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ARTICLE

Long-term surgical outcomes of preoperative prism adaptation in patients with partially accommodative esotropia

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Abstract

Background: To determine the long-term surgical outcomes of preoperative prism adaptation test (PAT) in patients with partially accommodative esotropia.

Methods: PAT was performed for the remaining esotropia after full correction of hyperopia. Prism adaptation (PA) responders were defined as patients with stable esodeviation between 0 and 8 prism diopters (PD) while developing sensory fusion throughout the prism adaptation period. Surgical success was defined as a deviation within 8 PD of both the far and near deviation angles at the last follow-up examination.

Results: Of the 102 patients, 43 (42.2%) were PA responders, and 59 were PA non-responders (57.8%). After a mean follow-up duration of 6 years after surgery, the surgical success rate was significantly higher in PA responders (76.7% vs. 54.2%, $p = 0.023$). By multivariate analysis, good stereoacuity at near before surgery significantly correlated with successful outcomes after surgery ($p = 0.001$, $\beta = 4.466$). The risk factors of undercorrection were preoperative esotropia >35 PD (OR 3.067, $p = 0.041$), and preoperative hyperopia >+5.25 diopters (OR 3.099, $p = 0.049$). Among undercorrected patients, the annual decrease of esodeviation was significantly greater in PA responders ($p = 0.043$).

Conclusions: PA responders showed a better long-term success rate than in PA nonresponders. Patients with high hyperopia and large esotropia had a higher risk of undercorrection. Undercorrected patients eventually achieved good motor outcome with postoperative prism correction if they were PA responders before surgery.

Introduction

Refractive accommodative esotropia is generally managed by full hyperopic correction, but nonaccommodative components of esodeviation should be treated surgically. However, conventional surgery performed on the remaining angle of esotropia after full correction of hyperopia showed a considerable incidence of undercorrection ranging up to 75% in some studies [1–3]. Several studies have suggested that the surgical table should be augmented for partially accommodative esotropia than for other types of esotropia with the same angle of esodeviation at distance [4–6].

To increase the chances of successful postoperative ocular alignment, the prism adaptation test (PAT) has been used to determine the surgical target angle for patients with acquired esotropia before surgery [7, 8]. A previous study evaluating the efficacy of prism adaptation in 322 patients via a prospective randomized multicentre clinical trial showed that PA responders who underwent augmented surgery for the prism-determined angle significantly improved their chances of postoperative surgical alignment with acquired esotropia at 1 year after surgery [9, 10]. However, the efficacy of preoperative PAT in patients with partially accommodative esotropia after a long-term follow-up has not yet been reported to our knowledge. The purpose of the present study was to evaluate the efficacy of preoperative PAT after an extended follow-up period of 2 years or more in subjects with partially accommodative esotropia.

Materials and methods

We screened the records of patients who underwent surgery with preoperative PAT between January 2004 and July 2018 for esotropia. We included patients who were at

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least four years old at the time of surgery and were followed-up for more than two years postoperatively. Exclusion criteria included hyperopia under +1.50 diopters, history of extraocular muscle surgery, ocular disease other than strabismus that could affect vision, systemic or neurologic diseases that could affect ocular alignment, vertical deviation in the primary position, A or V pattern, paralytic or restrictive esotropia, and amblyopia. The study protocol was approved by the institutional review board of Seoul National University Bundang Hospital and adhered to the tenets of the Declaration of Helsinki.

Group classification according to the response of prism adaptation test

Prism prescription was determined using the method described by the Prism Adaptation Study Research Group [9]. Patients received full hyperopic correction determined by cycloplegic refraction. Prism prescription was based on the angle of esodeviation measured using the simultaneous prism and cover test (SPCT) on targets at 6 and 0.33 m, while the patient was wearing full hyperopic correction. Patients undergoing prism adaptation were re-examined at 4–6-week intervals. If the deviation was greater than 8 prism diopters (PD) with full hyperopic correction, more prisms were added until stability was achieved. Prisms were readjusted if necessary, until prism response or nonresponse was determined. The maximal amount of prism correction with ground-in prisms was 16 PD of esodeviation, and a deviation of more than 16 PD of esodeviation was corrected with Fresnel press-on prisms. PA responders were defined as a patient with stable esotropia between 0 and 8 PD based on the SPCT, while developing fusion or diplopia on the Worth 4-dot (W4D) test at near and identifying at least two of nine circles or two of three animals on the Randot stereoacuity test (StereoOptical Co. Inc., Chicago, IL) through the prism adaptation period. Prism adaptation nonresponders (PA non-responder) were defined as one meeting any of the following conditions: (1) a stable esotropia of 8 PD or less by SPCT and no development of the sensory response as described above after 30 days of prism-wear; (2) developed more than 60 PD of esotropia; or (3) became exotropia through the prism adaptation period by SPCT. All patients underwent augmented surgery for the prism-determined angle.

Postsurgical evaluation and main outcome measures

Follow-up examinations of all of the patients were scheduled at 1, 6, 12, and 24 months after surgery. A successful outcome was defined as a deviation of 8 PD or less of esotropia or exotropia. Binocular sensory function was measured with the W4D test at near and at distance. If a patient required a second surgery, this was considered to be a failure for all outcome measures.

Statistical analysis

The data were statistically analysed using SPSS software version 21.0 (SPSS Inc., Chicago, IL, USA). The Student *t*-test and Pearson chi-square test were used to compare preoperative and postoperative characteristics between groups. The Fisher's exact test was used to determine if there are nonrandom associations between groups. Multivariate logistic regression was performed to identify the factors affecting undercorrection at the final visit. *P*-values of less than 0.05 were considered statistically significant. The data are presented as means ± standard deviation unless stated otherwise.

Results

A total of 102 patients with partially accommodative esotropia were included in this study. Patients' demographics and characteristics are shown in Table 1. In total, 43 patients (42.2%) were PA responders, and 59 patients (57.8%) were PA nonresponders. The mean age of onset, age at surgery, duration of prism adaptation before surgery, postoperative follow-up duration, duration of wearing prism glasses after surgery, amount of preoperative prism build-up through the PAT, and spherical equivalent refractive errors were not significantly different between the two groups.

In terms of the types of surgery, 77 patients (75.5%) underwent bilateral medial rectus muscle recession, 13 patients (12.7%) received unilateral medial rectus recession–lateral rectus muscle resection, and 12 patients (11.8%) had unilateral medial rectus muscle recession.

The preoperative range of esodeviation was significantly larger in PA nonresponders (42.4 ± 14.9 PD) than in PA responders (34.2 ± 9.9 PD) ($p = 0.002$). Regarding the sensory status, preoperative stereopsis of PA responders was better than PA nonresponders ($p < 0.001$). However, postoperative stereopsis measured at the final follow-up examination was not statistically different between both groups ($p = 0.207$). The mean follow-up duration after surgery was 76.6 ± 37.0 months (interquartile range [IQR], 41.8–99.2), and it was not significantly different between PA responders and PA nonresponders ($p = 0.610$). Finally, after a mean of follow-up duration of 6 years after surgery in PA responders, 33 (76.7%) of 43 patients were successful; of the unsuccessful patients, 2 patients (4.7%) had overcorrection and 8 patients (18.6%) had undercorrection (Table 2). In PA nonresponders, 32 of 59 patients (54.2%) were successful; of the 27 unsuccessful patients, 7 patients (11.9%) had overcorrection and 20

Table 1 Preoperative patient characteristics in partially accommodative esotropia between prism adaptation responders and nonresponders.

	PA responder ($n = 43$)	PA nonresponder ($n = 59$)	P value
Gender (M:F)	20:23	25:34	0.678*
Age at onset (years)	3.3 ± 1.8 (2.1–4.4)	3.1 ± 1.5 (1.9–4.3)	0.555†
Age at surgery (years)	6.4 ± 2.2 (4.6–7.4)	6.5 ± 3.1 (4.7–7.0)	0.887†
Duration of prism adaptation before surgery (months)	15.7 ± 19.8 (1.9–22.7)	10.9 ± 17.9 (1.3–12.9)	0.212†
Duration of postoperative follow-up (months)	74.5 ± 31.3 (48.5–93.7)	78.2 ± 41.1 (37.3–110.8)	0.610†
Duration of wearing prism glasses after surgery (months)	38.8 ± 39.5 (1.1–58.0)	36.5 ± 36.9 (6.6–58.0)	0.760†
Amount of preoperative prism build-up (PD)	15.0 ± 10.4 (10–20)	17.3 ± 14.3 (0–29)	0.372†
Spherical equivalent refractive errors (D)	4.23 ± 1.60 (3.06–5.25)	4.05 ± 1.44 (3.00–5.19)	0.566†
Stereopsis (LogArcsec)	2.4 ± 0.6 (2.0–3.2)	2.8 ± 0.5 (2.3–3.2)	<0.001†

PA prism adaptation, *PD* prism diopters, *D* diopters.

Values are presented as mean ± standard deviation (interquartile range).

*P value by Chi-square test.

†Student t-test.

patients (33.9%) had undercorrection. The final success rate was significantly higher in PA responders than in PA non-responders ($p = 0.020$).

Among patients with undercorrection, a continuous reduction of esodeviation was noted after wearing base-out prism glasses up to the final examination. The mean duration of wearing prism glasses after surgery was 38.8 ± 39.5 months (IQR, 1.1–58.0) in PA responders and 36.5 ± 36.9 months (IQR, 6.6–58.0) in PA nonresponders. Among the initially undercorrected patients at one year after surgery, 9 out of 14 patients (64.3%) in PA responders and 11 out of 28 patients (39.3%) in PA nonresponders became successful with less than 8 PD of esodeviation at the last follow-up examination. The annual decrease of esodeviation from 1 year after surgery to the last follow-up examination was 1.6 ± 1.3 PD/year in PA responders, which was significantly larger than PA non-responders with an annual decrease of 0.4 ± 2.0 PD/year ($p = 0.043$).

By multivariate analysis, preoperative stereoacuity at near was found to be a significant factor of successful postoperative alignment. The risk factors of undercorrection were preoperative esotropia of >35 PD (OR 3.067, $p = 0.041$), and preoperative high hyperopia of >+5.25 diopters (OR 3.099, $p = 0.049$).

Discussion

In this study, we showed the long-term efficacy of preoperative prism adaptation for partially accommodative esotropia. While previous studies regarding the pre-surgical benefit of prism adaptation presented good outcomes within one year after surgery [7, 9, 11, 12], we examined the long-term outcomes (average of six years) and showed a relatively good success rate (76.7%) in prism responders. Patients with high hyperopia and a large angle of esotropia had a higher possibility of undercorrection.

Previous studies showed that the prism adaptation test performed before surgery significantly improved the surgical outcomes for patients with acquired esotropia. The Prism Adaptation Study showed a success rate of 89% with minimal overcorrections at one year after surgery for patients with acquired esotropia [9, 10]. However, to the best of our knowledge, only a few studies evaluated the efficacy of PAT for patients with partially accommodative esotropia. Hwang et al. [13] presented the efficacy of PAT for patients with partially accommodative esotropia and achieved a 89% success rate in prism responders without any overcorrection at one year after surgery.

Meanwhile, undercorrection appears to be common in patients with partially accommodative esotropia following the standard surgical dosages. Various approaches were tried, including additional recession to the standard surgical dosages [1, 14], operating for the near deviation [15], or combining medial rectus recession with posterior fixation sutures [16]. These methods have effectively reduced the rate of undercorrection, but it increased overcorrection.

In this study, there was no difference in the success rates between the two groups for up to two years after surgery. However, in PA responders, the average residual angle of esodeviation continuously decreased while wearing prism glasses for an average of 38.8 ± 39.5 (IQR, 1.1–58.0) months, postoperatively; and finally, after 6 years, PA responders showed a better successful outcome compared with PA nonresponders. Choe et al. [17] reported that in 124 partially accommodative esotropia patients with residual esotropia of 20 PD or less, about one-third achieved successful ocular alignment by wearing prism glasses for more than three years without surgery. Han and Hwang [18] reported that prismatic correction was successful in 44% of

Table 2 Surgical motor outcomes at 6 months, 1 year, 2 years, and the final examination after surgery with preoperative prism adaptation test.

	Successful alignment				Overcorrection (>8 PD XT)				Undercorrection (>8 PD ET)			
	6 months	1 year	2 years	Final[a]	6 months	1 year	2 years	Final[a]	6 months	1 year	2 years	Final[a]
PA responder (*n*, %)	21 (60.0)	23 (59.0)	25 (58.1)	33 (76.7)	2 (5.7)	2 (5.1)	1 (2.3)	2 (4.7)	12 (34.3)	14 (35.9)	17 (39.5)	8 (18.6)
PA nonresponder (*n*, %)	19 (38.0)	26 (44.8)	32 (58.2)	32 (54.2)	2 (4.0)	4 (6.9)	2 (3.5)	7 (11.9)	29 (58.0)	28 (48.3)	23 (41.8)	20 (33.9)
p value	**0.046**[b]	0.218[b]	0.997[b]	**0.020**[b]	1.000[c]	1.000[c]	1.000[c]	0.296[c]	**0.031**[b]	0.192[b]	0.819[b]	0.087[b]

Successful alignment was defined as ≤8 prism diopters (PD) of deviation. Overcorrection was defined as >8 PD of exodeviation and undercorrection as >8 PD of esodeviation.

Bold values indicate statistical significance of $p < 0.05$.

PA prism adaptation, *PD* prism diopters, *XT* exodeviation, *ET* esodeviation.

[a]Follow-up duration was 74.5 ± 31.3 (IQR, 48.5–93.7) months in PA responders and 78.2 ± 41.1 (IQR, 37.3–110.8) months in PA nonresponders.

[b]Chi-square test.

[c]Fisher's exact test.

patients with residual esotropia of 20 PD or less after full hyperopic correction in patients with partially accommodative esotropia for 1 year, and patients with good stereoacuity and good fusion ability were advised to use prism correction as a first-line treatment. In our study, among the initially undercorrected patients at 1 year after surgery, 9 out of 14 (64.3%) PA responders and 11 out of 28 (39.3%) PA nonresponders showed successful outcome with less than 8 PD of deviation at the last follow-up examination. In addition, among patients who were undercorrected at 1 year after surgery, the annual decrease of esodeviation of PA responders (1.6 ± 1.3 PD/year) was greater than that of PA nonresponders (0.4 ± 2.0 PD/year). This suggests that long-term postoperative prism-wear resulted in successful ocular alignment in PA responders with undercorrection because they had good stereopsis. On the other hand, since PA nonresponders had poor stereoacuity and fusion ability, postoperative prismatic correction was ineffective for managing undercorrection, in which case, early intervention may be advisable.

In our study, preoperative stereoacuity at near was a significant factor of surgical success. The presence of binocular vision with fusion undoubtedly contributes to the maintenance of ocular alignment [19, 20]. Lee et al. [21] analysed patients with refractive accommodative esotropia, and those with orthotropia with spectacle correction had better stereopsis than those with residual esotropia. Wilson et al. [19] revealed that patients with accommodative esotropia with better stereopsis were less likely to undergo surgery. Our study found that preoperative stereoacuity is an important factor not only as a prognostic indicator of postoperative sensory fusion but also as a predictor of maintaining motor fusion in patients with partially accommodative esotropia.

Risk factors of undercorrection include a large preoperative angle of esotropia >35 PD and preoperative high hyperopia of >+5.25 diopters. The relationship between surgical outcome and refractive error in partially accommodative esotropia still remains unclear. Some authors have reported that undercorrection may be associated with high hyperopia and overcorrection may be associated with low hyperopia [22, 23]; however, others have reported the opposite [1, 14]. Meanwhile, the Prism Adaptation Study revealed that prism responders with deviations of ≥10 PD by prism build-up presented worse surgical success than the group with a deviation of 0–8 PD [9]. Since our study revealed that preoperative large angle of deviation and high hyperopia were associated with undercorrection, augmented surgery or botulinum toxin treatment could be considered for those with large angle of esotropia and high hyperopia. However, to the best of our knowledge, studies regarding augmented surgery combined with PAT have not been performed to date, and as such, future research is needed.

The advantage of our study is that we only included patients with partially accommodative esotropia among variable causes of acquired esotropia, and analysed the long-term surgical effects of preoperative PAT in a relatively large number of patients. Meanwhile, full hyperopic correction was performed based on the cycloplegic refraction using 1% cyclopentolate hydrochloride, and additional refraction using 1% atropine sulfate was not performed to completely exclude the remaining accommodation. Nonetheless, since the overcorrection rate was not high in our study, the lack of atropine refraction may not have had a significant impact.

In conclusion, the surgical success rate was higher in PA responders, who maintained at most 8 prism diopters of esotropia with sensory fusion by the prism adaptation test before surgery, than in PA nonresponders. Patients with high hyperopia and large esotropia have the possibility of undercorrection. Undercorrected patients after surgery may be corrected with prisms, and eventually achieve long-term success if they are capable of maintaining sensory fusion during the prism adaptation test before surgery.

Summary

What was known before

- In partially accommodative esotropia, the conventional surgery showed a considerable incidence of undercorrection ranging up to 75% in some studies.

What this study adds

- The prism adaptation test is predictive of long-term surgical success in partially accommodative esotropia.
- Patients with high hyperopia and large esotropia have a higher risk of undercorrection.
- Undercorrected patients after surgery may be corrected with prisms, and eventually achieve long-term success if they are capable of maintaining sensory fusion during the prism adaptation test before surgery.

Data availability

Data are available on request. Any requests for data can be made to the corresponding author and are subject to ethics approval.

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Author contributions All authors took an active part in the design, conduct, data analysis, and publication drafting and approval.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval The Institutional Review Board of Seoul National University Bundang Hospital (IRB No.: SNUBH B-2004/607-102)

Patient consent for publication The Institutional Review Board of Seoul National University Bundang Hospital waived the requirement of informed consent. Patient records and information were anonymized prior to access.

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