anterior staphyloma (83.33%). As elaborated in table 6, prediction of extent of synechiae was almost 83.33%. As per the density of these synechaie, pupillary distortion was confirmed intraoperatively in corneal opacities by 91.66%, in adherent leucoma by 84.66% and anterior staphyloma by 83.33%. This helped in pre-operative preparation for iris reconstruction and thus, membranectomy and synechiolysis were executed intraoperatively. Extensive iris incarceration in the form of annular anterior synechiae or membrane formation were found to be the most in anterior staphyloma. Such patients were explained about the aniridic status preoperatively. Intraoperative confirmation of phakic, aphakic or IOL status; posterior capsule and zonular status to preoperative UBM findings in shown in table 7. 27.02% dense cataract were predicted on UBM which were confirmed intra-operatively and predictability was found to be 100%. Such patients were planned for triple procedure of PK (penetrating keratoplasty) along with cataract extraction and IOL (intra-ocular lens) placement. PC (posterior chamber) status predictability in the form of presence of absence ranged from 83.33% to 91.66% and zonular status predictability which was 100% accurate helped to decide the type of IOL in the form of IOL exchange or secondary IOL placement.

3.2 Discussion

Corneal pathologies where anterior segment details are not visualized need to be evaluated preoperatively for proper management before planning for surgery. Multiple imaging modalities are available but UBM's ability to penetrate through the structures of the eye and provide depth perception and extension of lesions has improved our ability to preoperatively strategize surgeries. UBM is a reliable way to peep into the anterior chamber and quantitatively and qualitatively assess the involvement of anterior chamber structures. Our study is unique because it is the first of its kinds that includes variety of corneal pathologies with associated comorbidities undergoing penetrating keratoplasty. The series included vast number of corneal pathology cases (simple corneal opacities without adhesions, opacities with vascularization, pseudophakic bullous keratopathy, Corneal dystrophy) and adherent leucoma and anterior staphyloma. Study done by Madhavan *et al* [16] was similar to our study but it differed on the fact that it was blind folded study in which the surgeon was unaware of the findings of

the UBM and they were corelated later only after surgeon had given out the findings on his/her own intraoperatively. In our study, operating surgeon studied the UBM findings, predicted anterior segment comorbidities and planned the surgery accordingly which was helpful in achieving the desired goal of less surgical surprise by overshadowing the unforeseen complications. Most of the studies done previously were either single case report studies [7, 8, 12, 13, 14] or studies done to differentiate staphyloma from other scleral pathologies [11] Graft size and trephination depth UBM was very helpful in all the cases planned for penetrating keratoplasty as the prediction of graft size could be made in all cases (100%) and no variability was found. We could also predict the thickness of cornea which may be due to edema (72.86%) or scarring (16.66%). This helped us in deciding the trephination size and in adjusting the depth of trephination correctly as shown in UBM preoperatively. Same was found intraoperatively by the surgeon. No other study has been found in literature that has elaborated on these UBM findings and taken an advantage of it in keratoplasty. Iris synechiae, entry into AC and prevention of iris deformity another important finding was variability of AC depth due to anterior synechiae or membrane formation which was seen on slit lamp in few cases but confirmed on UBM. We could enter the AC from the available AC depth site. As per the density and strength of these synechaie, prediction for distortion of pupil was 91.66% in corneal opacities, 84.66% in adherent leucoma and 83.33% in anterior staphyloma. Intraoperative modifications were 8.37% in corneal opacities, 15.38% in adherent leucoma and 16.66% in anterior staphyloma. In a similar study by Madhavan *et al* (16) positive predictive value of anterior synechiae was 55.6% (5/9) and PAS was 73.1% (19/26). Posterior synechiae were also found showing annular (25% in corneal opacities, 7.69% in adherent leucoma) and sectoral pattern (8.33% in corneal opacities, 7.69% in adherent leucoma). In these cases, membranectomy (20.7%) and synechiolysis (21.14%) were planned and executed intraoperatively. This helped in management of any abrupt injuries to the iris and other anterior segment structures. Only study by Madhavan *et al* (16) gave positive predictive value of posterior synechiae as 80% (12/15).

In cases of anterior staphyloma, extensive irido-corneal incarceration was seen which was accurately predicted (83.33%) and so the surgeon was prepared for aniridia (16.66%) and possibility of the same was explained to the patient. In a few cases, there was confusion (23.08%) in irido-corneal adhesions or mere touch which could be confirmed only intraoperatively. Zhang *et al* also demonstrated the clock hours and locations of lens-iris–corneal touch which was similar to our study [10]. No other studies have mentioned about extent or course of synechiae in such details Study on congenital corneal opacification by Nischal *et al* has been done where they also found UBM examination as a preoperative guide, emphasized only on congenital cases undergoing PK and corelated ocular abnormalities such as aniridia and congenital Aphakia [8, 9].

In our study, cases from all age groups were included and the operating surgeon studied these cases along with their UBM findings, predicted intraoperative complications and planned the surgery accordingly which was helpful in achieving less surgical surprise. Lens and zonular status Patient showing cataractous changes (27.02%) were planned for triple procedure of penetrating keratoplasty with cataract extraction along with IOL implantation. In a case with zonular dialysis and another case with iris fixated lens showed corneal decompensation on UBM. Replacement of IOL were executed for these cases. Further, study by Rutnin *et al*[17] have also demonstrated the utility of UBM in managing of pseudophakic/AC IOL-related complications in general, and in evaluating the ease of cataract removal or IOL insertion during PK. Pavlin *et al* also stated that UBM could be used as an alternative to gonioscopy as it can't be used in corneal opacities. It also allows the surgeon to be prepared for difficulties that may be encountered on IOL extraction. In addition to this, UBM also helped in defining the mechanism of angle closure induced by zonular weakness and changes in lenticular configuration and position. [15] Our study has further demonstrated this finding by giving 100% accurate prediction for lens status in terms of presence/absence and location and PC status ranging from 83.33 - 91.66% accuracy. Madhavan *et al* [16] gave positive prediction value of posterior capsule (PC) in the form of presence of PC/PC remnants which was 92.9% (13/14). Status of pseudophakia in the form of - presence, centration, location in anterior chamber or posterior chamber. Presence of crystalline lens was also predicted by 100% (4/4) by them along with cataractous changes in anterior part of lens by 50% (1/2). If surgeon knows preoperatively the status of anterior segment as a whole hiding behind opaque cornea then this can be useful not only in detecting thickness of cornea but also the extent of the lesion, AC depth, angle details, iris synechiae, lens and zonular status. Our surgical success in penetrating keratoplasty was due to preplanning aided by the findings of the UBM done by an ophthalmologist and similar findings being rectified intraoperatively with required manipulation by the surgeon. Prognosis could be explained to the patient and follow up was recommended accordingly.

4. Tables and figures

Table 1: Corneal pathology grouping

Corneal Pathologies (37)	Number of cases
Corneal opacities	12
Simple corneal opacities	8
Corneal dystrophy	1
Bullous keratopathy	2
Band shaped keratopathy with post PK graft failure	1
Adherent Leucoma	13
Anterior Staphyloma	12

Table 2: Corneal findings on UBM in various corneal pathologies

	Corneal Opacity (12)	Adherent Leucoma (13)	Anterior Staphyloma (12)
Corneal Involvement			
Full thickness	10 (83.33%)	13 (100%)	12 (100%)
Half stroma with scarring	2 (16.66%)	-	-
Corneal Edema			
Present	8 (66.66%)	10 (76.92%)	9 (75%)
Absent	4 (33.33%)	3 (23.07%)	3 (25%)
Corneal Extent			
Central 3-8mm	11 (91.66%)	11 (84.61%)	12 (100%)
Nasal	1 (8.33 %)	2 (15.38%)	-
Corneal Thickness	100% Increased	100 % increased	Normal in 4 (33.33%) Increased in 8 (66.66%)

Status of anterior chamber on UBM

Table 3: Status of anterior chamber on UBM

Anterior chamber depth (ACD)	Corneal Opacity (12)	Adherent Leucoma (13)	Anterior Staphyloma (12)
Normal	10 (83.33%)	-	-
Shallow	1 (8.33%)	-	8 (66.66%)
Variable	1 (8.33%)	13 (100%)	4 (33.33%)
Angle Position			
Normal	10 (83.33%)	10 (76.92%)	12 (100%)
Membrane closed	2 (16.66%)	2 (15.38%)	-
Receding angle	-	1 (7.69%)	-
Anterior Synechaie			
Membrane (involving angles)	1 (8.33%)	6 (46.15%)	5 (41.66%)
Sectoral	In 1 at 2-3 o clock (8.33%)	6 (46.15%)	7 (58.33%)
Central	-	1 (7.69%)	-
Absent	10 (83.33%)	-	-
posterior synechai**e**			
Annular	3 (25%)	1 (7.69%)	-
Sectoral	1 (8.33%)	1 (7.69%)	-
Membrane	1 (8.33%)	-	1 (8.33%)
Absent	7 (58.33%)	11 (84.6%)	11 (91.66%)

Table 4: Status of lens and zonules on UBM

Zonules	Corneal Opacity (12)	Adherent Leucoma (13)	Anterior Staphyloma (12)
Intact	10 (83.33%)	11 (84.6%)	11 (91.66%)
Dehiscence	1 (8.33%) at 6-8 o clock	1 (7.69%)	-
Dialysis	1 (8.33%) at 10-12 o clock	1 (7.69%)	1 (8.33%)
Lens			
Phakic	9 (75%)	12 (92.3%)	12 (100%)
Pseudophakic	2 (16.66%)	1 (7.69%)	-
Iris claw	1 (8.33%)	-	-

Table 5: Intraoperative confirmation of preoperative predictability of corneal findings on UBM

	Size of graft			Trephination depth			Anterior chamber entry		
	Adequate	Not adequae	Prediction (%)	Adequate	Not adequae	Prediction (%)	Achievd in estimatd clock hours (same)	Not achieved (different)	Prediction (%)
Corneal Opacities (12**)**	12	-	100%	12	-	100%	11	1	91.66%
Adherent Leucoma (13)	13	-	100%	13	-	100%	12	1	92.30%
Anterior Staphyloma (12)	12	-	100%	12	-	100%	10	2	83.33%

Table 6: Intraoperative confirmation of prediction of preoperative UBM findings on status of Iris

	Extent of synechaie				Iris reconstruction			Pupil distortion		
	more than expected	less than expected	same	Prediction (%)	as predicted	changes	Prediction (%)	as predicted	changes	Prediction (%)
corneal opacities (12)	1	1	10	83.33%	11	1	91.66%	11	1	91.66%
adherent leucoma (13)	2	1	10	76.92%	11	2	84.66%	11	2	84.66%
anterior staphyloma (12)	1	1	10	83.33%	10	2	83.33%	10	2	83.33%

Table 7: Intraoperative confirmation of phakic, aphakic or IOL status; posterior capsule and zonular status to preoperative UBM findings

	Phakic Status Interms of Cataract			Iol position				Posterior Capsule Status			Status of Zonules			
	Cataractous	Non Cataractous	Prediction (%)	In the bag	In sulcus	Elsewhere	Prediction (%)	Present	Absent	Prediction (%)	Intact	Dehiscence /Dialysis	Absent	Predicition (%)
corneal opacities (12)	3	6	100%	2	-	1	100%	10	2	83.33%	10	2	-	100%
Adherent leucoma (13)	3	9	100%	1	-	-	100%	11	2	84.61%	11	2	-	100%
anterior staphyloma (12)	4	8	100%	-	-	-	100%	11	1	91.66%	11	1	-	100%

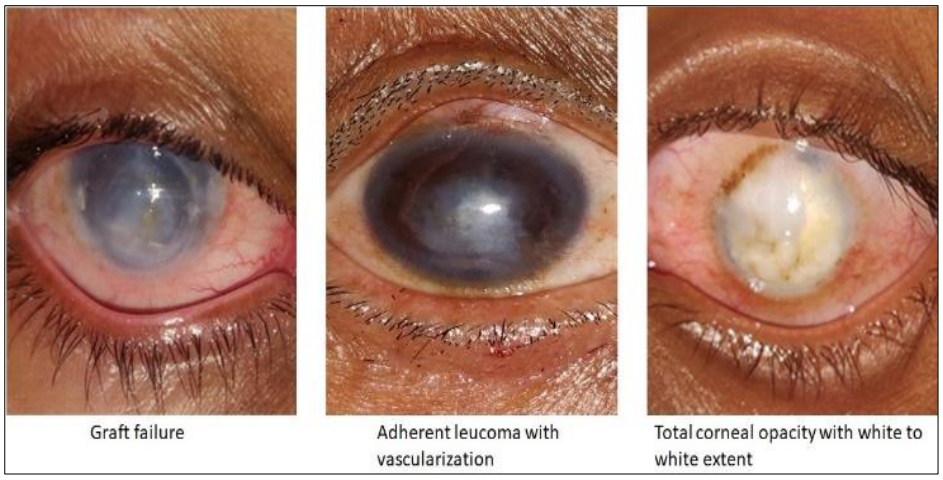


Fig 1: Various groups **o**f Cornal pathologies

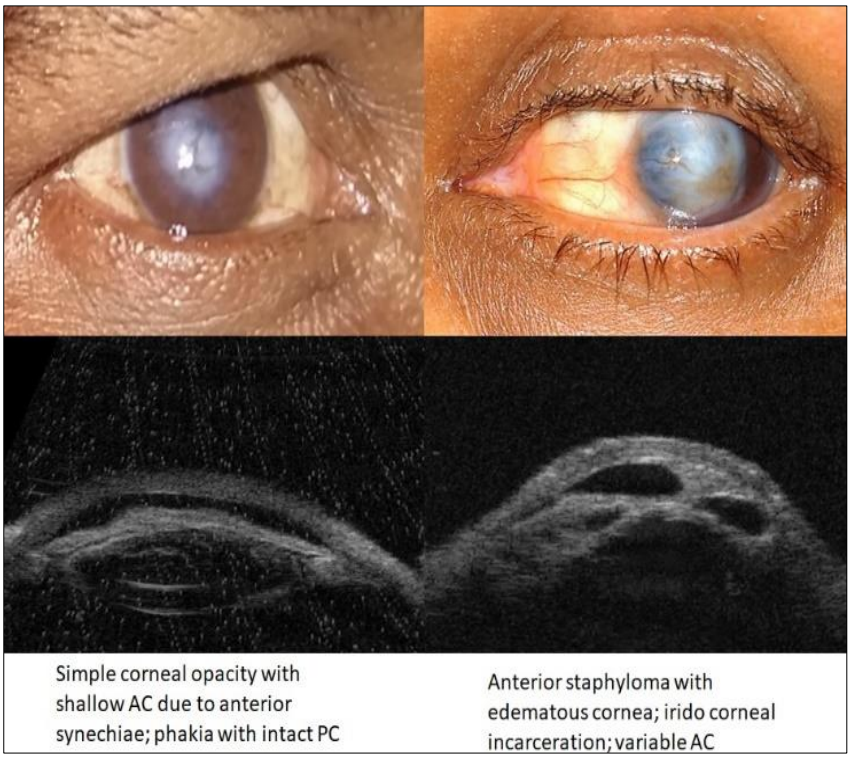


Fig 2: Clinical pictuer with UBM finding im simple corneal opacity and anterior staphyloma

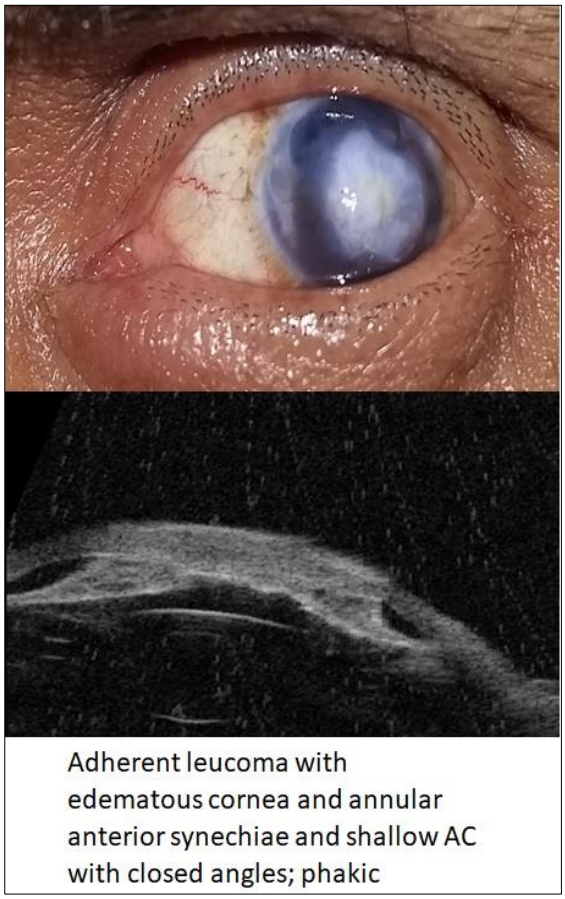


Fig 3: Clinilcal picture and ubm finding in adherent leucoma

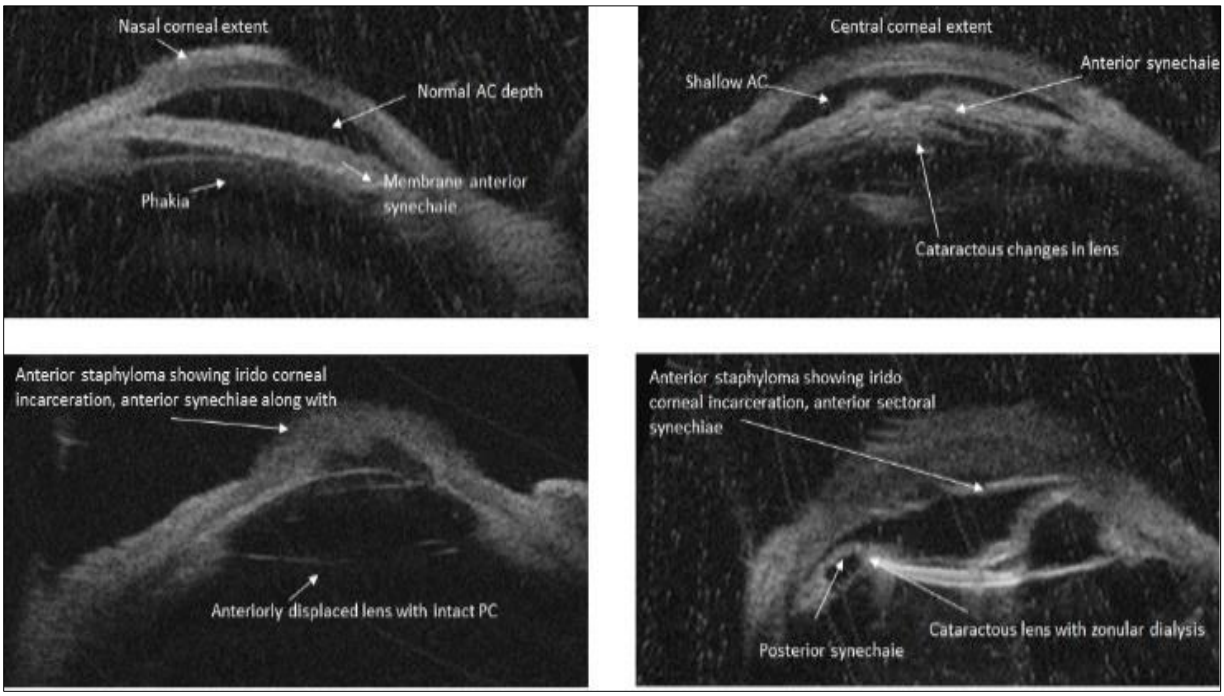
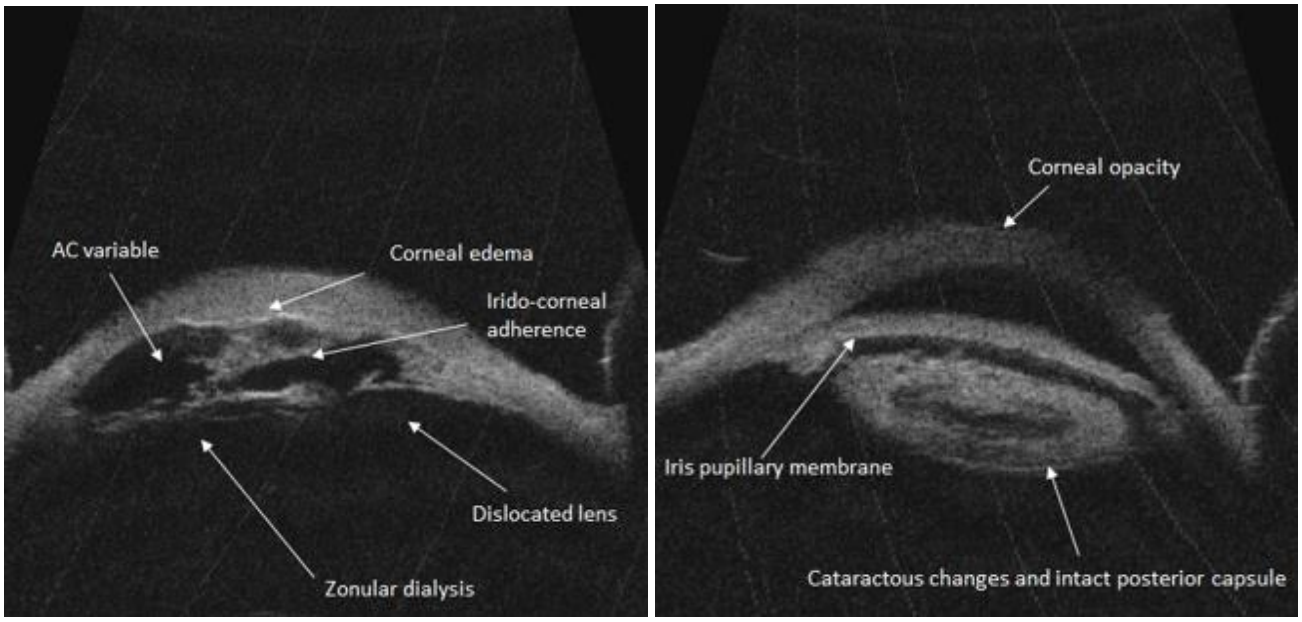


Fig 4: Ubm showing various anterior segment pathologies



Adherent Leucoma Corneal Opacity

Fig 5: Ubm showing position of lens and zonules

5. Conclusion

UBM is essential in proper diagnosis of cases with opaque media and to note anterior segment properties. Accordingly, we can strategize a procedure preoperatively. Even though techniques like anterior segment optical coherence tomography and Penta-cam have the advantage of being noncontact with better resolution of anterior structures, UBM still stands superordinate because of the cost effectiveness, easy handling, deeper penetration and better visualization.

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