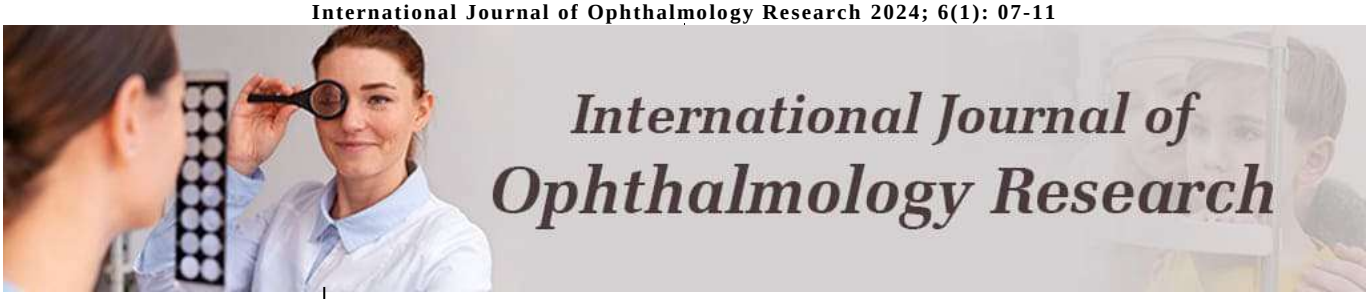

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A study of application of anterior segment optical coherence tomography in glaucoma

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Abstract
Introduction: Glaucoma is a chronic progressive optic neuropathy leading to irreversible blindness, emphasizing the need for early diagnosis and effective management. Anterior segment optical coherence tomography (AS-OCT) has emerged as a critical tool for diagnosing and monitoring glaucoma, offering high-resolution imaging of anterior segment structures and aiding in the evaluation of various glaucoma subtypes.
Method: This prospective observational study, conducted at the Department of Ophthalmology, Shri Ram Murti Smarak Institute of Medical Sciences, Bareilly, aimed to assess the relationship between intraocular pressure (IOP) and anterior chamber angle configurations using gonioscopy and AS-OCT. A total of 102 glaucoma patients aged 50 and older were included. Various ocular parameters were measured, including visual acuity, central corneal thickness (CCT), anterior chamber depth (ACD), and angle measurements via AS-OCT and gonioscopy.
Result: The study revealed a higher prevalence of angle-closure glaucoma (52%) and primary open-angle glaucoma (48%). Significant variations in iris configurations and angle structures were observed, with 64.7% of patients having open angles and 19.6% showing peripheral anterior synechiae. The study found a significant difference in ACA measurements between AS-OCT and gonioscopy ($p<0.001$).
Conclusion: AS-OCT offers valuable insights into the evaluation and monitoring of glaucoma, demonstrating a high degree of accuracy in assessing anterior chamber angles and iris configurations, complementing traditional diagnostic techniques.

Keywords: Glaucoma, anterior segment optical coherence tomography, gonioscopy, intraocular pressure, iris configuration, anterior chamber angle, angle-closure glaucoma, primary open-angle glaucoma

Introduction

Glaucoma is a chronic progressive optic neuropathy characterized by structural damage to the optic nerve and corresponding functional visual field loss. It remains a leading cause of irreversible blindness worldwide, necessitating timely diagnosis and effective management. Early detection and monitoring of glaucoma progression are pivotal for preserving vision and improving patient outcomes [1].

Anterior segment optical coherence tomography (AS-OCT) has emerged as a vital imaging tool in the evaluation of glaucoma. Unlike conventional imaging techniques, AS-OCT provides high-resolution, cross-sectional imaging of the anterior segment structures, including the cornea, iris, angle, and anterior chamber. This non-invasive modality allows precise assessment of angle configurations, scleral spur identification, and anterior chamber depth-parameters crucial for diagnosing and managing various subtypes of glaucoma [2].

The application of AS-OCT in primary angle-closure glaucoma (PACG), secondary glaucoma, and post-surgical evaluations has provided valuable insights into the pathophysiology and progression of the disease. Its ability to visualize structural changes over time has further enhanced its role in longitudinal patient monitoring [3].

This study aims to explore the clinical utility of AS-OCT in diagnosing and monitoring glaucoma, emphasizing its diagnostic accuracy, predictive value, and impact on management strategies. By analyzing its applications, this research seeks to contribute to the growing body of evidence supporting AS-OCT as an indispensable tool in modern glaucoma care.

Methods

This prospective observational hospital-based study was conducted at the Department of Ophthalmology, Shri Ram Murti Smarak Institute of Medical Sciences, Bareilly, over an 18-month period from August 1, 2022, to January 31, 2024. The study aimed to assess and compare the relationship between corrected intraocular pressure (IOP) and anterior chamber angle configuration using gonioscopy and anterior segment optical coherence tomography (AS-OCT).

Patients aged 50 years or older, diagnosed with glaucoma, and providing informed consent were included in the study. Exclusion criteria included prior intraocular surgery, penetrating eye injuries, corneal disorders (e.g., endothelial dystrophy or opacity), and use of medications affecting pupillary diameter. A total of 102 patients were recruited, determined using Cochran's formula, with a 10% margin for non-respondents.

Demographic and clinical data were recorded using a structured proforma. Comprehensive ocular examinations included visual acuity assessment, slit-lamp biomicroscopy, gonioscopy, Goldmann applanation tonometry for IOP measurement, and anterior segment imaging with the Carl Zeiss AS-OCT. Gonioscopy, performed by a single examiner blinded to AS-OCT findings, used a Goldman four-mirror lens under standardized dark conditions. The anterior chamber angle was graded using the Schaffer system and peripheral anterior synechiae (PAS) were assessed.

AS-OCT imaging was performed under dark conditions, capturing scans of nasal, temporal, superior, and inferior angle quadrants. A masked observer analyzed images to measure anterior chamber parameters, including anterior chamber depth (ACD), angle opening distance (AOD), and anterior chamber area (ACA), using specialized software.

Quantitative data were summarized as means and standard deviations, while categorical data were expressed as frequencies and percentages. Statistical analyses were conducted using SPSS version 25.0, employing ANOVA for quantitative variables and Chi-Square or Fisher's exact tests for categorical variables. A p-value of <0.05 was considered statistically significant.

Ethical clearance was obtained from the Institutional Ethics Committee. A pilot study was conducted on 10 participants to validate the methodology, ensuring feasibility, reliability, and validity of the study instruments and parameters.

Result

The study assessed the distribution of glaucoma subtypes among patients. Of the 102 individuals diagnosed with glaucoma, 52% (n=53) had angle-closure glaucoma, while 48**%** (n=49) had primary open-angle glaucoma.

The demographic distribution of patients in the study evaluating the application of anterior segment optical coherence tomography (AS-OCT) in glaucoma reveals that the majority of participants (41.2%) were aged between 50 and 55 years, followed by 25.5% in the 56–60 years age group, 13.7% in the 61–65 years age group, and 19.6% aged over 66 years. The study had a predominantly male population, with 72.5% males compared to 27.5% females. These findings highlight that middle-aged and older adults, particularly men, comprised the majority of the study population.

Table 1: Visual Acuity Distribution

Visual Acuity	Right Eye (%)	Left Eye (%)
6/6	27.5%	23.6%
6/9	3.9%	3.9%
6/12	25.5%	25.2%
6/18	8.8%	11.8%
6/24	16.7%	17.3%
6/36	10.8%	11%
6/60	6.9%	7.1%

The visual acuity distribution among the study participants shows varying degrees of vision in both eyes. For the right eye, the most common acuity was 6/6, observed in 27.5% of cases, followed by 6/12 in 25.5%, and 6/24 in 16.7%. Similarly, for the left eye, 6/6 was the most frequent at 23.6%, followed by 6/12 at 25.2%, and 6/24 at 17.3%. Visual acuities of 6/36, 6/60, and below were less frequent, seen in 10.8% and 6.9% of right eyes, and 11% and 7.1% of left eyes, respectively. These results indicate a significant proportion of participants with mild to moderate visual impairment in both eyes.

Table 2: Evaluation Parameters

Parameter	Frequency	Percentage
ACA (Anterior Chamber Angle)		
<20	22	21.6%
20–24	22	21.6%
25–30	28	27.5%
>30	30	29.4%
CCT (Central Corneal Thickness)		
460–500	6	5.9%
500–550	96	94.1%
Anterior Chamber Depth (mm)		
<2.5	24	23.5%
2.5–3	53	52%
>3	25	24.5%

The anterior chamber angle (ACA) was most commonly measured at >30° in 29.4% of cases, followed by 25–30° in 27.5%, while narrower angles (<20°) were observed in 21.6% of patients. The central corneal thickness (CCT) was predominantly within the 500–550 µm range, accounting for 94.1% of cases, with only 5.9% measuring between 460–500 µm. The anterior chamber depth (ACD) was found to be between 2.5–3 mm in 52% of patients, with 24.5% exceeding 3 mm, and 23.5% measuring below 2.5 mm.

This analysis highlights the diverse iris configurations, angle structures, and grading systems in patients evaluated for glaucoma. Among iris configurations, 34.3% were normal, while 16.7% had steep iris, and 15.7% showed a queer configuration. Regarding angle structure, 64.7% had open angles, 19.6% exhibited peripheral anterior synechiae, and 15.7% displayed iris concavity. Scheie's grading revealed that 34.3% were classified as Grade 0 (wide open), with higher grades (Grade 3 and 4) accounting for 26.5% collectively. The "Over the Hill" grading showed a progressive distribution, with Grade 0 in 34.3% and Grade 3 in 15.7%. Indentation testing indicated 50% indentable angles, while 15.7% had closed angles.

The study compares intra-ocular pressure (IOP) measurements with central corneal thickness (CCT) to evaluate their association in glaucoma patients. Tonometry showed that 45.1% of patients had an IOP of 16–20 mmHg, while 50% had an IOP of 21–25 mmHg, and 4.9% exceeded 26 mmHg.

Table 3: Iris and Angle Characteristics in Glaucoma: Analysis Using Anterior Segment OCT

Parameter	Frequency	Percentage
Iris Configuration		
Normal	35	34.3%
Flat	16	15.7%
Steep	17	16.7%
Bowed Anteriorly	6	5.9%
Plateau Iris	6	5.9%
Queer	16	15.7%
Concave	6	5.9%
Angle Structure		
Open Angle	66	64.7%
Peripheral Anterior Synechiae	20	19.6%
Iris Concavity	16	15.7%
Scheie's Grading		
Grade 0	35	34.3%
Grade 1	22	21.6%
Grade 2	18	17.6%
Grade 3	11	10.8%
Grade 4	16	15.7%
''Over the hill'' grading		
Grade 0	35	34.3%
Grade 1	22	21.6%
Grade 2	29	28.4%
Grade 3	16	15.7%
Indentation		
Non-indentable	35	34.3%
Indentable	51	50%
Closed angle	16	15.7%

Table 4: Distribution and Comparison of Intra-Ocular Pressure (IOP) with CCT

IOP Variables	10–15	16–20	21–25	26–30	p-value*
IOP by Tonometry (n, %)	0 (0%)	46 (45.1%)	51 (50%)	5 (4.9%)	<0.001
Corrected IOP (n, %)	11 (10.8%)	57 (55.9%)	34 (33.3%)	0 (0%)	
CCT (460–500 mm)	0 (0%)	4 (66.7%)	2 (33.3%)	0 (0%)	<0.001
CCT (500–550 mm)	0 (0%)	42 (43.8%)	49 (51%)	5 (5.2%)	
CCT (550–600 mm)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
Corrected IOP by CCT	-	11 (23.9%), 35 (76.1%)	22 (43.1%), 29 (56.9%)	5 (100%)	

Corrected IOP distribution revealed a shift, with 55.9% in the 16–20 mmHg range and 33.3% in the 21–25 mmHg range, indicating the importance of CCT-adjusted IOP values. Among those with thinner corneas (CCT: 460–500 mm), 66.7% fell into the 16–20 mmHg range, highlighting their susceptibility to underestimation of IOP. In contrast, those with CCT in the 500–550 mm range predominantly showed an IOP of 21–25 mmHg (51%).

Table 5: Comparison of Iris Insertion and Anterior Chamber Angle (ACA) Between Two Groups

Variable	Category	ASOCT n (%)	Gonioscopy n (%)	p-value*
Iris Insertion	Normal	33 (32.4%)	33 (32.4%)	0.998
	Anterior to Schwalbe’s line	13 (12.7%)	14 (13.7%)	
	Between Schwalbe’s line and scleral spur	9 (8.8%)	10 (9.8%)	
	Scleral spur visible	20 (19.6%)	18 (17.6%)	
	Deep with ciliary body	13 (12.7%)	14 (13.7%)	
	Extremely deep (>1mm ciliary body)	14 (13.7%)	13 (12.7%)	
Anterior Chamber Angle (ACA)	<20	22 (21.6%)	39 (38.2%)	<0.001
	20–24	22 (21.6%)	0 (0%)	
	25–29	28 (27.5%)	27 (26.5%)	
	>30	30 (29.4%)	36 (35.3%)	

This study compares iris insertion and anterior chamber angle (ACA) measurements between anterior segment optical coherence tomography (AS-OCT) and gonioscopy. For iris insertion, AS-OCT and gonioscopy demonstrated similar distributions across categories, with normal insertion reported in 32.4% of cases for both methods. Slight variations were observed in other categories, such as "extremely deep (>1 mm ciliary body)," which accounted for 13.7% on AS-OCT versus 12.7% on gonioscopy ($p = 0.998$).

ACA measurements, however, showed significant differences between the two methods ($p < 0.001$). Gonioscopy identified more cases with angles <20° (38.2%) compared to AS-OCT (21.6%), while AS-OCT reported more cases in the 20–24° range (21.6%) compared to none detected by gonioscopy. Both methods showed similar

proportions for wider angles, with AS-OCT reporting 29.4% and gonioscopy 35.3% for angles >30°.

Discussion

The current study highlights the potential of anterior segment optical coherence tomography (AS-OCT) as a valuable diagnostic tool for glaucoma. The findings underscore the efficacy of AS-OCT in early detection, diagnosis, and monitoring of glaucoma, offering insights into the role of anterior segment structures in the disease's progression. The study emphasizes how AS-OCT can improve glaucoma risk assessment by precisely visualizing and quantifying critical structures, enabling early intervention and the prevention of permanent vision loss by identifying biomarkers such as trabecular meshwork and angle factors associated with elevated glaucoma risk [4].

Moreover, the longitudinal analysis in this study demonstrates that AS-OCT can serve as an effective method for tracking disease progression and evaluating treatment outcomes. The correlation between conventional glaucoma assessments (Like visual field tests and optic nerve head evaluations) and AS-OCT imaging biomarkers highlights the potential for more comprehensive evaluations, aiding in informed treatment decisions. Additionally, this study examines how AS-OCT could enhance treatment strategies by assessing structural changes in the anterior segment following medication or surgical interventions [5, 6].

However, despite the promising outcomes, the study acknowledges limitations such as the need for standardization of imaging protocols and analysis techniques before broader clinical application. Further research is required to establish normative databases and validate the imaging biomarkers across diverse populations [7, 8].

In comparison to traditional gonioscopy, AS-OCT's ability to provide detailed cross-sectional imaging offers advantages, although it cannot fully replace gonioscopy as the gold standard for anterior chamber angle (ACA) evaluation [9, 10]. Gonioscopy remains vital for assessing angle structures, despite its subjectivity and dependence on examiner skill and patient cooperation. This study demonstrates that AS-OCT can complement gonioscopy, providing more detailed imaging of the anterior segment while enhancing glaucoma diagnosis and treatment [11-13].

In terms of demographics, our study population had a mean age of 58.08±6.02 years, with 70% of participants being male. These findings are consistent with similar studies, including Patel *et al*. and Narayanaswamy *et al*., which also found a predominance of male participants and an average age of around 57 years. Our investigation further revealed an average central corneal thickness of 514.5±9.8 µm, though our findings differ from those of Patel *et al*. and other studies, suggesting that corneal thickness may vary across different populations[14, 15]. Additionally, our study identified a variety of iris configurations, with 35% of patients showing a normal iris configuration, similar to findings by Kumar *et al*. and Verma *et al* [16, 17].

AS-OCT's capacity to visualize structural variations such as iris bowing, scleral spurs, and angle configurations provides critical insights into glaucoma pathophysiology. However, there are discrepancies in the prevalence of iris configurations compared to other studies, and our findings suggest the need for further research to explore the clinical relevance of these variations in different glaucoma subtypes.

While AS-OCT shows promising advantage, further studies with larger sample sizes and standardized methodologies are necessary to validate its utility in routine clinical practice [18, 19].

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