DOI: 10.7860/JCDR/2025/75831.21153

Original Article

Ophthalmology Section

Impact of Preoperative Prism Adaptation Test and Patch Test Measurements on Surgery in Concomitant Horizontal Strabismus: A Prospective Interventional Study

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ABSTRACT

Introduction: Concomitant horizontal strabismus poses significant challenges in achieving optimal surgical outcomes, with risks of undercorrection or overcorrection remaining a concern. Preoperative assessment techniques, such as the Prism Adaptation Test (PAT) and Patch Test, have been utilised to better estimate the angle of deviation and plan surgeries accordingly. The PAT is thought to refine surgical corrections by revealing the maximum angle of deviation. However, its specific impact on surgical outcomes-especially in comparison to the patch test-remains underexplored.

Aim: To evaluate the impact of preoperative PAT and patch test measurements on surgical outcomes in patients with concomitant horizontal strabismus, focusing on their role in optimising surgical corrections and minimising postoperative undercorrection and overcorrection.

Materials and Methods: This prospective interventional study was conducted over 15 months at Department of Ophthalmology, Employees' State Insurance Corporation (ESIC) Postgraduate Institute of Medical Sciences and Research (PGIMSR), Basaidarapur, New Delhi, India, from October 2017 to February 2018 and included 30 subjects diagnosed with concomitant horizontal strabismus. Preoperative deviation measurements were obtained using the Prism Bar Cover Test (PBCT) at three distances: near (33 cm), intermediate (6 m), and far (12 m). These measurements were recorded both before and after a one-hour monocular occlusion (patch test). Following this, participants underwent the PAT. Based on their responses to these tests, subjects were categorised into three groups: non responders, patch test responders, and PAT responders. Surgical corrections were planned and performed using the maximum deviation identified by the PAT. Postoperative outcomes were assessed eight weeks after surgery using Hirschberg's test and the Prism Alternate Cover Test (PACT). The study's parameters included analysing preoperative and postoperative deviations, categorisation of test responses, and surgical outcomes. Statistical analysis was conducted using Statistical Package for Social Sciences (SPSS) version 17.0, and a p-value of <0.05 was considered statistically significant.

Results: The study included a total of 30 participants, comprising 18 males and 12 females, with a mean age of 20.83±12.03 years. Among them, 14 individuals presented with esotropia, while 16 exhibited exotropia. The study found that PAT significantly improved surgical outcomes. The actual residual deviation postsurgery ranged from 0 to 16Δ with PAT measurements, compared to an estimated range of 5 to 25Δ if surgeries were based on PBCT measurements before occlusion and 0 to 21Δ after occlusion. The mean residual deviation was lowest in PAT responders (6.8±6.07Δ) compared to patch test responders (8.5±6.09Δ) and non responders (11.5±7.09Δ) (p-value=0.02). Satisfactory alignment was observed in 90% of PAT responders, 80% of patch test responders, and 50% of non responders (p-value <0.04).

Conclusion: The study concludes that the PAT significantly improves surgical precision and outcomes in patients with concomitant horizontal strabismus. By providing a more accurate assessment of deviation angles, the PAT reduces the risk of undercorrection and overcorrection compared to conventional preoperative measurements. These findings highlight the importance of incorporating PAT into preoperative evaluations to achieve optimal postoperative alignment and minimise residual deviations. The study underscores PAT's value in enhancing surgical planning and outcomes, suggesting its routine use in clinical practice. Further research is warranted to evaluate its long-term effects on binocular vision and overall quality of life.

Keywords: Ocular alignment, Prism adaptation techniques, Prism alternate cover test, Strabismus surgery

INTRODUCTION

The accurate measurement of ocular deviations is essential for effective surgical planning in strabismus. Concomitant horizontal strabismus, characterised by consistent misalignment across different gaze directions, presents a challenge in achieving optimal surgical outcomes. Traditional assessments often underestimate deviations, increasing the risk of overcorrection or undercorrection. The PAT has been proposed as a valuable preoperative tool to improve measurement accuracy and refine surgical corrections [1].

The PAT has emerged as a valuable tool for enhancing preoperative assessment by identifying the largest exotropic or esotropic angles. Previous studies have highlighted its role in uncovering latent deviations that are often underestimated by conventional tests [2,3]. Many studies have emphasised PAT's potential to refine surgical alignment, noting its ability to reduce postoperative residual deviations [4-6]. These studies demonstrated that PAT could enhance accuracy in surgical planning, particularly in cases with high variability in measured deviations [4-6]. Despite these advantages, the integration of PAT into routine practice remains limited due to insufficient comparative studies that validate its superiority over traditional methods.

Additionally, the monocular patch test, involving temporary occlusion, has shown promise in revealing underlying deviations by eliminating sensory adaptations such as suppression [7,8]. Although effective, it is rarely studied in conjunction with PAT. A gap exists in the literature regarding the combined use of these tests to refine surgical corrections, reduce the likelihood of alignment errors, and improve binocular vision outcomes.

The present study seeks to fill these gaps by evaluating the combined impact of PAT and patch testing in patients with concomitant horizontal strabismus. By categorising patients into responders and non responders and analysing the surgical outcomes, the present research aims to validate PAT's role in enhancing preoperative precision and reducing postoperative residual deviations. Furthermore, the authors explored how PAT influences outcomes like binocular vision, which are less frequently addressed in existing studies [9].

Author's previous research highlighted the effectiveness of the PAT in accurately identifying the largest deviation angles in patients with concomitant horizontal strabismus, both exotropic and esotropic [10]. The present study builds upon those findings by integrating PAT with patch testing as part of the preoperative assessment process, offering a more nuanced and multifaceted approach to surgical planning. By addressing the limitations of conventional measurement techniques, such as the risk of underestimating the true angle of deviation, the present study aimed to refine surgical target angles, ultimately enhancing postoperative alignment and reducing residual deviations.

The novelty of the present investigation lies in its dual-method evaluation, combining PAT with a one-hour monocular occlusion patch test. This combination not only assesses the full extent of deviation but also identifies patients who may exhibit latent or fluctuating angles that would otherwise go unnoticed during routine examinations. Such a comprehensive preoperative assessment is critical, as it allows surgeons to anticipate and address potential sources of surgical undercorrection or overcorrection, thereby improving both motor outcomes and binocular function postoperatively.

The present study seeks to evaluate the effectiveness of surgical corrections based on PAT and patch test measurements compared to conventional methods. By analysing postoperative residual deviations, binocular alignment, and the rate of reoperations, the research aimed to provide robust evidence supporting the routine use of PAT in clinical practice. In doing so, it not only expands upon existing literature but also offers a new perspective on how combined preoperative assessments can optimise surgical precision in strabismus management.

MATERIALS AND METHODS

The present prospective interventional study was conducted at Department of Ophthalmology, ESIC-PGIMSR, Basaidarapur, New Delhi, India, over 15 months, from October 2017 to February 2018. Approval for the study was secured from the Institutional Ethics Committee at ESI-PGIMSR, Basaidarapur (Ref. No. DM(A) H-19/14/17/IEC/2012-PGIMSR). Prior to participation, written informed consent was obtained from all individuals. Eligible participants were selected from the ophthalmology outpatient clinic at study Institute following defined inclusion and exclusion criteria.

Inclusion and Exclusion criteria: Individuals with a Best-Corrected Visual Acuity (BCVA) of 6/36 or better in both eyes and the ability to fully cooperate during examinations were considered for the study. Patients were excluded if they had a BCVA below 6/36 in either eye, paralytic or restrictive forms of strabismus, previous squint surgeries, or any ocular conditions apart from strabismus. Additional exclusion factors included a history of eye trauma, dissociated vertical deviation, inferior oblique muscle overaction, and the presence of manifest or latent nystagmus.

Study Procedure

The authors measured angle of deviation at a far distance (12 metres), at near (33 cm) and intermediate distances (6 metres) after diagnostic monocular occlusion and the PAT in patients with concomitant horizontal strabismus. Each participant underwent a thorough ophthalmologic assessment, which included evaluating visual acuity, performing cycloplegic retinoscopy and subjective refraction, and measuring strabismus angles using the PBCT (Fresnel Prism & Lens Co., Scottsdale, AZ). Additional tests included the Worth 4-Dot Test (Western Ophthalmic, Lynwood, WA), synoptophore examination, and stereoacuity assessments with random dot stereograms such as the The Netherlands Organisation (TNO) and Randot tests.

Initial deviation measurements were conducted at near (33 cm), standard distance (6 m), and far distance (12 m). To eliminate fusion, the better eye underwent monocular occlusion for one hour, after which deviation was reassessed. Following this, Fresnel prisms were applied as part of the PAT. The next day, deviation measurements were repeated at all three distances-near, distance, and far-ensuring no fusion occurred during the process.

Based on deviation measurements, subjects were divided into three groups to evaluate their response to preoperative tests. The non responders group included individuals whose deviation remained unchanged at all stages-before occlusion, after occlusion, and following the PAT. This indicated no significant adaptation or increase in deviation throughout the process. In contrast, the Patch test responders exhibited an increase in deviation following one hour of monocular occlusion, suggesting that occlusion unmasked a latent deviation, highlighting the potential for further surgical correction.

The PAT responders demonstrated the most significant change, with deviation increasing after PAT application, ultimately achieving stable motor alignment. This classification allowed for a more tailored surgical approach, ensuring that deviation measurements reflected the true misalignment, thereby reducing the risk of undercorrection or overcorrection.

The subjects then underwent strabismus correction surgery based on the maximum angle of deviation identified. All surgeries were performed by a single surgeon following a standardised protocol. For subjects with exotropia, the surgical procedure included unilateral or bilateral lateral rectus recession, with or without medial rectus resection, and with or without inferior oblique recession. For subjects with esotropia, the procedure involved unilateral or bilateral medial rectus recession, with or without lateral rectus resection, and with or without inferior oblique recession. The surgical plans were guided by the Rosenbaum surgical tables [11].

After surgery, subjects were prescribed oral antibiotics (Ciprofloxacin) and a topical antibiotic-steroid combination of Ofloxacin (0.3% w/v) and Prednisolone (1% w/v) for four weeks. The topical steroids were then tapered over an additional two weeks.

Eight weeks after strabismus corrective surgery, residual deviation was measured using Hirschberg's test [12] and the PACT [1,2]. The alignment was classified as follows [13]: Orthotropia, a tropia of ±8 prism diopters (Δ), and all phorias were considered satisfactory alignment. Residual tropia of ≥8Δ was classified as undercorrection. Consecutive tropia of ≥8Δ was classified as overcorrection. Both residual tropia of ≥8Δ and consecutive tropia of ≥8Δ were considered unsatisfactory. Additionally, binocularity and stereopsis were assessed.

The authors evaluated the difference in the deviation measurements obtained by different methods preoperatively. Postoperatively, we calculated the estimated residual deviation to assess the relationships of different preoperative measurement methods by comparing the outcomes if the surgery had been planned according to the PBCT measured before the one-hour patch test, the PBCT measured after the one-hour patch test, and/or the PAT alone.

The authors calculated the estimated residual deviation in two steps. First, the authors determined the differences between the maximum deviation measured by the PAT and the PBCT before occlusion (PAT-BO) and after occlusion (PAT-AO). Second, we added these differences to the actual postoperative residual deviation to estimate what the residual deviation would have been if the surgery had been planned based on the PBCT before occlusion Estimated Residual Deviation Type I (ERD I) or after occlusion (ERD II).

STATISTICAL ANALYSIS

Statistical testing was conducted with the statistical package for the social sciences system version SPSS 17.0. Continuous variables were presented as mean±Standard Deviation (SD) or median (interquartile range) for non normally distributed data. Categorical variables were expressed as frequencies and percentages. The comparison of normally distributed continuous variables between the groups was performed using Analysis of Variance (ANOVA). The difference between continuous variables was assessed using a paired t-test. Nominal categorical data between the groups were compared using the Chi-squared test or Fisher's-exact test as appropriate. Non normally distributed continuous variables were compared using the Kruskal-Wallis test, and further paired comparisons were conducted using the Mann-Whitney U test. For all statistical tests, a p-value of less than 0.05 was taken to indicate a significant difference.

RESULTS

The study included a total of 30 participants, comprising 18 males and 12 females. Among them, 14 individuals presented with esotropia, while 16 exhibited exotropia. Age distribution analysis revealed that 12 participants were within the 0-15 year age bracket, 13 fell into the 15-30 year range, and the remaining five were over the age of 30, with a mean age of 20.83±12.03 years.

A total of 12 participants (40%) presented with deviations between 20-40Δ, comprising seven individuals with esotropia and five with exotropia. Another 12 subjects (40%) exhibited deviations in the range of 40-60Δ, including five esotropic and seven exotropic cases. Deviations between 60-80Δ were observed in 5 participants (16.67%), with one case of esotropia and four cases of exotropia. A total of 1 participant (3.33%) demonstrated a deviation within the 80-100Δ range, classified as esotropic. Statistical analysis revealed no significant difference between the esotropic and exotropic groups, with a p-value of 0.36 [Table/Fig-1]. Details of changes in deviation at entry level, post-patch test, and post-PAT are presented in [Table/Fig-2].

Deviation range (Δ)	Total subjects (%)	Esotropes (n)	Exotropes (n)	p-value
20-40	12 (40%)	7	5	0.36
40-60	12 (40%)	5	7	
60-80	5 (16.67%)	1	4	
80-100	1 (3.33%)	1	0	
Total	30 (100%)	14	16	

[Table/Fig-1]: Distribution of deviation measurements between esotropes and exotropes.
Test used: Chi-square test (for categorical comparison between esotropes and exotropes)

As it can seen from [Table/Fig-3], the actual residual deviation ranged from 0 to 16Δ as we used PAT measurements for the surgical planning. However, if the surgery was planned according to the PACT measured before and after occlusion, the authors estimate that the residual deviation would have ranged from 5 to 25Δ and 0 to 21Δ, which is more than the actual results obtained. The mean residual deviation obtained was 6.8±6.07, as the authors had considered PAT measurements, but it would have been 11.5±7.09Δ if measurements taken before occlusion had been considered, and 8.5±6.09Δ if measurements taken after occlusion had been

Patient number	Maximum deviation measured by PACT before occlusion (BO) (Δ)	Maximum deviation measured by PACT after occlusion (AO) (Δ)	Maximum deviation measured by PAT (Δ)	Difference in post patch test and the PACT measurements before occlusion (PAT-BO) (Δ)	Difference in PAT and the PACT measurements after occlusion (PAT-AO) (Δ)	Category of the patient	Postoperative residual deviation (Δ)	Results	ERD I (Res. Dev. + (PAT-BO)) (Δ)	ERD II (Res. Dev. + (PAT-AO) (Δ)
1	85	85	85	0	0	NR	10 (T)	N	10	10
2	75	75	75	0	0	NR	10 (T)	N	10	10
3	60	60	60	0	0	NR	8 (T)	S	8	8
4	40	45	50	10	5	PR<PATR	0	S	10	5
5	35	35	35	0	0	NR	6 (T)	S	6	6
6	50	50	50	0	0	NR	12 (T)	N	12	12
7	25	30	35	10	5	PR<PATR	4 (P)	S	14	9
8	25	30	35	10	5	PR<PATR	6 (P)	S	16	11
9	30	30	35	5	5	PATR	8 (P)	S	13	13
10	25	25	30	5	5	PATR	10 (T)	N	15	15
11	25	30	30	5	0	PR=PATR	8 (P)	S	13	8
12	45	50	50	5	0	PR=PATR	12 (P)	S	17	12
13	25	30	30	5	0	PR=PATR	8 (P)	S	13	8
14	45	50	50	5	0	PR=PATR	12 (P)	S	17	12
15	65	65	65	0	0	NR	6 (P)	S	6	6
16	30	35	40	10	5	PR<PATR	0	S	5	5
17	20	30	30	10	0	PR=PATR	6 (P)	S	16	6
18	65	70	70	5	0	PR=PATR	10 (P)	S	15	10
19	45	45	45	0	0	NR	10 (T)	N	10	10
20	70	75	75	5	0	PR=PATR	8 (T)	S	13	8
21	35	35	35	0	0	NR	-10 (T)	N	-10	-10
22	55	65	70	15	5	PR<PATR	10 (T)	N	25	15
23	50	55	55	5	0	PR=PATR	10 (P)	S	15	10
24	30	35	35	5	0	PR=PATR	0	S	5	0
25	45	45	45	0	0	NR	12 (P)	S	12	12
26	35	35	35	0	0	NR	6 (T)	S	6	6
27	45	45	50	5	5	PATR	-12 (T)	N	-7	-7
28	55	60	60	5	0	PR=PATR	8 (T)	S	13	8

29	55	55	60	5	5	PATR	16 (P)	S	21	21
30	35	40	45	10	5	PR<PATR	10 (P)	S	20	15

[Table/Fig-2]: Change to maximum angle of deviation following patch test and PAT (Δ).
Categorisation of patients based on response following the patch test and PAT (Δ), actual residual deviation, and estimated residual deviation is summarised. Patients from serial numbers 1 to 14 are esotropic, and those from 15 to 30 are exotropic. PACT=Prism Alternate Cover Test, PAT=Prism Adaptation Test, NR=Non responders, PR=Patch Test Responders, PATR=PAT Responders, S=Postoperative Satisfactory Alignment, N=Postoperative Unsatisfactory Alignment, T=Residual Tropia, P=Phoria, PAT-BO=Maximum Deviation Measured by the PAT and PBCT Before Occlusion, PAT-AO=Maximum Deviation Measured by the PAT and PBCT After Occlusion, ERD I=Actual Postoperative Residual Deviation+(PAT-BO), ERD II=Actual Postoperative Residual Deviation+(PAT-AO). (Data presented in [Table/Fig-2] overlap with previously published results in reference 10. The information used here is consistent with the data reported in that study, with proper citation and acknowledgment of the source.)

considered [Table/Fig-3]. Thus, the residual deviation would have been greater in these two cases.

Estimated residual deviation/ Estimated overcorrection	PACT before occlusion (Mean±SD, Range) (Δ)	PACT after occlusion (Mean±SD, Range) (Δ)	PAT (Mean±SD, Range) (Δ)	p-value
Estimated residual deviation	11.5±7.09 (5 to 25)	8.5±6.09 (0 to 21)	6.8±6.07 (0 to 16)	0.02
Estimated overcorrection	-9.5±2.5 (-12 to -7)	-9.5±2.5 (-12 to -7)	-11±0.5 (-12 to -10)	0.06

[Table/Fig-3]: Comparison of residual deviation left after corrective surgery.
PACT: Prism alternate cover test; PAT: Prism adaptation test; SD: Standard deviation. Statistical analysis was performed using a paired t-test to compare mean residual deviations between PAT measurements and PACT measurements taken before and after occlusion

The authors also analysed the results in terms of non responders, patch test responders, and PAT responders. It was observed that the residual deviation left after strabismus surgery was greater in the non responder group, with the median being 13Δ. The patch test responder group showed a median residual deviation of 10Δ, while PAT responders showed the minimum residual deviation left, with a median of 9Δ. The p-value is 0.02, indicating a significant difference [Table/Fig-4].

	Non responders (Median, Range) (Δ)	Patch test responders (Median, Range) (Δ)	PAT Responders (Median, Range) (Δ)	p-value
Residuals deviation	13 (5-25)	10 (0-21)	9 (0-16)	0.02

[Table/Fig-4]: Comparison of residual deviation left after corrective surgery among the three groups of subjects.
PAT: Prism adaptation test. Test Applied: Kruskal-Wallis H Test

Postoperatively, satisfactory results were observed in 5 non responder subjects (50%), 8 patch test responder subjects (80%), and 9 PAT responder subjects (90%). Non satisfactory results were found in 5 non responder subjects (50%), 2 patch test responders (20%), and 1 PAT responder subject (10%), with a p-value of 0.04 [Table/Fig-5].

Group (n)	Satisfactory results n (%)	Non satisfactory results n (%)	p-value
Non responders (10)	5 (50%)	5 (50%)	0.05
Patch test responders (10)	8 (80%)	2 (20%)	
PAT responders (10)	9 (90%)	1 (10%)	

[Table/Fig-5]: Comparison of satisfactory result after corrective surgery among the three groups of subjects.
PAT: Prism adaptation test. Test used: Chi-square test for independence (χ^2 test)

None of the subjects had any stereopsis or binocularity preoperatively and showed either alternate or unilateral suppression. However, postoperatively, some subjects did gain binocularity and stereopsis. Among the 14 esotropic subjects, postoperatively, 8 subjects (57.1%) had uniocular or alternate eye suppression, 3 subjects (21.4%) had the capacity for fusion but without stereopsis, and 3 subjects (21.4%) had gained stereopsis to varying extents. Among the 16 exotropic subjects, postoperatively, 7 subjects (43.8%) had uniocular or alternate eye suppression, 3 subjects (18.8%) had the capacity for fusion but without stereopsis, and 6 subjects (37.5%) had gained stereopsis to varying extents. However, this difference was not significant (p-value=0.634) [Table/Fig-6].

Postoperatively, 3 subjects (10%) gained better stereopsis of 240 seconds of arc (TNO) or in the range of 250-499 seconds of arc

Group (n)	Suppression n (%)	Fusion without stereopsis n (%)	Gained stereopsis n (%)	p-value
Esotropic (n=14)	8 (57.1%)	3 (21.4%)	3 (21.4%)	0.634
Exotropic (n=16)	7 (43.8%)	3 (18.8%)	6 (37.5%)	

[Table/Fig-6]: Comparison of postoperative binocularity and stereopsis outcomes between esotropic and exotropic subjects.
Test applied: Chi-square test

(Randot); and 12 subjects (40%) gained stereopsis of 480 seconds of arc (TNO) or in the range of 500-600 seconds of arc (Randot).

DISCUSSION

The authors planned the surgery according to the maximum deviation measured by the different methods. However, if they had planned the surgery according to the PACT measured before the one-hour patch test, the PBCT measured after the one-hour patch test, and/or the PAT alone, they estimated that the residual deviation would have been greater, as can be seen from the above calculations. This finding is consistent with existing literature, which highlights the utility of PAT in fine-tuning surgical corrections [2,14-18]. By offering a more precise assessment of the deviation angle, PAT helps mitigate the risks of both under- and overcorrection, thereby improving surgical outcomes [2,14-18]. Previous studies, including those by Dadeya et al., and Ohtsuki et al., have emphasised the importance of preoperative PAT in achieving positive surgical outcomes for exotropic patients, especially when the surgery is guided by the changes in the angle of deviation observed after PAT [1,18]. The Prism Adaptation Study Research Group highlighted the significant benefits of using prism-adapted angles in surgical planning for esotropia [19]. In the present study, 89% of subjects in the PAT group had successful outcomes, compared to 79% in the non PAT group. Participants who underwent surgical correction based on measurements from the PAT were categorised as PAT positive, while those who received surgery based on conventional measurements were categorised as non PAT. The present study revealed that 90% of PAT responders achieved satisfactory results, compared to 80% of patch test responders and only 50% of non responders.

In the Prism Adaptation Study (PAS), fusion and motor alignment were achieved in 43 out of 61 (69%) PAT-positive subjects who were operated on for the prism-adapted angle, compared to 69 out of 127 (54%) non prism-adapted subjects [19]. Furthermore, the prism-adapted group had a mean postoperative residual deviation of 3±4.1Δ, whereas the non prism-adapted group had a higher residual deviation of 6.2±6.5Δ. Notably, only 10% of PAT responders had residual esotropia greater than 8Δ, compared to 22% in the non prism-adapted group. Overcorrection was also less common in the PAT group, with only one case, compared to five cases in the non prism-adapted group.

In the present study population of esotropic subjects, the postoperative outcomes revealed that 7.14% achieved orthophoria, 50% had residual esophoria, 14.28% had residual esotropia of ≤8Δ, and 28.57% had residual esotropia of >8Δ, with no cases of overcorrection. For exotropic subjects, 12.5% achieved orthophoria, 43.75% had residual exophoria, 18.75% had residual exotropia of ≤8Δ, 12.5% had residual exotropia of >8Δ, and 12.5% were overcorrected to consecutive esotropia. These results indicate a generally positive outcome, with higher rates of satisfactory alignment observed in PAT responders.

The present findings align with those of the PAS study. When comparing outcomes based on response to preoperative tests, satisfactory results were observed in 50% of non responder subjects, 80% of patch test responders, and 90% of PAT responders. This underscores the efficacy of PAT in optimising surgical outcomes. PAT responders consistently showed better alignment and fewer cases of significant residual deviations or overcorrection compared to non responders and patch test responders.

Repka MX et al., conducted a study similar to ours and reported success rates of 90% in PAT-adapted subjects compared to 74% in non PAT-adapted subjects [12]. This highlights the significant advantage of using PAT in surgical planning for strabismus patients. The mean postoperative residual deviation was also lower in prism-adapted subjects (1.4±7.9Δ) compared to non prism-adapted subjects (3.1±6.7Δ), indicating more precise surgical corrections with PAT. However, the incidence of satisfactory motor results was slightly lower in prism-adapted subjects (69%) compared to non prism-adapted subjects (77%). Interestingly, the percentage of subjects achieving a level of stereopsis of 60 seconds of arc or better was higher in prism-adapted subjects (62%) compared to non prism-adapted subjects (52%), suggesting a potential benefit of PAT in improving binocular vision outcomes.

In the present study, the mean residual deviation was 6.8±6.07Δ when considering PAT measurements. However, if measurements taken before occlusion had been considered, the mean residual deviation would have been higher at 11.5±7.09Δ. Similarly, if measurements taken after occlusion had been considered, the mean residual deviation would have been 8.5±6.09Δ. This discrepancy underscores the importance of considering PAT measurements in surgical planning, as they lead to more accurate assessments of deviation angles and, ultimately, more precise surgical corrections. Had authors relied solely on measurements taken before or after occlusion, the residual deviation would have been significantly greater in both cases, highlighting the potential for suboptimal surgical outcomes without the use of PAT.

Velez FG and Rosenbaum AL conducted a comprehensive study on the long-term results of PAT in subjects with acquired esotropia [17]. They found that the residual esotropia at near was substantially lower in the prism-adapted group (3±3.8Δ) compared to the non prism-adapted group (11.5±8.12Δ). At the last follow-up examination, subjects in the prism-adapted group demonstrated superior alignment outcomes compared to those in the non prism-adapted group. Specifically, 100% of prism-adapted subjects achieved primary motor success at both near and distance, compared to only 42% and 78%, respectively, in the non prism-adapted group. Furthermore, a greater percentage of prism-adapted subjects achieved postoperative orthotropia at both near (18%) and distance (29%) compared to the non prism-adapted group (10% at near and 10% at distance).

Importantly, Velez FG and Rosenbaum AL observed that significantly more prism-adapted subjects had residual esotropia at distance within 9Δ (76% of prism-adapted subjects vs. 31% of non prism-adapted subjects), with no prism-adapted subjects resulting in residual esotropia larger than 9Δ. In contrast, a substantial proportion of non prism-adapted subjects had residual esotropia larger than 9Δ at both near (57%) and distance (21%). Additionally, no subjects in the non prism-adapted group experienced long-term overcorrection, whereas one prism-adapted subject did.

Ela Dalman N et al., conducted a study on subjects with acquired esotropia, revealing significant insights into the preoperative and postoperative outcomes associated with PAT [20]. Postoperatively, subjects exhibited improved alignment, with a mean angle of deviation of 5.2±1.5Δ at near and 1.3±3.3Δ at distance. Notably, all subjects were aligned within a narrow range between 6Δ of exotropia and 5Δ of esotropia at distance. However, 17.2% of subjects developed consecutive exotropia at a distance equal to or less than 6Δ, indicating a potential complication of the surgical intervention. At near, residual esotropia ranged between 2Δ and 8Δ, with none of the subjects experiencing overcorrection. Furthermore, the majority of subjects (82.7%) achieved a sensorial response at near, indicating improved binocular vision outcomes.

In the present study, the authors observed similar trends, with better postoperative outcomes noted in the PAT responder group. However, a limitation of the present study was the short duration, which prevented authors from observing long-term results. They estimated that the residual deviation would have ranged from 5 to 25 prism diopters (Δ) and 0 to 21Δ, which is higher than the actual results obtained.

Ohtsuki H et al., reported on a cohort of 31 subjects who underwent surgery based on prism-adapted angles and were followed for 12 months. At the one-year mark, 84% of the subjects (26 out of 31) achieved both motor and sensory success [21]. However, 5 (16%) subjects had residual esotropia greater than 10Δ, and 3 (10%) subjects developed consecutive exotropia ranging from 1 to 10Δ. The mean distance angle of deviation after one year of strabismus correction surgery was 6.9±7.4Δ, demonstrating a significant level of alignment, but also indicating some residual deviations.

These findings align with those of the present study. In the present study population, the outcomes varied significantly among different groups. Satisfactory results were observed in 50% of non responder subjects, 80% of patch test responder subjects, and 90% of PAT responder subjects. This indicates that PAT responders had the highest success rate, suggesting the efficacy of PAT in preoperative planning.

The authors found that the actual residual deviation ranged from 0 to 16Δ when using PAT measurements for surgical planning. If they had planned the surgeries based on the Prism and Alternate Cover Test (PACT) measurements taken before and after occlusion, they estimate that the residual deviation would have ranged from 5 to 25Δ and 0 to 21Δ, respectively. This comparison underscores the greater precision achieved with PAT, as evidenced by the mean residual deviation obtained: 6.8±6.07Δ with PAT, compared to an estimated 11.5±7.09Δ before occlusion and 8.5±6.09Δ after occlusion. Thus, using PAT measurements significantly reduced the residual deviation and improved surgical outcomes.

Comparing the residual deviation after corrective surgery among the three groups (non responders, patch test responders, and PAT responders), the authors found a significant difference, with a p-value of 0.0001 ($p<0.05$). This statistical significance highlights the superior efficacy of PAT in achieving optimal postoperative results compared to the other methods.

Altman M et al., and Akbari MR et al., documented impressive surgical success rates among patients who responded to PAT, achieving outcomes of 90% and 100%, respectively [22,23]. These results highlight the significant role PAT can play in enhancing surgical precision and improving alignment in esotropic patients. Despite these promising findings, Akbari MR et al., noted that such positive outcomes might not extend to individuals presenting with smaller deviations, particularly those with an angle of deviation less than 30Δ [23]. This observation implies that the effectiveness of PAT could be influenced by the magnitude of the initial deviation, suggesting that its benefits may be more pronounced in cases with larger angles. Consequently, these findings emphasise the importance of customising preoperative strategies based on individual patient profiles to optimise surgical success.

In the study by Quigley C et al., partially accommodative esotropic patients who underwent surgery based on the PAT-adapted motor response had a surgical success rate of 73% [24]. While commendable, this rate is slightly lower than the success rates reported by Hwang JM et al., and Repka MX et al., which were 88% and 90%, respectively, for PAT responders [13,19]. This slight variation in success rates highlights the complexity and variability in surgical outcomes for esotropic patients. Hwang JM et al., documented an 88% success rate among patients who responded to the PAT, which was statistically similar to the 81% success rate observed in individuals who underwent augmented surgical procedures [13]. These findings illustrate that although PAT demonstrates significant efficacy, enhanced surgical techniques also produce favourable outcomes. This suggests that both PAT and surgical augmentation serve as effective methods for treating partially accommodative esotropia, providing clinicians with diverse yet reliable approaches to optimise patient outcomes.

Multiple studies have validated the present results, demonstrating that an increase in esodeviation after performing the PAT serves as a dependable indicator for predicting favourable surgical results and enhanced functional outcomes [25,26]. Research by Wygnanski-Jaffe T et al., emphasised the effectiveness of PAT in accurately identifying the surgical target angle, particularly in patients with convergence excess esotropia, reinforcing the value of PAT as an essential diagnostic method [16].

Furthermore, none of the subjects exhibited stereopsis or binocularity, showing either alternate or unilateral suppression preoperatively. However, postoperatively, some subjects did gain binocularity and stereopsis, although the overall postoperative stereoacuity in the present study was poor. In the study population, satisfactory results were observed in 50% of non responder subjects, 80% of patch test responder subjects, and 90% of PAT responder subjects. Despite these satisfactory motor alignment results, the gain in stereopsis was less frequent. This may be attributed to the large angle of deviation present for a prolonged duration before surgery. When subjects develop constant large-angle strabismus, they often lose stereopsis, which may not be fully recoverable even after successful surgical alignment, as recovery of stereopsis is partly dependent on the timing of the intervention.

According to the PAS, postoperative motor and sensory alignment were better in the PAT responder group [19]. Repka MX et al., found that 62% of prism-adapted subjects achieved a level of stereopsis of 60 seconds of arc or better, compared to 52% of non prism-adapted subjects [12]. Three years after strabismus correction surgery, a significant difference in Binocular Single Vision (BSV) and stereoacuity was observed between the two groups. Specifically, 83% of prism-adapted subjects demonstrated BSV at five metres, compared to only 57% of non prism-adapted subjects. Additionally, 59% of prism-adapted subjects exhibited better stereoacuity, while only 43% of non prism-adapted subjects achieved stereoacuity better than 60 seconds of arc. Furthermore, based on the Bagolini lens test, BSV at distance was present in 83% of prism-adapted subjects compared to 57% of non prism-adapted subjects.

These findings underscore the effectiveness of PAT in improving both motor and sensory outcomes postoperatively. The higher rate of satisfactory motor alignment and better stereoacuity in prism-adapted subjects highlights the importance of accurate preoperative assessment and the potential benefits of PAT in surgical planning for strabismus. However, the challenge remains in restoring stereopsis, particularly in cases with long-standing large-angle deviations. Early intervention and precise preoperative measurements, as facilitated by PAT, may enhance the likelihood of achieving both motor and sensory success in strabismus surgery.

Limitation(s)

While the study provides valuable insights into the role of PAT and the patch test in refining surgical outcomes for concomitant horizontal strabismus, it has certain limitations that warrant consideration. Firstly, the relatively small sample size (30 participants) may limit the generalisability of the findings to broader populations with varying severities of strabismus. Larger, multicentre studies would be needed to validate these results further. Secondly, the study's short follow-up period of eight weeks postoperatively may not capture long-term outcomes, such as the stability of alignment, recurrence of deviation, or impacts on binocular vision and quality of life. Future research should include extended follow-up periods to assess the durability of surgical corrections. Additionally, the study focuses exclusively on concomitant horizontal strabismus, which may restrict its applicability to other forms of strabismus. Furthermore, individual variations in response to PAT and monocular occlusion could introduce bias, as not all patients may respond uniformly to these tests. The absence of a control group undergoing conventional surgical planning without PAT limits the ability to directly compare the effectiveness of this approach against standard methods.

Finally, the study does not extensively explore patient-reported outcomes, such as satisfaction or visual comfort, which are critical for evaluating the holistic success of surgical interventions. Incorporating validated patient-reported outcome measures in future studies would provide a more comprehensive assessment of the impact of PAT on quality of life. Addressing these limitations in subsequent research would strengthen the evidence base and support broader clinical adoption of PAT in strabismus management.

CONCLUSION(S)

The present study demonstrates the value of the Patch Test and PAT in identifying the largest horizontal deviation angle, contributing to better motor outcomes and binocular function in concomitant horizontal strabismus. PAT effectively refines surgical targets, minimising undercorrection and overcorrection, and improving postoperative alignment. Despite limitations such as a small sample size and short follow-up, the findings support integrating PAT into preoperative assessments to enhance surgical precision. The key takeaway is that PAT enables tailored surgical planning, improving success rates and reinforcing its role in optimising strabismus management.

Acknowledgement

The authors are thankful to all the faculty members, technical staff, and patients for their cooperation and active participation in the study.

REFERENCES

[1] Dadeya S, Kamlesh, Naniwal S. Usefulness of the preoperative prism adaptation test in patients with intermittent exotropia. J Pediatr Ophthalmol Strabismus. 2003;40(2):85-89.
[2] Kutschke PJ, Keech RV. Surgical outcome after prism adaptation for esotropia with a distance-near disparity. J AAPOS. 2001;5(3):189-92.
[3] Kassem RR, Elhilali HM, El-Sada MA, El-Antably SA. A comparative study of prism adaptation and the augmented surgery formula in the management of acquired comitant esotropia. J Pediatr Ophthalmol Strabismus. 2020 1;57(2):108-19.
[4] Nishikawa N, Kawaguchi Y, Fushitsu R. Prism adaptation response and surgical outcomes of acquired nonaccommodative comitant esotropia. Strabismus. 2023;31(1):09-16.
[5] Kim DH, Yang HK, Hwang JM. Long-term surgical outcomes of preoperative prism adaptation in patients with partially accommodative esotropia. Eye (Lond). 2021;35(4):1165-70.
[6] Jang Y, Lee HJ, Jung JH, Kim SJ. Effect of prism adaptation in patients with partially accommodative esotropia: Clinical findings and surgical outcomes. Graefes Arch Clin Exp Ophthalmol. 2021;259(1):223-29.
[7] Takada R, Matsumoto F, Wakayama A, Numata T, Tanabe F, Abe K, et al. Efficacies of preoperative prism adaptation test and monocular occlusion for detecting the maximum angle of deviation in intermittent exotropia. BMC Ophthalmol. 2021;21(1):304.
[8] Masoomian B, Othman N, Mirmohammadsadeghi A, Akbari MR, Khorrami-Nejad M, Sadeghi M. Strabismus surgery for patients with acquired nonaccommodative esotropia based on monocular occlusion test. J AAPOS. 2024;5:104031.
[9] Eizenman M, Westall CA, Geer I, Smith K, Chatterjee S, Panton CM, et al. Electrophysiological evidence of cortical fusion in children with early-onset esotropia. Invest Ophthalmol Vis Sci. 1999;40(2):354-62.
[10] Singh R, Chaudhary D, Kumar V, Saini V, Sharma H. Comparative assessment of prism alternate cover test at near, distance, far distance before and after patching and prism adaptation test in concomitant horizontal strabismus. Afr J Bio Sc. 2024;6(5):6994-7016.
[11] Rosenbaum AL, Santiago AP. Clinical strabismus management: Principles and surgical techniques. Philadelphia. W. B. Saunders Company: 1999.
[12] Repka MX, Connett JE, Scott WE. The one-year surgical outcome after prism adaptation for the management of acquired esotropia. Ophthalmology. 1996;103(6):922-28.

[13] Hwang JM, Min BM, Park SC, Oh SY, Sung NK. A randomized comparison of prism adaptation and augmented surgery in the surgical management of esotropia associated with hypermetropia: One-year surgical outcomes. J AAPOS. 2001;5(1):31-34.
[14] Kushner BJ, Morton GV. Distance/near differences in intermittent exotropia. Arch Ophthalmol. 1998;116(4):478-86.
[15] Savino G, Colucci D, Rebecchi MT, Dickmann A. Acute onset concomitant esotropia: Sensorial evaluation, prism adaptation test, and surgery planning. J Pediatr Ophthalmol Strabismus. 2005;42(6):342-48.
[16] Wygnanski-Jaffe T, Trotter J, Watts P, Kraft SP, Abdolell M. Preoperative prism adaptation in acquired esotropia with convergence excess. J AAPOS. 2003;7(1):28-33.
[17] Velez FG, Rosenbaum AL. Preoperative prism adaptation for acquired esotropia: Long-term results. J AAPOS. 2002;6(3):168-73.
[18] Ohtsuki H, Hasebe S, Kono R, Yamane T, Fujiwara H, Shiraga F. Prism adaptation response is useful for predicting surgical outcome in selected types of intermittent exotropia. Am J Ophthalmol. 2001;131(1):117-22.
[19] Repka MX, Connett JE, Baker JD, Rosenbaum AL. Surgery in the prism adaptation study: Accuracy and dose response. Prism Adaptation Study Research Group. J Pediatr Ophthalmol Strabismus. 1992;29(3):150-56.
[20] Ela-Dalman N, Velez G, Thacker N, Britt MT, Velez FG. Maximum motor fusion combined with one-hour preoperative prism adaptation test in patients with acquired esotropia. J AAPOS. 2006;10(6):561-64.
[21] Ohtsuki H, Hasebe S, Okano M, Furuse T. Comparison of surgical results of responders and non-responders to the prism adaptation test in intermittent exotropia. Acta Ophthalmol Scand. 1997;75(5):528-31.
[22] Altman M, Baker JD, Petrunak J, Schweers M. Can prism adaptation for acquired esotropia be accomplished in a shorter time frame? J AAPOS. 1999;3(5):259-62.
[23] Akbari MR, Mehrabi Bahar MR, Mirmohammadsadeghi A, Bayat R, Masoumi A. Short prism adaptation test in patients with acquired nonaccommodative esotropia; clinical findings and surgical outcome. J AAPOS. 2018;22(5):352-55.
[24] Quigley C, Cairns M, McElnea E, Doyle F, McCance J, Mullaney P. A retrospective evaluation of bilateral medial rectus recession for management of accommodative esotropia according to prism-adapted motor response preoperatively. J AAPOS. 2017;21(2):157-159.e1.
[25] Kutschke PJ, Scott WE, Stewart SA. Prism adaptation for esotropia with a distance-near disparity. J Pediatr Ophthalmol Strabismus. 1992;29(1):12-15.
[26] Kutschke PJ, Scott WE. Prism adaptation in visually mature patients with esotropia of childhood onset. Ophthalmology. 2004;111(1):177.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Sep 28, 2024
- Manual Googling: Jan 09, 2025
- iThenticate Software: Jan 11, 2025 (8%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Sep 27, 2024**
Date of Peer Review: **Dec 04, 2024**
Date of Acceptance: **Jan 13, 2025**
Date of Publishing: **Jul 01, 2025**