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ARCHITECTURAL ANALYSIS OF POST TRABECULECTOMY BLEB USING AS-OCT

Ophthalomology

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ABSTRACT

Introduction: Trabeculectomy remains a pivotal treatment for glaucoma, where the success hinges critically on the morphology and functionality of the filtration bleb. **Aim & Objective:** To study the Architectural Analysis of Post Trabeculectomy Bleb Using AS-OCT. **Material & Methods:** Prospective observational study carried out on 70 patients in department of Ophthalmology in a tertiary care centre in Gorakhpur in a duration of 12 months (May 2023-April 2024). **Results:** Diffuse and Cystic blebs were the most common morphological forms and were associated with better IOP controls whereas encapsulated and flattened blebs were considered as failed blebs. Quantitative measurements of filtration blebs immediately post surgery and over a 6 months period indicated gradual increase in bleb height, internal cavity height and bleb all thickness. **Conclusion:** AS-OCT is a valuable tool for the detailed analysis of post-trabeculectomy blebs. By providing high-resolution images and quantitative data, it enhances the understanding of bleb function, guides postoperative management, and helps predict long-term surgical outcomes.

KEYWORDS

IOP, AS-OCT, Diffuse; Cystic; Encapsulated; Flattened blebs

INTRODUCTION

Glaucoma is a significant eye disorder that leads to progressive and permanent vision loss as a result of damage to the optic nerve[1]

Trabeculectomy is a type of surgery used to treat glaucoma when other treatments like medications are not effectively controlling the condition. The success of a trabeculectomy, a common surgical procedure for glaucoma, primarily hinges on the creation of an effective filtration bleb. This bleb is essential because it allows for the drainage of aqueous fluid from the eye. Its continued functionality is important for maintaining intraocular pressure within the appropriate limits, which is critical for the surgery's ongoing effectiveness and long-term success.[2]

After surgery, the appearance of the bleb can be different, like diffuse, cystic, encapsulated, or flattened. Blebs that look diffuse and sit low on the eye's surface are usually linked to good control of intraocular pressure (IOP), typically below 21 mm Hg.[3],[4]

With the invention of AS-OCT, we can take detailed, non-contact images of the eye's front part, including filtering blebs. This helps us see the bleb's internal structure better and understand how it might affect the surgery's success. It is a procedure that is both patient-friendly and well-tolerated. that offers quick, high-resolution imaging. without touching the eye directly[5]

Aim And Objectives

- To Study the Architectural Analysis of Post Trabeculectomy Bleb Using AS-OCT
- To analyse structural morphology of bleb after trabeculectomy and study the relation between intrableb morphology and bleb function

Review Of Literature

Trabeculectomy may be deemed necessary when the potential gains from the procedure surpass the associated surgical risks. This surgical option is typically considered for patients whose intraocular pressures are at levels that pose a substantial threat of ongoing damage from glaucoma, potentially leading to significant visual impairment.[6], [7]

In cases where only a moderate reduction in intraocular pressure is required, and the glaucoma is not severely advanced, laser surgery might be an appropriate alternative.[8] However, trabeculectomy is generally indicated for cases where the glaucoma is moderately to severely advanced, the progression of the disease is rapid, previous laser treatments have not been effective, or there is a considerable risk of further progression leading to symptomatic visual disability.[9]

Waibel et al. (2019) evaluated 30 eyes post-trabeculectomy with 0.02% mitomycin-C using AS-OCT. They found 63% of eyes had functioning blebs, with IOP decreasing from 18.4±1.3 mm Hg preoperatively to 9.75±1.4 mm Hg postoperatively. Encapsulated blebs were detected in 30% of cases, characterized by higher bleb height (P=0.005), thinner bleb wall thickness (P=0.036), and elevated IOP at week 3 (P=0.016). Early scarring was observed in only 7% of cases.[10]

Raj and Bahadur et al. (2020) used AS-OCT to analyze 55 eyes with functional blebs one month after trabeculectomy to predict six-month outcomes. Measurements included a subconjunctival fluid space of 0.64 ± 0.26 mm, bleb wall thickness of 0.63 ± 0.25 mm, bleb height of 1.45 ± 0.39 mm, and scleral flap thickness of 0.45 ± 0.068 mm. Significant negative correlations were found between IOP and bleb height at one month ($r = -0.25$, $p = 0.05$), cavity size and IOP at six months ($r = -0.318$, $p = 0.018$), and bleb height and supra-scleral space ($r = -0.31$, $p = 0.02$). The study concluded that AS-O

Kim et al. (2023) studied 68 eyes post-trabeculectomy with amniotic membrane transplantation using AS-OCT. Successful outcomes (56 eyes) showed higher bleb height, wall thickness, striping layer thickness, fluid-filled space scores, and microcyst formation (all $P \leq 0.009$), while failed cases (12 eyes) had higher bleb wall reflectivity ($P < 0.001$). A history of cataract surgery increased the risk of failure (odds ratio 5.769, $P = 0.032$). Successful blebs had a thick striping layer, tall blebs with low reflectivity, and posteriorly extended fluid-filled gaps.[12]

Barua et al. (2023) studied modified trabeculectomy blebs using spectral-domain OCT at a tertiary care center. Functional blebs had an average IOP of 12.5 ± 2.502 mmHg and showed a significant negative correlation between bleb width and vertical subconjunctival depth ($P < 0.0001$). Functional blebs had higher vertical subconjunctival fluid pockets ($P = 0.003$) and thinner walls ($P = 0.007$), while nonfunctional blebs had thicker walls and higher reflectivity. The study highlighted spectral OCT as a useful tool for assessing bleb architecture and functionality using quantitative and qualitative metrics[13]

MATERIALS AND METHODS

The study was conducted on patients at tertiary care centre after written informed consent from either the patients or the guardians.
It was a prospective observational study conducted in 1 year duration.

Inclusion Criteria

- Age >18 years, irrespective of gender
- The eyes had primary glaucoma before trabeculectomy
- IOP measuring more than 21 mmHg

Exclusion Criteria

- Previous eye surgery

- Requirement to perform trabeculectomy alongside cataract extraction
- Immunodeficiency, connective tissue disease, and uncontrolled diabetes

Individuals above the age of 18 years with a clinical diagnosis of glaucoma who underwent trabeculectomy. Postoperatively, patients were prescribed topical dexamethasone six times daily for four weeks with gradual tapering and 0.5% moxifloxacin four times daily for two weeks. Bleb evaluation was performed at each follow-up using AS-OCT, an optical device designed to analyse the anterior segment of the eye.

Three intrableb parameters were measured, Bleb height, bleb wall thickness and internal cavity height in microns (µm) using AS-OCT. Different type of bleb morphologies and intrableb parameters were correlated with IOP control to determine the association between anatomical changes and functional outcomes. Bleb function or IOP control was deemed successful if IOP was less than 21 mmHg without the use of topical anti glaucoma drugs at 6 months.

Technique Of Trabeculectomy:
The eye was anesthetized with 2% lidocaine. A fornix-based conjunctival flap and a 4x4 mm scleral flap were created. A 1x1 mm sclerostomy and a peripheral iridectomy were performed. The scleral flap was sutured with 10-0 nylon, the conjunctival flap was closed, antibiotic drops were applied, and the eye was patched.

Patients were followed up at day 0, 1 week, 3 weeks, 6 weeks, 3 months and 6 months post-trabeculectomy

Statistical Analysis: Collected data were analyzed using software SPSS (Statistical Package for Social Sciences, version 22, SPSS Inc, Chicago, IL) applying statistical tests, and the obtained results were saved in document format.

RESULTS

Table 1: Frequencies of PreOp IOP

Pre Op IOP	Frequency	Percentage of Total(%)
26	7	10.0
28	10	14.2
30	13	18.5
32	15	21.4
34	3	4.2
36	11	15.7
38	5	7.1
40	4	5.7
42	2	2.8

The table shows preoperative IOP distribution: 32 mmHg was most common (21.4%), followed by 30 mmHg (18.5%) and 36 mmHg (15.7%). Lower levels (26 mmHg, 28 mmHg) accounted for 10.0% and 14.2%, while higher levels (38 mmHg, 40 mmHg, 42 mmHg) made up 15.6% of the sample.

Table 2: Bleb Morphology

Bleb type	Counts	Percentage
Diffuse	30	42.9%
Cystic	22	31.4%
Encapsulated	10	14.3%
Flattened	8	11.4%

The table shows that diffuse blebs were the most common (42.9%), followed by cystic blebs (31.4%) and encapsulated blebs (14.3%). Cystic blebs are linked to good IOP control but may cause hypotony, while encapsulated blebs indicate higher IOP and may require additional interventions.

Table 3: Intraocular Pressure (IOP) at follow-up visits

PreOp IOP	32.34 ± 4.30
Follow-Up Time	Mean IOP (mmHg) ± SD
Day 1	10.94 ± 1.62
1 Week	10.85 ± 2.71
3 Weeks	13.51 ± 3.01
6 Weeks	14.85 ± 6.64
3 Months	13.62 ± 5.27
6 Months	12.68 ±7.19

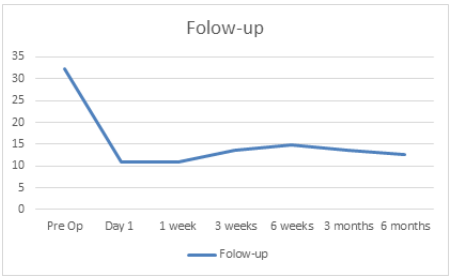

Figure 1: Intraocular Pressure (IOP) at follow-up visits

Preoperative IOP was 32.34 mmHg (±4.30 mmHg). Post-surgery, IOP dropped to 10.94 mmHg (±1.62 mmHg) on Day 1, remained stable in the first week, and gradually increased to 14.85 mmHg (±6.64 mmHg) by 6 weeks. By 3 and 6 months, IOP decreased slightly to 13.62 mmHg (±5.27 mmHg) and 12.68 mmHg (±7.19 mmHg), still lower than preoperative levels.

Table 4: AS-OCT Measurements at Follow-Up

Follow-Up Time	Bleb Height (µm) ± SD	Internal Cavity Height (µm) ± SD	Wall Thickness (µm) ± SD
Day 1 (Baseline)	455.84±154.24	260.68±165.59	183.64±107.76
1 Week	519.38±155.72	300.15±161.18	217.18±123.72
3 Weeks	575.22±178.00	336.41±166.20	241.55±135.69
6 Weeks	643.11±223.41	372.15±187.39	271.12±152.98
3 Months	669.71 ±235.46	394.84±192.23	286.71±159.33
6 Months	714.40±253.16	409.87±198.67	303.10±169.83

The table shows gradual increases in bleb height (455.84µm to 714.40µm), internal cavity height (260.68µm to 409.87µm), and wall thickness (183.64µm to 303.10µm) over 6 months, reflecting healing and bleb formation post-surgery, important for IOP control and bleb functionality.

Table 5: Correlation between intrableb morphology and IOP Control

Variable	Correlation coefficient	p-value
Bleb Height	0.69	0.12
Internal Cavity Height	0.71	0.11
Bleb Wall Thickness	0.69	0.12

The table shows the correlation between intrableb features (bleb height, internal cavity height, and bleb wall thickness) and IOP control at 6 months post-trabeculectomy. Bleb height had a correlation coefficient of 0.69, indicating a moderate positive relationship with IOP control, but the p-value of 0.12 suggests that this correlation is not statistically significant.

Table 6: Success Rate of different bleb morphologies at 6-month follow-up

Bleb morphology	Frequency	IOP Control (success %)
Diffuse	30	100
Cystic	22	100
Encapsulated	1	10.0
Flattened	1	12.5

This table shows that diffuse and cystic blebs had a 100% success rate in IOP control, while flattened and encapsulated blebs had much lower success rates (12.5% and 10%, respectively). Diffuse blebs are the most effective for IOP control, while encapsulated and flattened blebs are associated with poorer outcomes.

DISCUSSION

AS-OCT analysis of post-trabeculectomy blebs has offered valuable insights into their structural morphology and functionality, which are key to understanding the long-term success of trabeculectomy for glaucoma treatment.

High preoperative IOP (30–36 mmHg) in this study indicated advanced glaucoma. While diffuse and cystic blebs were common, 14.3% developed encapsulated blebs after 3 weeks, likely due to fibrosis, limiting IOP reduction.

Zhang Yi et al. (2008) classified blebs via slit-lamp OCT: Diffuse blebs have an aqueous channel, fluid gap, and thick conjunctiva.

Cystic blebs show a broad or medium aqueous cavity. **Encapsulated blebs** are non-functional, with scarring and high echogenicity. **Flattened blebs** lack an aqueous gap and are also non-functional.[14]

Waibel et al. (2019) observed a similar IOP trend, with IOP decreasing immediately after surgery in encapsulated blebs but rising from week 1 to week 4, requiring bleb needling. In contrast, our study did not perform needling, yet postoperative IOP remained consistently low.[10]

Narita et al. (2018) reported an increase in bleb height from 1.264 mm at 2 weeks to 1.640 mm at 1 year. However, they observed a slight decrease in bleb wall thickness, from 0.851 mm at 2 weeks to 0.848 mm at 1 year.[15]

Our study found a positive but statistically insignificant correlation between bleb height, internal cavity height, and bleb wall thickness with IOP ($p \approx 0.12$, $r \approx 0.69–0.71$). In contrast, Fakhraie et al. (2011) reported significant positive correlations for these parameters with IOP ($p<0.001$, $r=0.59–0.91$).[16]

In contrast, Raj and Bahadur et al. (2020) reported a negative correlation between bleb height, bleb wall thickness, and internal cavity height with IOP, though the p-values were non-significant.[11]

Diffuse and cystic blebs had a 100% success rate in controlling IOP, while encapsulated and flattened blebs had much lower success rates of 10% and 12.5%, respectively, due to impaired fluid drainage. **Napoli et al (2014)**[17] showed that diffuse blebs had 62.5% success rate and cystic with 100% success rate with 1310 nm OCT. **Leung et al (2006)** observed 100% success rate in diffuse blebs, 100% in cystic blebs, 33.3% in flattened blebs and failure in encapsulated blebs[18]

CONCLUSION

- Different types of bleb morphologies were observed, with diffuse being the most common, indicating variability that could influence treatment outcomes and strategies in ocular health management.
- Quantitative measurements of filtration blebs post-surgery showed a gradual increase in bleb height, internal cavity height, and wall thickness over six months, highlighting the complex and individualized nature of the healing and remodelling processes.
- IOP dropped sharply in the first two weeks, indicating effective surgery. Slight fluctuations followed, but by 6 months, IOP remained lower than preoperative levels, showing sustained efficacy.
- Diffuse and cystic blebs showed a significant correlation with better IOP control six months post-surgery.
- AS-OCT is a valuable tool for analysing post-trabeculectomy blebs, offering high-resolution images and data that improve understanding of bleb function, guide management, and predict long-term outcomes.

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