Long-Term Surgical Outcome of Partially Accommodative Esotropia

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ABSTRACT

Partially accommodative esotropia is an acquired strabismus characterized by high hyperopia, a normal AC/A ratio, and a deviation that responds only partially to spectacle correction. Surgery is done for the non-accommodative portion of the deviation. Over-corrections are managed by reducing the hyperopic power of the spectacles. This retrospective study was done to determine the risk factors for a poor surgical outcome, and to evaluate the efficacy of hyperopic spectacle reduction in the long-term management of consecutive exotropia.

Of the 108 patients enrolled, 19% had a residual esotropia, 37% were surgical successes, and 44% developed consecutive exotropia. Residual ET was associated with deteriorated refractive esotropia, moderate to severe amblyopia, and increasing hyperopia with age. Consecutive XT was associated with a distance-near disparity, low hyperopic refractive error, anisometropia, poor binocular vision, and undercorrection of the hyperopic refractive error prior to surgery. Intentional reduction of the hyperopic correction was not successful in the long-term management of consecutive XT. Fifty-eight percent of those managed in this manner developed a pseudo-dissociated horizontal deviation. The high rate of consecutive exotropia following standard surgery suggests that augmented surgery for partially accommodative esotropia is highly likely to result in over-correction.

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INTRODUCTION

Partially accommodative esotropia can be characterized as having a high hyperopic refractive error ($>+2.00$), a normal gradient AC/A ratio ($\leq 5:1$), and an onset between age six months to five years of life.[1,2] The esotropic angle responds only partially to reduction in accommodative

 American Orthoptic Journal, Volume 52, 2002, ISSN 0065-955X

effort through spectacle correction of the hyperopia, and the non-accommodative component of $\geq 12\Delta$ is managed surgically. Partially accommodative esotropia is reported to take one of two clinical forms.[3] The first type manifests as a late-onset accommodative esodeviation that develops in a patient with a history of infantile esotropia. The second type results from a deterioration of a refractive accommodative esotropia, previously fully corrected with spectacles.

Standard surgery for partially accommodative esotropia is based on the maximum non-accommodative component of the deviation measured through the full cycloplegic refraction.[3] The over-correction rate following standard surgery is reported to be low, from 2 to 18%,[3,4,7] while under-correction rates as high as 60% have been reported.[5] To address the high prevalence of residual or recurrent esotropia, augmented surgery has been proposed by several authors.[6,7] For example, augmented surgery may be based on the average of the deviation measured with and without spectacles.[7]

Should a significant consecutive exotropia develop following surgery, the hyperopic spectacle power is usually reduced so that accommodative convergence can be used to control the exodeviation. Proponents of augmented surgery usually consider consecutive exotropic patients to be surgical successes if the deviation can be controlled in this manner.[5,6,10] For this reason, the over-correction rate for partially accommodative esotropia may be underestimated in the literature. In addition, little has been published on the long-term success of reduced hyperopic correction in the management of these patients. Finally, many earlier studies on surgical outcome have studied non-homogenous patient populations, combining accommodative esotropia with a high AC/A ratio and partially accommodative esotropia in the same cohort. This study was designed to determine the true over-correction rate following standard surgery for partially accommodative esotropia, in patients with normal AC/A ratios, to identify the risk factors for poor surgical outcome, and to evaluate the efficacy of hyperopic spectacle reduction in the long-term management of consecutive exotropia.

PATIENTS AND METHODS

To answer these questions, a review of medical records was done to identify patients with acquired partially accommodative esotropia who had undergone surgery and had a minimum of 24 months post-surgical follow-up. Included were patients with a minimum spherical equivalent of +2.50 diopters of hyperopia in the least hyperopic eye, which reduced the esotropia by $\geq 10^{\Delta}$. Patients were required to have worn the glasses for at least three months prior to surgery. Those with a distance-near disparity $>10^{\Delta}$ and/or a gradient AC/A ratio $>5:1$ were excluded. Also excluded were those with a history of prior strabismus surgery, restrictive or paretic strabismus, intraocular or sensory pathway lesions, and motor signs of infantile strabismus such as latent nystagmus, optokinetic or pursuit asymmetry, or dissociated vertical or horizontal deviation. Surgery was done for the largest angle of esotropia measured through the hyperopic spectacles, with the amount of recession or resection based on standard surgical tables. No patient had planned augmented surgery.

The following information was gathered from the pre-operative visit, the three-month, six-month, and one-year post-operative visits, and the most recent visit to the Eye Center: visual acuity, current spectacle prescription, cycloplegic refraction, and the angle of strabismus measured through the current spectacles at

both distance and near fixation on an accommodative target. Cycloplegic refractions were obtained 30 minutes after instillation of one drop of a mixture of two parts cyclogyl 1%, one part cyclogyl 2%, and one part phenylephrine hydrochloride 10% in each eye. Also recorded were the presence or absence of fusion and/or stereopsis, A- or V-pattern, oblique muscle dysfunction, and results of prism adaptation testing where available. Stereopsis and fusion was measured through prism offset of the deviation if necessary. The family's compliance with recommended treatment, including spectacle wear, amblyopia therapy, and follow-up visits were recorded. Surgical success was defined as a tropia $\leq 8^{\Delta}$ at distance and near fixation measured through the cycloplegic refraction on an accommodative target, with evidence of fusion and/or stereopsis.

RESULTS

One hundred and eight consecutive patients met the inclusion criteria. Eighty-one percent manifested both an accommodative and non-accommodative component to the deviation at presentation. Deteriorated refractive accommodative esotropia could be documented in only 19%. One hundred and three (95%) underwent bilateral medial rectus recessions as the initial surgical procedure. The remaining five patients underwent unilateral recess-resect procedures. Forty patients (37%) were surgical successes following the one procedure, 21 (19%) had a persistent residual esotropia $\geq 10^{\Delta}$ and 47 (44%) developed a persistent consecutive exotropia $\geq 10^{\Delta}$ necessitating further treatment. The mean age at time of surgery was statistically identical in all three groups: 3.8 ± .46 years in the success (S) group, 3.5 ± .59 years in the residual esotropia (RET) group, and 3.8 ± .34 years in the consecutive exotropia (CXT) group. Thirty percent of the residual esotropic patients had a history of deteriorated refractive accommodative esotropia, compared to only 18% of the successes and 15% of the consecutive exotropia cases. Chi-square testing revealed a statistical relationship between etiology (mixed esotropia at onset vs. deteriorated accommodative esotropia) and surgical ($P = .05$). Mean total follow-up time was similar in the three groups: 5.2 ± 0.6 years (range 2.0 to 8.3 years) in the S group; 5.1 ± 0.5 years (range 2.0 to 8.1 years) in the RET group; and 5.4 ± 0.36 years (range 1.8 to 10 years) in the CXT group. The pre-operative clinical characteristics of each outcome group are listed in Table 1.

TABLE 1
PRE-OPERATIVE CLINICAL CHARACTERISTICS OF 108 PATIENTS WITH PARTIALLY ACCOMMODATIVE ESOTROPIA

Outcome Group	Mean Distance Deviation†	Mean Near Deviation	Mean Refractive Error* of Fixing eye	Spectacle Rx at Time of Pre-op Exam
Residual ET				
N = 21	26.6 ± 3$^{\Delta}$	31.6 ± 2$^{\Delta}$	+4.50 ± .4D	+4.20 ± .4D
Success				
N = 40	31.9 ± 2$^{\Delta}$	34.8 ± 2$^{\Delta}$	+4.95 ± .3D	+4.48 ± .3D
Consecutive XT				
N = 47	27.4 ± 2$^{\Delta}$	32.5 ± 2$^{\Delta}$	+4.65 ± .3D	+4.20 ± .4D

* spherical equivalent of cycloplegic refractive error
† statistical difference between outcome categories

Deviation at Distance And Near Fixation

Though the mean preoperative near deviation was similar in all three groups, the outcome groups differed significantly in the distance deviation. Both the RET ($P = .15$) and CXT ($P = .10$) groups had less esotropia at distance through the hyperopic spectacles than the S group. Mean difference between the distance and near deviation (distance-near disparity) was $3.7 \pm 1^{\Delta}$ in the S group and $5.0 \pm 2^{\Delta}$ in the RET group. Mean distance-near disparity was significantly higher at $6.0 \pm 1^{\Delta}$ in the CXT group ($P = .05$).

Refractive Error

Preoperatively, the mean spherical equivalent of the cycloplegic refraction of the dominant eye was similar in all three groups ($P > 0.25$). There was no significant difference between the cycloplegic refraction and the hyperopic spectacles worn at the preoperative visit for the 108 patients overall. However, 26% of the CXT group were under-corrected by more than 0.50D when the pre-operative strabismus measurements were taken. This may have resulted in unintentional augmented surgery in these "under-plussed" patients. In contrast, only 17% of the S group and 10% of the RET group wore under-corrected spectacles.

No patient in the RET group had an anisometropia greater than 0.75D, compared to 30% of the S group and 38% of the CXT group with anisometropia (Figure 1). Average anisometropia ranged from $+0.35 \pm 0.1$D in RET, $+0.50 \pm 0.1$D in the S group, and $+1.10 \pm 0.4$D in the CXT group. The mean anisometropia in the CXT group was significantly greater than in the RET group ($P = 0.05$). Though statistically different from the S group to a P value of only 0.15, the severity of the anisometropia in the CXT group may be clinically relevant.

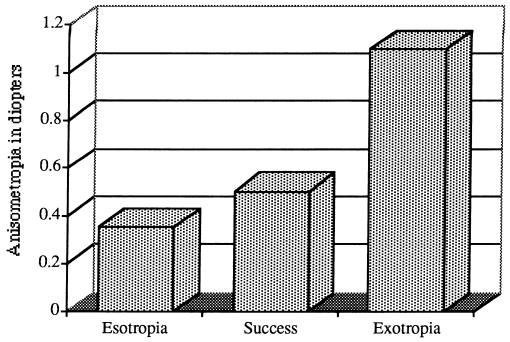

FIGURE 1: Surgical Outcome and Preoperative Anisometropia. The magnitude of the anisometropia was significantly greater in those who developed consecutive exotropia (vs. residual esotropia P = 0.05; vs. successful outcome P = 0.15).

Visual Acuity

Moderate to severe amblyopia, defined as a difference in linear optotype vision of > 2 lines, was present at the time of surgery in 35% of the S group, 36% of the CXT group, and 55% of the RET group. Though this difference was not statistically significant ($P > 0.2$), patients with moderate to severe amblyopia were more likely to develop a residual esotropia.

Binocular Vision

Stereopsis of at least 400 seconds of arc was found in 35% of patients in the S group, 14% of the RET group, and 13% of the CXT group (Figure 2). Chi-square testing showed that patients with stereopsis were more likely to have a successful outcome ($P = 0.05$). The correlation between degree of stereoacuity and surgical outcome was weakly positive ($\phi = 0.26$).

Prism Adaptation Test Results

Twenty-nine of the 108 patients had preoperative prism adaptation testing (PAT) prior to the initial surgery. Forty-one percent were PAT successes, and 58%

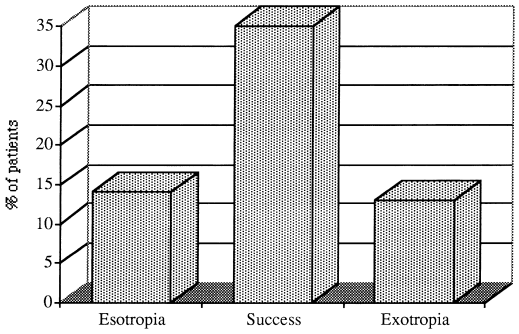

FIGURE 2: Surgical Outcome and Stereopsis. Patients with stereopsis of at least 400 seconds of arc prior to surgery were more likely to have a successful outcome (P = 0.05).

were PAT failures. Only 33% of the PAT successes were also surgical successes. Thirty-five percent of the PAT failures were also surgical successes. Though the numbers suggest a negative correlation between prism adaptation and surgery, this is most likely due to the small numbers of patients who underwent prism adaptation. There was no correlation between PAT outcome and surgical outcome with the chi-square test ($P > 0.99$).

Compliance with Treatment

Poor compliance with spectacle wear was noted in 37% of the S group, 40% of the RET group, and 34% of the CXT group. The differences were not significant. Poor compliance with follow-up visits was statistically less common in the RET group (10%) than in the S (35%) or the CXT (36%) groups ($P \leq 0.10$).

Postoperative Results

The post-operative results are listed in Table 2. Mean time to recurrence of the esotropia in the RET group was 1.3 ± 0.4 years (range 3 months to 5.5 years). Consecutive exotropia developed at a mean 1.3 ± 0.3 years (range 3 months to 9 years) following surgery. Strabismus recurred in 75% of the RET and 68% of the CXT groups within twelve months of the surgery.

Though not statistically significant, the mean spherical equivalent of the cycloplegic refractive error became slightly more hyperopic with time in all three groups (Figure 3). Although the increase in hyperopia was not significant in the RET group ($P \leq 0.2$), patients with increasing hyperopia over time were more likely to develop RET ($P = .O1$). Approximately one third of the CXT group had low to moderate hyperopia, defined as a mean spherical equivalent of the dominant eye less than 4.00 diopters. Low hyperopia was twice as common in the CXT group as in the other two outcome groups, though this difference was not significant ($P = 0.15$). Mean spherical equivalent of the refractive error < 4.00 diopters strongly cor-

TABLE 2
POST-OPERATIVE RESULTS

Outcome Group	Mean Distance Deviation†	Mean Near Deviation†	Mean Refractive Error* of Fixing Eye	Mean Change in Refractive Error†
Residual ET				
N = 21	+16.2 ± 2$^{\Delta}$	+21.1 ± 2$^{\Delta}$	+4.90 ± .2D	+0.51 ± .2D
Success				
N = 40	+1.4 ± .5$^{\Delta}$	+3.6 ± .5$^{\Delta}$	+5.15 ± .3D	+0.32 ± .2D
Consecutive XT				
N = 47	−20.1 ± 1$^{\Delta}$	−15.7 ± 2$^{\Delta}$	+4.76 ± .3D	+0.18 ± .2D

* spherical equivalent of cycloplegic refractive error
† statistical difference between outcome categories

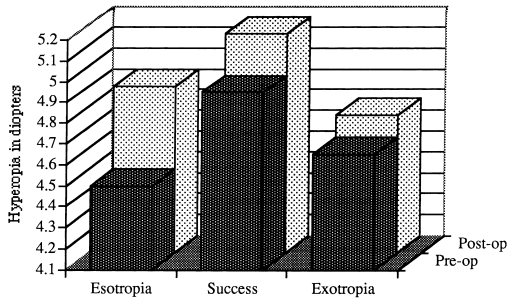

FIGURE 3: Pre- and Postoperative Refractive Error. The mean spherical equivalent of the refractive error of the dominant eye became more hyperopic over time in all three groups. The hyperopic shift was significant only in the RET group (P = 0.15).

related with surgical over-correction (P = .10).

Consecutive Exotropia Management with Reduced Hyperopic Correction

Thirty-three (70%) of the 47 patients with consecutive exotropia were initially managed with reduction of the hyperopic correction by a mean 2.50 ± 0.27 diopters (range 1 to 5 diopters) (Figure 4). Decreasing the hyperopic power of the spectacles had no effect on alignment in 15 (45%) cases. Twelve (36%) had a temporary reduction in the exotropic angle to within fusion range (≤ 8$^{\Delta}$ of orthotropia). The full consecutive exotropia returned through the reduced hyperopic correction in all of these cases and surgery was performed at an average 1.6 ± 0.3 years after the institution of reduced hyperopic power. Only six cases (18%) have been successfully managed with reduced spectacle power. However, the mean follow-up since the start of reduced hyperopic correction treatment in these six cases is only 0.58 years (about 7 months), which is significantly less than the follow-up time of those who had a temporary effect (P = .01).

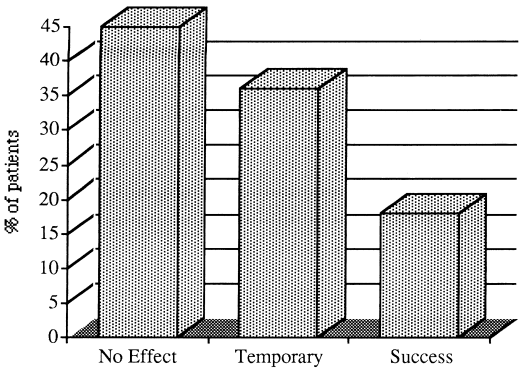

FIGURE 4: Management of Consecutive Exotropia with Reduced Hyperopic Correction. Only 18% of cases have been successfully managed with intentional refractive undercorrection over an average follow-up time of only seven months.

Nineteen of the 33 cases (58%) originally managed with reduction of the hyperopic correction underwent supplemental cover test measurements on a non-accommodative target, in addition to distance and near testing through the reduced correction on an accommodative target. This was done in each case because the family had reported a large divergent deviation at home, in spite of the esotropia or orthotropia seen in the office with prism and alternate cover test measurements on an accommodative target. These 19 patients were under-corrected by an average of 3.13 ± 0.75 diopters of hyperopia, and their exodeviation increased by a mean 22.7 ± 0.5$^{\Delta}$ on the non-accommodative target. The exotropia increased in every case with relaxation of accommodation.

Re-operations

Thirteen of the 21 RET patients have had re-operation to date. Of these, two (15%) have persistent ET, four (31%) have had good surgical outcomes, and six (54%) have developed consecutive exotropia. Twenty-seven (57%) of the 47 patients in the CXT group have had a second surgery. Three (11%) developed esotropia, 18 (64%) had a successful outcome, and

seven (25%) developed a recurrent exotropia.

DISCUSSION

Residual ET is more likely to occur in patients with moderate to severe amblyopia, and increasing hyperopia with age. Patients who develop a non-accommodative component after a period of full correction of the esotropia with hyperopic spectacles are about twice as likely to develop a residual esotropia following surgery. Consecutive exotropia was more likely to develop in patients with a distance-near disparity, anisometropia, and poor stereopsis, who were not wearing the full cycloplegic refraction prior to surgery. Undercorrection of the hyperopic spectacles was not effective in the long-term management of CXT. Only 18% of cases have maintained orthotropia through reduced hyperopic correction for an average of only 7 months.

Partially accommodative esotropia is usually described as a secondary accommodative esotropia that develops in a non-accommodative case, such as an infantile esotropia,[3] or a secondary non-accommodative esotropia that develops in a patient with refractive accommodative esotropia.[1,11,12] The 81% of patients in this study with both accommodative and non-accommodative components at presentation, without evidence of infantile strabismus, suggest that a primary mixed mechanism esotropia may also exist.

The relationship between refractive error and surgical outcome in partially accommodative esotropia is unclear. Some authors report better surgical results in patients with higher refractive error,[13] while others report the opposite.[7] In this study, hyperopia of < 4 diopters was significantly more likely to be found in consecutive exotropia than in the two other outcome groups.

Recent longitudinal studies on the development of refractive error in infants and children suggest that hyperopia remains stable or decreases over time after the age of 6 months in normal children.[14] Increasing hyperopia with age, as was found in this study, is unusual. It may be that the subset of patients with strabismus and high refractive error differs significantly from the population of normal children with refractive error, in that they may be prone to increasing hyperopia. However, the results of this study may also be explained by inadequate cycloplegia at the initial exam. If this is the case, it is not surprising that low hyperopia preoperatively was so common in patients that eventually developed consecutive exotropia. These patients may represent a subgroup that did not cycloplege well, resulting in under-correction in glasses and unintentional augmented surgery. A preoperative atropine refraction would minimize the risk of underestimation of the hyperopic refractive error.

Prism adaptation has been recommended to identify those patients who can safely undergo enhanced surgery without risk of over-correction.[15] In the report by Repka and co-authors, the over-correction rate following prism adaptation and standard esotropia surgery was only 1.6%. However, only 20 of their 305 study patients had hyperopia $\geq +3.00$, and, therefore, are possible cases of partially accommodative esotropia. It is not clear from the report if the five consecutive exotropic patients fell into this small sub-group. The results of the present study indicate that prism adaptation is not helpful in identifying patients at risk for over-correction.

Spontaneous secondary exotropia has been reported to occur after age 8 or 9 years in approximately 10% of fully refractive accommodative esotropia cases.[9,16,17] One might predict that surgery for the non-accommodative component of the eso-

tropia would result in consecutive exotropia in patients at risk for spontaneous exotropia. Previous reports suggest that spontaneous exotropia is a very rare condition, and therefore unlikely to account for the relatively large percentage of over-corrected cases in this study. In addition, the 29 reported cases of spontaneous secondary exotropia in the literature have little in common with the cases of consecutive exotropia in this study. For example, 72% of the spontaneous secondary cases had a refractive error greater than five diopters of hyperopia, compared to only 32% of the CXT cases in this study. Another risk factor for secondary exotropia identified in these earlier studies is onset of the esotropia within the first two years of life. In the present study, 46% of the CXT group and 50% of the S group had an onset of the strabismus at age two years or younger. Secondary exotropia is reported to occur at age 8 years or older. Forty-eight percent of the surgical successes have been followed beyond age 8 years without development of a consecutive exotropia.

Surgical over-corrections have been interpreted as evidence of the resolution of the accommodative component of the esotropia following surgery,[10] or of the natural emmetropization process.[5] Results of this study do not support either of these theories. There was ample evidence of the persistence of the accommodative component and the hyperopia in all outcome groups. First, the average amount of hyperopia increased slightly over the years of follow-up in all three groups. Second, with the exception of the 15 CXT cases that had no response to decreased hyperopic correction postoperatively, eye alignment continued to respond to changes in accommodative effort after surgery in all three groups as evidenced by their continued need for hyperopic correction to maintain eye alignment. Third, only two (5%) of the 40 surgical successes have been able to eliminate their hyperopic spectacles while maintaining alignment and fusion. Even these two patients have a persistent accommodative esophoria, controlled with divergence fusional amplitudes, suggesting that true resolution of the accommodative component is exceptionally rare.

Consecutive exotropia has also been viewed as evidence of an evolving dissociated horizontal deviation.[18] True dissociated strabismus is associated with infantile rather than acquired strabismus.[19] In the report by Wilson and co-workers, only two of the six cases with presumed dissociated horizontal deviation had documented infantile esotropia. In their report, preoperative measurements of the strabismus were taken through reduced hyperopic power in each reported case. All were wearing spectacles that were at least 1.25 diopters less than the full hyperopic correction. In each case, the consecutive exotropia was evident when the patient relaxed accommodation. If a refractive esotropia were surgically corrected, one might expect a clinical picture that mimics DHD. When accommodating, orthotropia or a small angle esotropia would be observed. When relaxing accommodation, an exotropia would result. This pseudo-DHD effect was seen in 19 patients in the present study. Like the four cases of acquired esotropia in the study by Wilson et al., the 19 patients who demonstrated the features of DHD in this study were under-corrected in their hyperopic spectacles. The added accommodative effort required by the reduced prescription diminished the angle of exotropia significantly when measured on an accommodative target. When measured on a non-accommodative target, or when in a familiar environment such as the child's home, the relaxation of accommodation produced a large angle exotropia.

At 44%, the over-correction rate following standard surgery for partially accommodative esotropia is much higher in this study than previously reported. This is due in a large part to the strict definition

of consecutive exotropia used. Cases that required any decrease in the hyperopic refractive error to bring the deviation within fusion range ($\leq 8^{\Delta}$) were considered over-corrected. The incidence of consecutive exotropia may also be influenced by the follow-up time. Yazawa found that postoperative alignment became more divergent with time, and did not become stable for at least five years after the esotropia surgery in his series of consecutive exotropic patients.[9] His results predicted that the number of cases of consecutive exotropia would double between five and ten years after surgery. Many of the earlier studies with low over-correction rates have analyzed the surgical outcome at one year or less.[4-17,15] Consecutive exotropia occurred at an average of 1.3 years following esotropia surgery in this study, and with a mean post-surgical follow-up of 5.2 years for the entire study population, it is to be expected that the rate of over-correction will be higher than that found in studies with only a 6 to 12 month follow-up period.

Small consecutive exodeviations $\leq 10^{\Delta}$ are often considered desirable in the immediate post-operative period. Dankner and co-authors reported that unintentional small-angle consecutive exodeviation at the one-week to one-month post-operative visit was predictive of a good outcome at six months and one year following surgery for acquired esotropia.[8] Surgeons recommending augmented surgery for partially accommodative esotropia often cite this study as proof of the efficacy of intentional over-correction. However, Dankner clearly advises against enhanced surgery for an accommodative component in his report. He and others caution against intentional over-correction, reporting that reduction of the spectacle correction is not effective in managing consecutive exotropia, and may result in an unstable deviation or asthenopia.[3,9]

To avoid consecutive exotropia, Yazawa recommends that the full accommodative component be corrected non-surgically; that the surgery be done for the minimum angle of the deviation; and that re-operations for residual esotropia be limited to angles greater than 15^{Δ}. The results of the present study support Yazawa's recommendations. Consecutive exotropia was associated with a preoperative under-correction of the hyperopic refractive error resulting in an unintentional augmented surgery, and more than half of the re-operations for residual esotropia resulted in consecutive exotropia.

CONCLUSIONS

Surgical under-correction occurred in only 19% of patients with partially accommodative esotropia, and was more likely to occur in those with deteriorated refractive esotropia, moderate to severe amblyopia, and increasing hyperopia with age. Standard surgery resulted in a high over-correction rate of 44%. The over correction rate exceeds most published reports due to the strict definition of over-correction and the extended follow-up time defined in this study. Patients at greatest risk for over-correction are those with anisometropia >0.75 diopters, spherical equivalent of the refractive error <4.00 diopters in the least hyperopic eye, a distance-near disparity, poor binocular vision, and under-correction of the hyperopic refractive error prior to surgery.

The high rate of consecutive exotropia following standard surgery suggests that intentional over-correction of partially accommodative esotropia is highly likely to result in a consecutive exotropia necessitating further treatment. Under-correction of the hyperopic refractive error is not effective in the long-term management of consecutive exotropia and may result in a pseudo-DHD. However, this strategy may postpone re-operation for approximately one year in some cases.

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Key words: accommodative esotropia, consecutive exotropia, dissociated horizontal deviation.