

A comparative study of various prism adaptation forms in the surgical management of esophoria

Ulrike Pichler,¹ Elke Schmidbauer,¹ Philipp Hermann,² Helga Wagner,^{2,3} Matthias Bolz^{1,4} and Anna Sophie Mursch-Edlmayr^{1,4} 

¹Department for Ophthalmology, Kepler University Hospital, Johannes Kepler University, Linz, Austria

²Center for Clinical Studies (CCS Linz), Johannes Kepler University, Linz, Austria

³Institute of Applied Statistics, Johannes Kepler University, Austria

⁴Johannes Kepler University, Linz, Austria

ABSTRACT.

Purpose: To evaluate the outcome in participants who underwent surgery for esophoria following one of three different methods of preoperative prism adaptation test (PAT).

Methods: This prospective, multicentre study was carried out at five eye departments from 2012 to 2019. 116 participants were included and allocated to three groups as per investigator choice: Group 1 ($n = 55$) had a short prism adaptation period ranging from 1 to 5 hours during their visit at the clinic. Group 2 ($n = 36$) underwent partial prism correction for at least 4 weeks before surgery. Group 3 ($n = 25$) underwent full prism correction for at least 4 weeks before surgery. Motoric success was determined by postoperative angle of deviation (AOD), and sensoric success was evaluated with Lang and Bagolini striated lens test.

Results: A significant increase ($p < 0.001$) in AOD after PAT was observed in all groups, with no significant difference between groups (distance: $p = 0.22$; near: $p = 0.31$). Motoric and sensoric success was comparable between groups 3 months ($p = 0.52$; $p = 0.55$) and 1 year ($p = 0.53$; $p = 0.29$) after surgery. Prolonged prism adaptation ($n = 24$) for more than 365 days was not associated with better results.

Conclusion: Our study indicates that the postoperative result is independent from the duration and amount (partial or full correction) of prism adaptation before surgery at least up to one year of follow-up. Prolonged prism adaptation (>365 days) before surgery does not improve the results.

Key words: esophoria – prism adaptation – prism adaptation test – strabismus surgery – surgical outcome

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Introduction

Esophoria is a common form of heterophoria that can be associated with ocular discomfort. Among the

symptoms are blurred vision, asthenopia, difficulties in accommodation and fatiguing eyes as well as diplopia, which is more common in constant

esotropia. (Embrey et al. 2020) The severity of discomfort does not necessarily correlate with the angle of deviation (AOD). When the AOD exceeds 14 prisms, surgical treatment is recommended. First-line treatment in Austria is combined horizontal surgery with recession of medial rectus and plication or resection of lateral rectus.

Initial examination often shows a small angle of deviation which can be increased by the prism adaptation test (PAT). It is recommended to perform a PAT before surgery in order to determine the maximum adapted angle. The adapted angle is then applied to determine the amount of muscle relocation. This has been shown to achieve better postoperative results in patients with acquired esotropia who could not be fully corrected with glasses (Prism Adaptation Study Research Group 1990). The recommended duration of PAT, however, varies among different studies (Prism Adaptation Study Research Group 1990; Ohtsuki et al. 1993; Altman et al. 1999; Ela-Dalman et al. 2006). An Austrian survey in 2018 also revealed great heterogeneity in the use of PAT (Pichler et al. 2018).

In Austria, some orthoptists and strabologists are convinced that only a longer PAT with Fresnel prisms for weeks to years leads to a good and lasting surgical result and therefore refuse surgery for patients if they are not willing to wear Fresnel prisms.

The aim of this study was to compare the surgical outcome in participants with esophoria who underwent

one of three different methods of pre-operative prism adaptation test (PAT). We wanted to find out, if longer prism adaptation really leads to a better motoric and sensoric success than short PAT to improve evidence for the pre-operative procedure.

Materials and Methods

Participants

This prospective, multicentre cohort study was carried out at five eye departments in Austria. All patients with symptomatic esophoria, for example double vision, asthenopia, who required surgery could be included if they were willing to participate in the trial and gave their consent. Study inclusion was not limited to a minimum AOD. Esophoria could be compensated or decompensated with double vision. In contrast to former studies no inclusion criteria on the amount of AOD were set, for some patients had initial small AODs which increased with PAT (Prism Adaptation Study Research Group 1990). Some patients with AOD <14 prisms wanted surgery because they were not willing to wear prism glasses. The study was compliant with the principles of the Declaration of Helsinki and was approved by the ethics committee of the Johann Kepler University Linz. Both children and adults with esophoria requiring surgical intervention were included. Written informed consent was obtained either by the participants themselves or from a legal guardian/parents. The study/observation period lasted from 2012 to 2019. Patients with accommodative esophoric strabismus, accommodative esophoria or myopic strabismus (myopia ≥ 15 dpt) were excluded.

Examination methods and groups

Before the orthoptic examination, the refraction and best corrected visual acuity was checked. Motoric function was assessed with alternate prism cover test (APCT) using an accommodative target for distance and near (5m and 40 cm, respectively). To examine sensoric function, Lang I stereotest and Bagolini striated lens test at 5 m and 40 cm were carried out. All participants underwent PAT before surgery. The initial PAT was based on the angle of

deviation measured for distance with APCT.

Participants were allocated to one of the following three groups (non-randomized allocation as per investigators preference):

Group 1 included participants who had a short adaptation period of 1–5 h during the orthoptic examination at the eye department. The AOD found at initial APCT was neutralized using prism glasses which were either put in trial frames or attached to the participants own glasses using a repositionable, reusable adhesive glue. Participants were asked to wear the prisms for a duration of 20–60 min, after which the AOD was measured again. If the angle of esodeviation had increased, the prism strength was adapted to fully correct the deviation and a further adaptation period was initiated. This process was repeated until no further increase in esodeviation was observed.

Group 2 consisted of participants who had received partial correction of their esodeviation. The amount of angle correction was defined by the investigator site. The amount of prisms was determined by the patients need to reduce symptoms. The deviation was corrected using either Fresnel prism or prism glasses. The prism adaptation period lasted for at least 4 weeks. One to seven days prior to surgery, the participants underwent PAT to determine the maximum angle.

Participants of Group 3 underwent full prismatic correction for their esodeviation found after initial APCT. Either Fresnel prisms or prism glasses were used to correct the deviation at home. The participants wore their prism correction for at least 4 weeks before undergoing PAT one to seven days prior to surgery.

Measurements of motoric and sensoric function were conducted 1–7 days preoperatively, three and 12 months after surgery.

Surgery

Surgery was performed under general anaesthesia. The surgical dosages were determined according to the following formula: AOD after PAT/3 = total required dislocation (mm). This was split in plication or resection (60%) and recession (40%).

Surgical success

Motoric success was classified depending on the AOD for both distance and near as very successful (0–5 prism dioptres), successful (5–10 prism dioptres) and poor (more than 10 prism dioptres) for distance and near. Sensoric success was tested without prisms and rated as very successful (positive Bagolini striated lens test for distance and near and positive Lang Stereotest), successful (positive Bagolini striated lens test for distance and near and negative Lang Stereotest) and failure (negative Bagolini striated lens test for distance and/or near and negative Lang Stereotest).

Statistics

Statistical analyses were conducted using R (<https://www.R-project.org/> n.d.). Nominal data are presented with frequencies, and metric data are presented using minimum, maximum, mean and standard deviation. Comparison of means between groups was performed with the Kruskal–Wallis test. Fisher's exact test was used to test nominal variables for differences between groups. Linear regression analysis was conducted to estimate the effect of prism duration and angle of deviation before PAT on the angle of deviation after PAT for both measurements, near and far. Comparisons of variables measured at two time points are conducted with Wilcoxon signed-rank tests. A p-value smaller than 0.05 was considered statistically significant.

Results

One hundred and sixteen participants were included, 61 of them were female. Mean age at presentation was 36.7 ± 20.8 years. Number of patients in groups 1–3 were 55, 35 and 25. Preoperatively, 30 participants complained of constant diplopia, 63 had intermittent diplopia and the remaining 22 participants experienced no double vision. Cycloplegic refraction was performed in 47 participants, and 62 participants underwent subjective refraction. 59% of the participants were myopic, 34% were hyperopic, and 7% had astigmatism.

Table 1 shows the AOD for far and near before and after PAT. Linear

Table 1. Descriptive statistics of angle of deviation (AOD) for far and near at baseline (AOD BL) and after prism adaption test (AOD PAT) and difference between AOD BL and AOD PAT (Diff).

	Group 1						Group 2						Group 3						
	N	Min	Max	Med	Mean	SD	N	Min	Max	Med	Mean	SD	N	Min	Max	Med	Mean	SD	Sig.
AOD BL far	55	4	50	20	21.4	11.9	36	2	30	15	15.9	7.1	25	6	42	16	17.7	8.8	0.1
AOD PAT far	55	11	67	38	36.8	11	36	12	46	30	29.2	8	25	18	42	30	29	8	>0.01
Diff far	55	-1	47	15	15.4	10	36	0	25	12	13.3	7.4	25	-3	34	11	11	11.4	0.22
AOD BL near	55	-8	50	20	21.3	13.5	36	0	35	12	14.8	9.7	25	0	45	12	14.7	9.3	0.01
AOD PAT near	55	14	70	37	37.3	11.6	36	10	46	30	28.3	9.1	25	12	45	25	27.5	10.1	<0.01
Diff near	55	-10	50	16	16	10.7	36	-2	28	14	13.5	8.8	25	-4	35	12	12.8	10.6	0.31

Max = Maximal deviation; Med = Median; Min = Minimal deviation; N = Number of patients; SD = Standard deviation. Kruskal-Wallis tests were conducted to test for differences between the three groups.

Table 2. Absolute frequencies of Lang Stereotest and Bagolini striated lens test far and near at first visit and the corresponding study group at baseline. (Pos) Positive. (Neg) Negative. (Excl) Exclusion. Stereotest and Bagolini test were performed without prismatic correction. Fisher's exact tests were conducted to test for differences between the three groups.

	Group 1 (n = 55)		Group 2 (n = 36)			Group 3 (n = 25)			Sig.	
	Pos	Neg	Pos	Neg	Excl	Pos	Neg	Excl		
Lang Stereotest	31	23	16	16		11	13		0.62	
	Pos	Neg	Excl	Pos	Neg	Excl	Pos	Neg	Excl	
Bagolini far	12	35	8	3	29	2	2	18	4	0.19
Bagolini near	13	33	9	10	23	1	5	18	1	0.26

regression analysis revealed significant increase in AOD with PAT ($p < 0.001$) irrespective of the duration of prism adaptation ($p = 0.12$ and $p = 0.22$ for both far and near, respectively). Amount of increase was similar between groups (near: $p = 0.31$; far: $p = 0.22$).

Table 2 shows the results on sensoric tests between the study groups at baseline visit. Results from Lang and Bagolini striated lens tests were similar between all groups. 3 months after surgery 97% and 1 year after surgery, 89% of the patients had motor fusion.

Surgery was based on the adapted AOD in all groups and was performed in 52 right eyes and in 64 left eyes with medial rectus recession and lateral rectus plication. Mean medial recession was 4.5 ± 1.2 mm, and mean lateral plication was 6.0 ± 1.9 mm.

Surgical success

Table 3 shows the residual AOD after surgery at every follow-up. Results were similar for all groups at any time.

No significant differences in motoric success (3 months $p = 0.52$, 1 year

$p = 0.53$) or sensoric success (3 months $p = 0.55$, 1 year $p = 0.29$) were shown between the groups at any time (Table 4).

Twenty four of the included participants had a prism correction of at least one year before surgery. Motoric success was not significantly different at any time for patients with prism correction duration shorter and longer than one year (Fisher's exact test $p = 0.91$ at 3 months, $p = 0.26$ at 1 year).

Discussion

Esophoria is a common form of heterophoria and can be associated with ocular discomfort such as double vision or asthenopia. Initial examination often shows a small angle of deviation which can be increased with the prism adaptation test (PAT). The effect of PAT has first been described in 1990 by the prism adaptation research study group and was later confirmed by multiple studies. (Prism Adaptation Study Research Group 1990) When surgical correction is planned, preoperative PAT is recommended, as better

motoric and sensoric outcomes have been shown when surgery was planned on the adapted angle (Prism Adaptation Study Research Group 1990; Ohtsuki et al. 1993; Repka, Connitt & Scott 1996; Altman et al. 1999; Ela-Dalman et al. 2006) However, the PAT protocols applied in former studies varied in terms of form of prism adaptation, duration of prism adaptation time, initial AOD and examination strategy.

A former study from our group has shown that in Austria, duration of PAT strongly depends on practical experience and less on evidence-based literature (Pichler, Rohleder & Ehrh 2018).

The aim of this study therefore was to evaluate the surgical outcomes following different preoperative regimens in esophoria to evaluate whether longer prism duration leads to better surgical results than a short PAT.

As expected, our results showed a significant increase in AOD with PAT ($p < 0.001$). The increase in AOD for far and near following PAT was independent from its duration ($p = 0.12$ and 0.22 , respectively). This finding is in alignment with a study by Altman et al. which showed that a 24-h prism adaptation duration was sufficient in order to reach maximum angle (Altman et al. 1999). Ela-Dalman et al. (2006) showed in a study with 29 participants with acquired esotropia that the maximum AOD can be reached after PAT within 1 h.

In our study, motoric success was similar between groups 3 months and 1 year after surgery. Sensoric success also was similar between groups at all follow-up visits.

These findings are in accordance with Ela-Dalman et al. (2006) who

Table 3. Descriptive statistics of angle of deviation (AOD) 3 months (3m) and 1 year (1y) after surgery for near and far.

	Group 1						Group 2						Group 3						p-val
	N	Min	Max	Med	Mean	SD	N	Min	Max	Med	Mean	SD	N	Min	Max	Med	Mean	SD	
AOD 3m far	53	-10	25	1	3	4.9	34	0	7	1	1.7	2	25	-1	8	0	2.1	3.1	0.89
AOD 1y far	24	-4	18	1	3	4.9	16	0	16	2	5.3	4.9	11	0	20	6	6	6.3	0.12
AOD 3m near	53	-10	20	0	2.1	5.2	34	-8	6	0	0.9	3.6	25	-18	10	1	0.3	5	0.68
AOD 1y near	24	-4	25	2	4.5	6.6	16	-3	8	2	2.9	3.6	11	-2	16	2	4.2	5.6	0.93

Max = Maximal deviation; Med = Median; Min = Minimal deviation; N = Number of patients; SD = Standard deviation. Kruskal-Wallis tests were conducted to test for differences between the three groups.

Table 4. Motoric and sensoric success 3 months and 1 year after surgery. Motoric success was defined as follows: AOD 0–5 prism far and near = very successful, AOD 5–10 prism far and near = successful, AOD >10 prism = failure. Sensoric success was defined as follows: Bagolini striated lens test positive far and near, positive Lang Stereotest = very successful, positive Bagolini test far and near, negative Lang Stereotest = successful, negative Bagolini test for far or/and near, negative Lang Stereotest = failure. Fisher’s exact test showed no significant differences between groups.

	Motoric Success				Sig.	Sensoric Success				Sig.
	Group 1 (n = 53)	Group 2 (n = 36)	Group 3 (n = 25)			Group 1 (n = 54)	Group 2 (n = 36)	Group 3 (n = 24)		
3 months										
Very successful	38	24	17		0.52	46	26	23		0.55
Successful	11	10	7			5	6	2		
Failure	4	0	1			2	2	0		
1 year										
Very successful	17	5	5		0.53	21	12	11		0.29
Successful	5	4	4			3	2	0		
Failure	3	3	3			1	2	1		

reported excellent surgical success after 18 months with an average distance angle of 1.3 ± 3.3 PD following a short PAT of only 1 h. More recently, Akbari et al (2018) showed that a short PAT is associated with a low rate of over- and undercorrection (Akbari et al. 2018). Zhang et al (2020) showed that surgery following PAT with a duration of 1 week to 3 months in participants with AACE (acute acquired comitant esotropia) leads to improved binocular function and reduced recurrence rate (Zhang et al. 2020).

A prolonged prism adaptation in esophoria before surgery is still considered favourable in some departments (Pichler et al. 2018). This, however, can be difficult for some patients who are unwilling or incapable of prism correction for longer periods. As far as we know our study is the first to show that prolonged prism adaptation of more than 365 days before surgery does not result in significant differences in the surgical success. Considering side

effects of Fresnel prisms such as yellow sight, peel of the prisms after about 3 months in place, reduction of visual acuity about one line per 5 prisms and related impact on quality of life, we conclude that a prolonged PAT is not in the patients best interest (Diamond 2019).

In contrast to other studies, our trial was conducted as a prospective analysis with a large number of participants. However, limitations can be found. As group allocation was not randomized, group sizes varied. Neither patients nor investigators were masked. Also, no sample size calculation was performed prior to study initiation. These points should be addressed in future trials.

In conclusion, surgery of esophoria should be planned based on the AOD after PAT. Short prism adaptation duration leads to similar results regarding motoric and sensoric success. Prolonged prism adaptation (>365 days) before surgery does not improve the results. Short PAT can help economising limited resources.

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Correspondence:

Anna Sophie Mursch-Edlmayr, MD
Department of Ophthalmology
Johannes Kepler University
Krankenhausstraße 9
4020 Linz
Austria
Tel: 0043 57680831110
Fax: 0043 5768083 1822
Email: Anna.mursch-edlmayr@jku.at