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Association of Nasal-Superior Manual Palpebral Fissure Width With Early Outcomes After PRESERFLO™ MicroShunt Implantation

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Abstract

Objective: The aim of this study was to investigate associations between preoperative palpebral fissure dimensions and postoperative outcomes after PRESERFLO™ MicroShunt (Glaukos Corporation, Aliso Viejo, California, United States) implantation.

Methods: This was a single-center prospective cohort study in which 107 eyes of 107 patients were evaluated. Preoperative palpebral fissure height (PFH) and nasal-superior manual palpebral fissure width (NS-mPFW) were measured. Associations with intraocular pressure (IOP) reduction at one, three, six, nine, and 12 months were assessed using Pearson correlation analysis. Factors associated with each measurement were evaluated using multiple linear regression.

Results: Mean PFH and NS-mPFW were 8.47±1.60 mm and 6.75±1.71 mm, respectively. The measurements were positively correlated ($r = 0.467$, $p < 0.001$). Older age was independently associated with smaller values of both parameters. Male sex was associated with larger PFH; right-eye laterality and fewer previous ocular surgeries were associated with smaller NS-mPFW. PFH was not significantly correlated with IOP reduction at any time point. NS-mPFW was positively correlated with IOP reduction at one month ($r = 0.268$, $p = 0.005$), with weaker, nonsignificant correlations thereafter.

Conclusion: NS-mPFW was associated with early postoperative IOP reduction after PRESERFLO MicroShunt implantation. It may complement PFH in assessing the effective surgical space before filtration surgery.

Categories: Ophthalmology, Healthcare Technology
Keywords: filtration surgery, glaucoma, intraocular pressure, palpebral fissure, preserflo microshunt

Introduction

PRESERFLO™ MicroShunt (PMS; Glaukos Corporation, Aliso Viejo, California, United States) is a minimally invasive filtration surgery device that has recently become increasingly widespread in glaucoma surgery [1]. PMS implantation can be performed using a standardised surgical procedure that does not require scleral flap creation and is characterised by relatively low surgeon dependence, including less influence from suture tension [2].

Traditionally, trabeculectomy has been the standard filtering surgery procedure, and since the widespread adoption of mitomycin C-augmented techniques in the 1990s, it has remained the gold standard for glaucoma surgery. However, trabeculectomy includes several factors that depend heavily on surgical skill, such as scleral flap creation and suture adjustment. Consequently, surgical outcomes tend to vary among surgeons [3]. In contrast, PMS implantation is attracting attention as a filtration surgery that has been reported to provide a relatively consistent therapeutic effect with limited inter-surgeon variability [4].

We previously reported that a small palpebral fissure is a risk factor for surgical failure in glaucoma surgery overall [5]. One possible mechanism is that a small palpebral fissure mechanically compresses the bleb, thereby impairing filtration function. Previous studies have also reported that severe prostaglandin-associated periorbitopathy (PAP) is associated with poorer trabeculectomy outcomes [6]. Because PAP causes a small palpebral fissure due to upper lid ptosis, our previous findings were consistent with this report. However, that study evaluated PAP severity subjectively, and few studies have objectively quantified eyelid morphology using quantitative parameters.

Therefore, in the present study, we investigated the association between palpebral fissure width as an objective quantitative parameter and glaucoma surgical outcomes. Furthermore, by focusing on PMS, which has relatively few surgeon-dependent factors, we attempted to minimise the influence of intraoperative factors such as suture tension and scleral flap size in trabeculectomy, thereby enabling evaluation of the direct impact of eyelid morphology on postoperative outcomes of filtration surgery. The purpose of this study was to clarify how quantitative preoperative palpebral fissure width parameters are associated with

postoperative intraocular pressure (IOP) reduction after PMS implantation.

Materials And Methods

This single-centre prospective cohort study included consecutive patients who underwent PMS implantation in the superonasal quadrant at Kobe University Hospital, Kobe, Japan, between October 2023 and May 2025. All procedures were performed by two surgeons (S.M. and M.N.). The study was approved by the Institutional Review Board of Kobe University Hospital (approval number: B260033).

Study population

Eligibility criteria included age ⩾18 years and the ability to complete at least one year of postoperative follow-up at our institution. During the study period, 146 surgical eyes were initially identified. Four were excluded because preoperative photographs could not be obtained, primarily due to severe cognitive impairment or intellectual disabilities; 11 were excluded because 12-month follow-up was incomplete, mainly owing to relocation or travel difficulties; 17 fellow eyes were excluded to avoid including both eyes of one patient; and seven superotemporal PMS implantations performed as subsequent filtration procedures were excluded. The final cohort comprised 107 eyes from 107 patients. All included eyes were followed at Kobe University Hospital for 12 months irrespective of postoperative course.

Surgical procedure

At our institution, the superonasal conjunctiva is routinely selected for the initial filtration surgery; therefore, eyes that had previously undergone trabeculectomy and subsequently received PMS implantation in the superotemporal quadrant as a second filtration surgery were excluded. Details of the surgical technique have been described in our previous reports [5,7,8]. In the present study, 0.04% mitomycin C was applied for three minutes in all cases. Topical corticosteroids were generally continued for three to six months. Glaucoma medications were restarted or added at the surgeon's discretion when IOP exceeded the individualized target. Needling was not routinely performed; bleb revision was undertaken when an additional surgical intervention was indicated.

Measurements and data collection

Two parameters were used to evaluate preoperative palpebral fissure width (Figure *1*). The first was palpebral fissure height (PFH), defined as the vertical distance between the upper and lower eyelids in the natural open-eye position during primary gaze. Measurements were performed using the same method as described in our previous report [8]. The second parameter was nasal-superior manual palpebral fissure width (NS-mPFW), defined as the minimum distance between the eyelid margin and the corneal limbus while the patient was instructed to gaze inferotemporally and the surgeon manually elevated the superonasal upper eyelid. NS-mPFW was considered to represent the effective surgical space available during filtration surgery. Preoperative anterior segment photographs were acquired using the same slit-lamp microscope. Distances were obtained from photographs after correction for image magnification. All measurements were obtained on the day before surgery by the same examiner (S.M.) using the same slit-lamp microscope (SL 130 Slit Lamp; Zeiss, Baden-Württemberg, Germany).

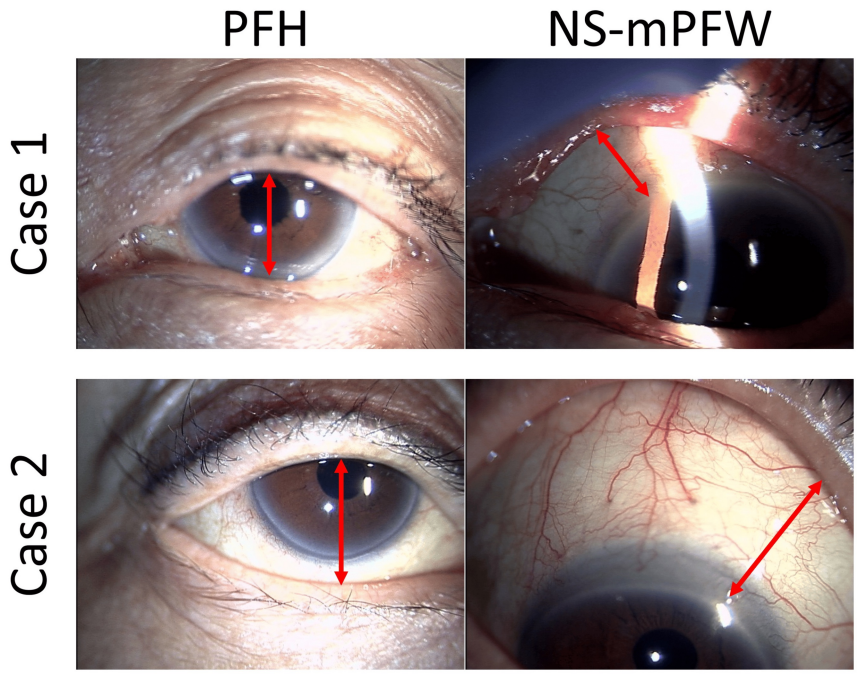


FIGURE 1: Representative cases for quantitative analysis of the palpebral fissure.

Palpebral fissure height (PFH) was defined as the vertical distance between the upper and lower eyelids in the natural open-eye position during primary gaze. Nasal-superior manual palpebral fissure width (NS-mPFW) was defined as the minimum distance between the eyelid margin and corneal limbus while the patient gazed inferotemporally and the surgeon manually elevated the superonasal upper eyelid

Baseline characteristics included age, sex, glaucoma disease type, preoperative IOP, glaucoma drug score (GDS), corneal endothelial cell density, axial length, and previous ocular surgical history in the study eye. GDS was calculated by assigning one point to each topical medication and two points to fixed-combination medications or oral carbonic anhydrase inhibitors [5,7]. For eyes requiring reoperation, other than bleb revision, within one year after surgery, data obtained immediately before reoperation were used as the final postoperative assessment.

Outcomes

Surgical variables included operating surgeon and whether concomitant cataract surgery was performed. Postoperative outcome measures included IOP and GDS at one year after surgery. Surgical success was defined according to our previous report [5] as fulfilment of all of the following criteria: (i) IOP ⩽21 mmHg; (ii) at least a 20% reduction from preoperative IOP; and (iii) no additional glaucoma surgery or bleb revision procedure. Among the 26 eyes classified as surgical failures during 12 months, early failure was defined as failure to meet the predefined composite success criteria at the one-month postoperative assessment or the need for additional glaucoma surgery or bleb revision within the first month. Late failure was defined as subsequent failure in eyes that initially met all success criteria at one month.

The primary outcome measure was the association between palpebral fissure width and postoperative outcomes. Associations between PFH or NS-mPFW and the postoperative IOP reduction rate were analysed using Pearson's correlation coefficient. As a secondary outcome, multiple linear regression analysis was performed to identify preoperative factors associated with palpebral fissure width. In addition, the relationship between PFH and NS-mPFW was evaluated as an exploratory analysis using Pearson's correlation coefficient.

Statistical analysis

Logistic regression was used to examine failure by 12 months separately for PFH and NS-mPFW, with univariable and baseline-IOP-adjusted models. Odds ratios were defined per 1 mm increase. Both analyses used 107 eyes and 26 failures. A longitudinal mixed-effects analysis was also proposed for repeated IOP reduction measurements, with time, eyelid measurement, and interaction as fixed effects and a patient-specific random intercept. Group comparisons were exploratory and used Mann-Whitney U and Fisher

exact/chi-square tests as appropriate.

Multivariable linear regression was used to assess the association of NS-mPFW with percentage IOP reduction at one month, adjusting for baseline IOP, combined cataract surgery, number of previous ocular surgeries, and operating surgeon. Heteroscedasticity-robust (HC3) standard errors were used for 95% confidence intervals (CIs) and p-values.

A longitudinal linear mixed-effects model was fitted to percentage IOP reduction at one, three, six, nine, and 12 months. Postoperative time was treated as categorical. NS-mPFW, time, and their interaction were included as fixed effects, together with baseline IOP, combined cataract surgery, number of previous ocular surgeries, and operating surgeon. A patient-specific random intercept accounted for within-eye correlation. Maximum likelihood estimation was used; the overall time-by-NS-mPFW interaction was tested using a four-degree-of-freedom Wald test.

Results

Patient characteristics and postoperative outcomes are summarised in Table *1*. A total of 107 eyes from 107 patients were included in the analysis. The mean age was 71.3±12.0 years. Regarding glaucoma disease type, 82 eyes (76.6%) had primary open-angle glaucoma, 18 eyes (16.8%) had exfoliation glaucoma, and seven eyes (6.5%) had other secondary glaucomas, including glaucoma following vitrectomy. Concomitant cataract surgery was performed in 37 eyes (34.6%). The number of previous ocular surgeries was 0 in 44 eyes, one in 56 eyes, and two in seven eyes; most previous procedures were cataract surgery or ab-interno trabeculotomy. The mean preoperative PFH was 8.47±1.60 mm, and the mean NS-mPFW was 6.75±1.71 mm. The mean IOP decreased from 24.8±8.9 mmHg preoperatively to 13.5±4.8 mmHg at one year postoperatively. The mean postoperative IOP reduction rate at one year was 39.6±26.6%. At 12 months, 81 eyes (75.7%) met the success criteria and 26 eyes (24.3%) were classified as failures.

Parameters		Values
Age (years)		71.3 ± 12.0
Sex	Male	50 (46.7%)
	Female	57 (53.3%)
Laterality	Right eye	49 (45.8%)
	Left eye	58 (54.2%)
Glaucoma	Primary open-angle glaucoma	82 (76.6%)
	Exfoliation glaucoma	18 (16.8%)
	Other secondary glaucoma	7 (6.5%)
Surgery details	Combined cataract surgery	37 (34.6%)
	Surgeon A	54 (50.5%)
	Surgeon B	53 (49.5%)
	General anesthesia	2 (1.9%)
	Number of previous ocular surgeries	0.65 ± 0.60
Preoperative measures	Preoperative IOP, mmHg	24.8 ± 8.9
	Preoperative glaucoma medication score	4.2 ± 1.4
	Humphrey visual field MD, dB	-17.8 ± 7.9
	Axial length, mm	25.17 ± 2.07
	PFH, mm	8.47 ± 1.60
	NS-mPFW, mm	6.75 ± 1.71
Postoperative outcomes at 12 months	IOP at 12 months, mmHg	13.5 ± 4.8
	Glaucoma medication score at 12 months	1.0 ± 1.7
	IOP reduction at 12 months, %[b]	39.6 ± 26.6
	Reoperation, including bleb revision[c]	15 (14.0%)
	Bleb revision	11 (10.3%)
	Surgical success	81 (75.7%)

TABLE 1: Preoperative characteristics and 12-month outcomes after PRESERFLO™ MicroShunt* implantation (N=107 eyes)

Values are presented as mean ± standard deviation or n (%).

*Glaukos Corporation, Aliso Viejo, California, United States

IOP, intraocular pressure; MD, mean deviation; PFH, palpebral fissure height; NS-mPFW, nasal-superior manual palpebral fissure width.

To identify preoperative factors associated with palpebral fissure width, multiple linear regression analysis was performed using age, laterality, sex, axial length, preoperative IOP, preoperative glaucoma drug score (GDS), and number of previous ocular surgeries as explanatory variables (Table *2*). Older age was independently associated with smaller PFH values (B = −0.035 mm per year, p = 0.011), whereas male sex was associated with larger PFH values than female sex (B = 0.776 mm, p = 0.014). Older age (B = −0.050 mm per year, p < 0.001) and right-eye laterality relative to left-eye laterality (B = −0.717 mm, p = 0.026) were independently associated with smaller NS-mPFW values. A greater number of previous ocular surgeries was associated with larger NS-mPFW values (B = 0.552 mm per surgery, p = 0.041).

Factor	PFH		NS-mPFW	
	B (95% CI)	P-value	B (95% CI)	P-Value
Age (per year)	-0.035 (-0.062, -0.008)	0.011	-0.050 (-0.079, -0.021)	<0.001
Right eye (vs left eye)	-0.170 (-0.754, 0.413)	0.564	-0.717 (-1.344, -0.090)	0.026
Male sex (vs female sex)	0.776 (0.163, 1.389)	0.014	-0.072 (-0.731, 0.587)	0.829
Axial length (per mm)	0.016 (-0.136, 0.169)	0.832	-0.015 (-0.179, 0.149)	0.857
Preoperative IOP (per mmHg)	0.019 (-0.016, 0.054)	0.295	0.021 (-0.016, 0.059)	0.263
Preoperative glaucoma medication score (per point)	-0.034 (-0.259, 0.191)	0.768	-0.131 (-0.373, 0.111)	0.287
Number of previous ocular surgeries (per surgery)	0.186 (-0.306, 0.679)	0.455	0.552 (0.022, 1.081)	0.041

TABLE 2: Multiple linear regression analysis of factors associated with PFH and NS-mPFW

B represents the unstandardized regression coefficient (mm), with its 95% CI. Each model simultaneously included all seven factors listed above. P values are two-sided and based on ordinary least squares regression with conventional standard errors. Coefficients were evaluated using two-sided t tests with 99 residual degrees of freedom. Overall model tests were PFH: $F(7, 99) = 3.30$, $p = 0.003$, and NS-mPFW: $F(7, 99) = 3.20$, $p = 0.004$.

CI, confidence interval; IOP, intraocular pressure; PFH, palpebral fissure height; NS-mPFW, nasal-superior manual palpebral fissure width.

The relationship between PFH and NS-mPFW is shown in Figure *2*. A significant positive correlation was observed between the two parameters ($r = 0.467$, 95% CI 0.304-0.603, $p < 0.001$). However, considerable variability between the two measurements was observed. Twenty-two eyes (20.6%) had a difference of ⩾3 mm between PFH and NS-mPFW, and in 21 of these eyes, NS-mPFW was smaller than PFH.

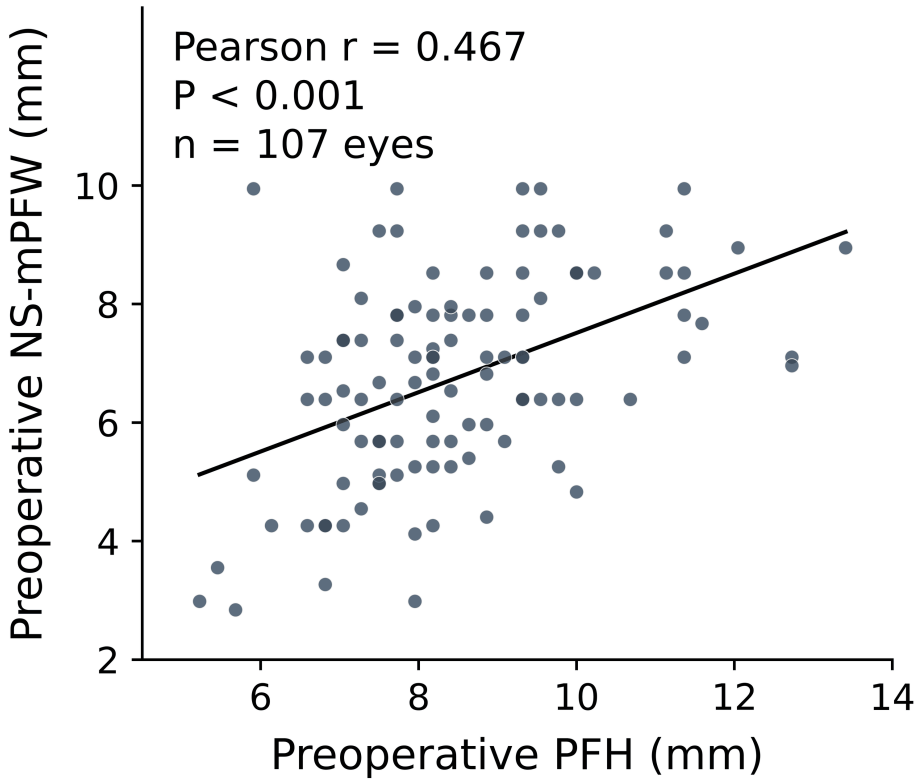


FIGURE 2: Correlation between palpebral fissure height (PFH) and nasal-superior manual palpebral fissure width (NS-mPFW).

Circles represent individual eyes (n = 107). Pearson's correlation coefficient was r = 0.467 (p < 0.001). The solid line is the fitted linear regression line.

The association between PFH and postoperative IOP reduction rate is shown in Figure *3A*. No significant correlation was observed between PFH and IOP reduction rate at any postoperative time point, including one, three, six, nine, and 12 months. The association between NS-mPFW and postoperative IOP reduction rate is shown in Figure *3B*. At one month postoperatively, NS-mPFW demonstrated a weak but statistically significant positive correlation with IOP reduction rate (r = 0.268, p = 0.005). At three, six, nine, and 12 months, the correlations were weaker and not statistically significant (r = 0.127, p = 0.194; r = 0.107, p = 0.274; r = 0.024, p = 0.806; and r = 0.051, p = 0.605, respectively).

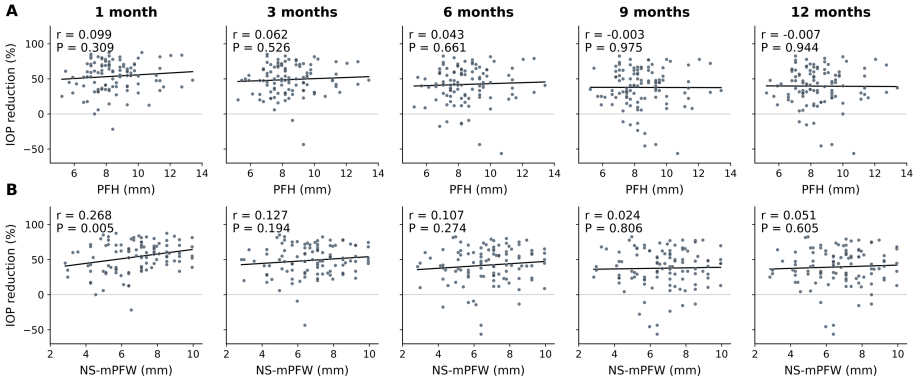


FIGURE 3: Correlations between preoperative palpebral fissure measurements and intraocular pressure (IOP) reduction over time.

Panel A shows PFH and panel B shows NS-mPFW at 1, 3, 6, 9, and 12 months postoperatively, from left to right. Circles represent individual eyes (n = 107 at each time point). Pearson's correlation coefficients and two-sided p values are displayed in each panel. Solid lines are fitted linear regression lines

PFH, palpebral fissure height; NS-mPFW, nasal-superior manual palpebral fissure width.

In multivariable linear regression adjusting for preoperative IOP, combined cataract surgery, previous ocular surgeries, and operating surgeon, NS-mPFW remained associated with IOP reduction at one month (B = 2.27 percentage points per 1-mm increase; 95% CI, 0.56-3.98; p = 0.009; HC3 robust standard errors).

The longitudinal mixed-effects analysis included 535 measurements from 107 eyes. The overall NS-mPFW-by-time interaction was statistically significant (Wald χ^2[4] = 12.39; p = 0.015). The fully adjusted estimated association at one month was 1.89 percentage points per 1 mm increase in NS-mPFW (95% CI, −0.21 to 3.99; p = 0.078). Therefore, the one-month coefficient did not reach statistical significance in this longitudinal model.

We performed an additional analysis of the 26 eyes that ultimately experienced surgical failure. These eyes were divided into an early failure group (13 eyes), defined as failure to achieve at least a 20% reduction in IOP at one month postoperatively, and a late failure group (13 eyes), defined as surgical failure occurring after the first postoperative month (Table *3*). Among the preoperative variables examined, NS-mPFW was the only parameter that differed significantly between the two groups, with a smaller median (interquartile range (IQR)) in the early failure group than in the late failure group (6.0 (4.4-6.4) vs 7.8 (6.5-8.5) mm, p = 0.001). Logistic regression: PFH OR 0.823 (95% CI 0.608-1.114; p = 0.207), adjusted OR 0.861 (95% CI 0.633-1.171; p = 0.339); NS-mPFW OR 0.926 (95% CI 0.715-1.199; p = 0.559), adjusted OR 0.965 (95% CI 0.741-1.256; p = 0.790). Among postoperative factors, GDS at one year was lower in the late failure group (median (IQR), 3 (0-4) vs 3 (2-5) in the early failure group; p = 0.049).

Characteristics	Early-failure group (n = 13)	Late-failure group (n = 13)	P-value
Age, years	77 (68, 84)	70 (64, 76)	0.11
Male sex, n (%)	9 (69)	6 (46)	0.42
Right eye, n (%)	5 (38)	6 (46)	1.00
Glaucoma type, n (%)			
POAG / XFG	9 (69) / 4 (31)	11 (85) / 2 (15)	0.65
Combined cataract surgery, n (%)	5 (38)	6 (46)	1.00
Surgeon A, n (%)	7 (54)	6 (46)	1.00
General anesthesia, n (%)	0 (0)	0 (0)	—[c]
Number of previous ocular surgeries	0 (0, 1)	1 (0, 1)	0.71
Preoperative IOP, mmHg	18 (17, 22)	18 (17, 34)	0.08
Preoperative glaucoma medication score	4 (3, 5)	4 (2, 5)	0.50
HVF mean deviation, dB	−17.8 (−24.4, −12.5)	−17.6 (−26.4, −13.0)	0.44
Axial length, mm	24.3 (22.9, 26.1)	24.9 (23.6, 26.2)	0.81
Corneal endothelial cell density, cells/mm²	2432 (2055, 2774)	2488 (2301, 2638)	0.40
Preoperative PFH, mm	8.2 (7.0, 8.6)	8.2 (7.7, 9.1)	0.44
Preoperative NS-mPFW, mm	6.0 (4.4, 6.4)	7.8 (6.5, 8.5)	0.001
Postoperative outcomes			
IOP at 1 month, mmHg	14 (11, 19)	9 (8, 11)	<0.001
Glaucoma medication score at 1 month	0 (0, 2)	0 (0, 1)	0.78
IOP reduction at 1 month, %	18 (13, 33)	58 (51, 70)	<0.00001
IOP at 12 months, mmHg	16 (15, 20)	16 (14, 21)	0.98
Glaucoma medication score at 12 months	3 (2, 5)	3 (0, 4)	0.049
IOP reduction at 12 months, %	11 (−20, 23)	13 (−3, 28)	0.13
Reoperation, including bleb revision, n (%)	7 (54)	8 (62)	1.00
Bleb revision, n (%)	7 (54)	4 (31)	0.43

TABLE 3: Comparison of the early- and late-failure groups

Data are presented as median (interquartile range) unless otherwise indicated; [c] P-value was not estimable because both groups had zero events.

Binary variables were compared using the Chi-squared test or Fisher's exact test, while quantitative variables were compared using the Mann-Whitney U test. A p-value < 0.05 was considered statistically significant.

POAG, primary open-angle glaucoma; XFG, exfoliation glaucoma; IOP, intraocular pressure; HVF, Humphrey visual field; PFH, palpebral fissure height; NS-mPFW, nasal-superior manual palpebral fissure width.

Discussion

Two principal findings emerged from this study. First, assessment of palpebral fissure width in glaucoma filtration surgery should not rely solely on conventional PFH, and NS-mPFW may provide additional clinically relevant information. Although PFH and NS-mPFW were significantly correlated, considerable variability between the two parameters was observed in a substantial proportion of eyes. In most of these cases, NS-mPFW was smaller than PFH, suggesting that PFH alone may not adequately capture the effective surgical space available during filtration surgery.

To better understand the determinants of these measurements, we examined preoperative factors associated with PFH and NS-mPFW. Increasing age was significantly associated with reductions in both parameters. Previous studies have demonstrated that age-related upper eyelid ptosis contributes to a reduction in PFH [9-11]. Of particular interest, however, NS-mPFW also decreased with advancing age despite being measured during manual eyelid elevation. In aponeurotic ptosis, disinsertion and attenuation of the levator aponeurosis are known to occur [12]. In addition, age-related laxity of the canthal support structures, weakening of orbital connective tissues, and loss of orbital fat have all been reported to reduce the maximal palpebral fissure opening [13]. Collectively, these structural changes may limit the effective surgical space even when the eyelid is manually elevated.

In our previous study evaluating glaucoma surgery as a whole, a greater number of previous surgeries was associated with smaller PFH values [8]. In the present cohort, however, this relationship was not observed. One possible explanation is the difference in the types of previous surgery included in the two studies. Whereas the previous cohort contained eyes with multiple prior glaucoma procedures, including Ahmed Glaucoma Valve implantation, most previous procedures in the present study were cataract surgery or minimally invasive glaucoma surgery. Such procedures may have relatively little influence on postoperative eyelid morphology and therefore a weaker association with PFH.

A second key finding was that NS-mPFW was significantly associated with the postoperative IOP reduction rate at one month following PMS implantation, whereas this association was weaker at later postoperative time points. These findings suggest that palpebral fissure width may influence early bleb development and filtration function, while longer-term surgical outcomes are likely to be governed by different biological processes. The association between NS-mPFW and one-month IOP reduction remained statistically significant in a prespecified-confounder-adjusted cross-sectional linear model, whereas the one-month coefficient from the fully adjusted longitudinal mixed-effects model was not statistically significant. The significant time interaction suggests variation in the association across visits, but does not establish a causal or exclusively early postoperative effect.

Several mechanisms may explain this observation. When the palpebral fissure is narrow, expansion of the filtering bleb may be mechanically restricted. Compression exerted by the upper eyelid on the conjunctiva, together with limitation of superior subconjunctival aqueous diffusion, may result in a smaller and more localised bleb. Consequently, a narrow palpebral fissure could contribute to reduced filtration capacity and less pronounced IOP reduction during the early postoperative period. Previous anterior segment OCT studies have demonstrated associations between bleb extent, postoperative IOP reduction, and surgical success [14,15]. Furthermore, early postoperative bleb leakage has been reported to affect subsequent bleb function [16]. No postoperative bleb leakage was observed in the present study, suggesting that the observed association was unlikely to be attributable to this mechanism.

To explore this hypothesis further, an additional analysis was done of the 26 eyes that ultimately experienced surgical failure, the findings of which support the notion that palpebral fissure width may influence the establishment of effective filtration during the early postoperative period. Rho kinase (ROCK) inhibitors have been reported to suppress activation, proliferation, and transdifferentiation of conjunctival and Tenon's fibroblasts [17]. However, postoperative use of ROCK inhibitors did not differ between the two groups in the present study. Consequently, it remains uncertain whether the observed difference in GDS reflects a biologically meaningful finding or merely a chance observation.

The temporal pattern observed in this study may be interpreted in the context of wound-healing processes following filtration surgery. Wound healing after trabeculectomy is characterised by an acute inflammatory response during the early postoperative period [18]. This is followed by activation, migration, and proliferation of episcleral fibroblasts, angiogenesis, extracellular matrix deposition, and collagen bundle formation [19]. Ultimately, progressive collagen contraction and scar formation lead to long-term remodelling of the bleb.

In the present study, the association between palpebral fissure width and IOP reduction was evident only during the early postoperative period. This finding suggests that mechanical factors related to eyelid anatomy may influence early bleb development and function before fibrosis becomes the dominant determinant of surgical outcome. During later postoperative stages, fibrosis-related bleb dysfunction may ultimately outweigh the effects of mechanical eyelid compression, thereby diminishing the influence of palpebral fissure width on IOP control.

This interpretation is consistent with previous studies evaluating bleb morphology after trabeculectomy. Earlier reports demonstrated that larger bleb extent was associated with surgical success during the first postoperative month, whereas this relationship became less apparent at later time points [20]. Taken together, these findings suggest that bleb size and morphology may be particularly important during the establishment phase of filtration, whereas long-term success may depend more heavily on maintenance of aqueous outflow through a functionally preserved bleb.

From a clinical perspective, these findings suggest that assessment of palpebral fissure width may be most

relevant when estimating the likelihood of successful early bleb formation. In particular, NS-mPFW appeared to provide information that was not fully captured by conventional PFH measurements and may therefore represent a more useful anatomical parameter when evaluating the surgical environment before filtration surgery.

Limitations of the study

This study has several limitations. The single-center Japanese cohort and exclusion of patients without full follow-up limit generalizability. NS-mPFW was obtained from magnification-corrected two-dimensional photographs of a curved surface; gaze direction, lid-elevation force, and precise device insertion meridian were not quantitatively standardized. Only one image acquisition per eye was available, so intra- and interexaminer repeatability were not assessed. The consistent examiner and 107-eye cohort reduce some sources of heterogeneity but do not establish measurement validity. No longitudinal bleb imaging or direct evidence of eyelid compression was available. The correlation at one month was weak, and the five postoperative time-point correlations were exploratory without multiplicity adjustment. Post-intervention IOP measurements were retained after reoperation or bleb revision and may reflect the effects of subsequent treatment rather than PSM implantation alone. These considerations limit causal interpretation and the generalizability of the observed temporal pattern. Therefore, the findings are hypothesis-generating and require prospective reproducibility and anatomical validation.

Conclusions

In this exploratory cohort, NS-mPFW showed a weak association with one-month postoperative IOP reduction after PMS implantation. This association persisted in a confounder-adjusted cross-sectional analysis, but the corresponding one-month estimate in a fully adjusted longitudinal mixed-effects model was not statistically significant. Further studies are needed to validate the measurement and determine its clinical relevance.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Sotaro Mori

Acquisition, analysis, or interpretation of data: Sotaro Mori, Nanami Okuzumi, Makoto Nakamura

Drafting of the manuscript: Sotaro Mori, Nanami Okuzumi

Critical review of the manuscript for important intellectual content: Makoto Nakamura

Supervision: Makoto Nakamura

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Institutional Review Board of Kobe University Hospital issued approval No. B260033. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **AI use statement:** The authors used ChatGTP 4.5 (OpenAI Group PBC, San Francisco, California, United States) as follows: language polishing, and as an additional quality control measure to identify potential numerical discrepancies across the dataset, manuscript text, figures, and tables in the entire manuscript. The English text, initially proofread using ChatGPT, was reviewed by the authors and subsequently refined to ensure greater clarity and coherence. The authors confirm that they have reviewed and verified all AI-assisted content and take full responsibility for the work. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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