BINOCULARITY FOLLOWING SURGICAL CORRECTION OF STRABISMUS IN ADULTS

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ABSTRACT

Introduction: This is a retrospective study to determine the preoperative and postoperative binocular status of adults who have undergone surgical correction of strabismus.

Methods: A list of all consecutive adult patients who underwent surgery for strabismus between June 1990 and December 2001 (surgery performed by M.B.M.) was compiled, and their medical charts were reviewed. Patients were included if their charts were available for review and if information on binocularity was recorded. Binocularity was measured by the Titmus stereo test, Worth 4-dot test, or synoptophore. Improvements or decreases in stereo acuity were noted 6 weeks postoperatively and at the final office visit. Prism management was incorporated preoperatively and/or postoperatively in some of our patients. A total of 112 patients underwent surgery for strabismus. Of these, 72 patients, aged 16 to 80, were included; 24 were excluded because their charts did not contain any information on stereo acuity at least 6 weeks postoperatively or they were lost to follow-up after surgery, and 16 were excluded because their charts were unavailable from storage.

Results: A variety of surgeries were performed, the most common being a bilateral medial rectus recession. Eleven patients required a second surgery, and two required a third surgery. Overall, 30 (42%) of the 72 patients improved in binocular function, 38 (53%) remained the same, and 4 (5%) had decreases in their stereo acuity.

Conclusion: The benefits of surgical correction of strabismus in adults include improvement in binocular function, as seen in 42% of the patients in the study.

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INTRODUCTION

Reconstructive surgery is performed to reestablish normal structural and functional relationships when abnormal structure and function are present. Numerous studies have demonstrated the functional benefits of strabismus surgery in adults.

Clearly, the presence of strabismus has a profound impact on the psychological well-being of patients. Patients have reported difficulty with self-image, employment, and interpersonal relationships.[1] The positive impact of correcting strabismus has been well documented by studies in which patients described improvements in interpersonal interactions, which they ascribed to the corrective surgery.[2] Another functional benefit, described by Wortham and Greenwald,[3] is the expansion of visual fields; in a study of 10 esotropic adults, surgery resulted in increase in horizontal visual field with an accompanying subjective increase in peripheral vision for many of the patients. Since loss of fusion is a valid indication for surgery, it is important to establish that strabismus surgery in adults leads to an improvement in sensory fusion.[4] In addition, previous studies have investigated the improvement of binocularity following surgical correction of strabismus in adults. Kushner and Morton[5] reported an increase in binocularity as determined by the Bagolini lenses, which was, in turn, correlated with long-term postoperative ocular alignment. In a study of 24 patients with long-standing strabismus, Morris and associates[6] achieved an improved postoperative alignment as well as peripheral fusion at near, demonstrated by the Worth 4-dot test. Scott and associates[7] reported both a successful alignment and an improvement in sensory fusion in patients who developed strabismus both before and after visual maturity.

In this study, we reviewed consecutive adult patients with strabismus to determine if there was an increase in binocularity following surgery. We found that improvement in binocularity, including stereopsis, can be obtained in a substantial portion of adults.

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METHODS

We performed a retrospective chart review of consecutive, adult strabismus patients operated on by one surgeon (M.B.M.) between June 1990 and December 2001. Patients were included in the study if they had a minimum of 6 weeks postoperative follow-up, if preoperative and postoperative data on binocular function was recorded, and if their charts were available for review. Patients lost to follow-up prior to the 6-week postoperative visit, patients with insufficient data regarding binocular function at the 6-week postoperative visit, and patients whose charts were not available for review were excluded from the study. A total of 112 patients, aged 16 to 80 years, underwent surgery for strabismus. Of these, 72 patients were included in the study. Twenty-four patients were excluded because of lack of information regarding binocular function, and an additional 16 were excluded because their charts were unavailable.

The following data for each patient were recorded: date of first visit; age at first visit; corrected visual acuity of each eye; previous strabismus surgery; current strabismus diagnosis; strabismus surgery performed; date of surgery; preoperative measurements of ocular alignment; 6-week postoperative measurements and final measurements with the appropriate dates of visit; and stereo acuity or other measure of binocular function at the preoperative visit, at the 6-week postoperative visit, and at the final visit. Binocularity was measured by the Titmus stereo test or assessed by Worth 4-dot or on the synoptophore. All measurements of ocular alignment, stereo acuity and other binocular function were performed by our orthoptist (B.A.H.).

In some of our patients, we used prisms preoperatively and/or postoperatively to eliminate diplopia or to provide binocular function in casual seeing conditions. These patients were monitored closely and their prisms adjusted as needed. Specific details of their prism management are not included in this paper.

RESULTS

The study included 30 males and 42 females. Overall, 30 (42%) of the 72 patients improved in binocular function, 38 (53%) remained the same, and 4 (6%) had decreases in their stereo acuity.

A total of 87 procedures were performed in the study group (Table I). Fifty-nine patients had only one surgery by us, 11 patients had two surgeries, and 2 patients had three surgeries. Fourteen of the patients had previous strabismus surgeries performed elsewhere. The surgeries were tailored to the needs of the patients. Many of them required exploration of muscles, lysis of scars, asymmetric surgery, and advancement of previously operated muscles. Adjustable sutures were used in only two patients, patients 16 and 67, who had Graves' disease with concurrent horizontal and vertical deviations.

Thirty patients had improved binocular function. Of those, 3 demonstrated binocularity by Worth 4-dot testing and 27 showed improvement by Titmus stereo acuity testing. They are summarized in Table II. Table IIA documents the types of strabismus and IIB summarizes onset time and etiology. In the group of 19 with improved binocular function who had adult onset of their strabismus (Table IIB), there were events such as head trauma and stroke that impacted on presumably well-developed sensory systems, and realigning the eyes improved testable binocular function. Those with improved binocular function and childhood onset of their strabismus are more puzzling. However, closer examination of the four patients with esotropia (Table IIB) reveals three with hyperopia who were accommodative esotropes

TABLE I: SURGERIES PERFORMED

ESOTROPIA (N = 30)	NO.	EXOTROPIA (N = 17)	NO.
BMR rec	14 (1 asymmetric)	BLR rec	8 (1 asymmetric)
BMR + vert displacement	3	LR rec unilateral	1
R&R	4	BMR res	2 (1 asymmetric)
MR rec unilateral	6	MR res (unilateral)	1
BLR res	3	MR advance LR rec	2
	30	LR rec modified Knapp	1
		R&R	2
			17

Combined horizontal and vertical	8
Vertical	30
Torsion (Harada-Ito)	2

BLR, bilateral lateral rectus; BMR, bilateral medial rectus; LR, lateral rectus; MR, medial rectus; Rec, recession; Res, resection; R&R, recession and resection.

TABLE II: IMPROVED BINOCULAR FUNCTION

N = 30	
Improved Worth 4-dot	3
Improved stereo (Titmus)	27

TABLE IIA: TYPES OF STRABISMUS

N = 30	
Esotropia	9
Exotropia	10
Superior oblique palsy	9
Vertical not superior oblique	2

TABLE IIB: ONSET TIME

Adult onset (N = 19)	
Trauma	6 (5 motor vehicle accident, 1 bicycle)
Neurologic	3 (cerebral vascular accident)
Following surgery	5 (2 cataracts, 2 retinal detachments, 1 sinus)
Miscellaneous	5 (2 esotropia, 3 exotropia)
Childhood onset (N = 11)	
Esotropia	4
Exotropia	3
Superior oblique palsy	3
Vertical not superior oblique	1 (plagiocephaly)

and one with an A-pattern esotropia. The exotropes most likely had intermittent exotropia in childhood, and the four patients with the vertical deviations could fuse with head positions. Thus, all of these patients would have been able to develop some binocular function during childhood though their strabismus was present at that time.

In 38 patients, stereo acuity remained unchanged preoperatively and postoperatively. Nineteen had no stereo recorded ever, 13 had 40 seconds preoperatively and postoperatively, and 6 had intermediate amounts of stereo preoperatively and postoperatively. Table IIIA summarizes those patients with no recorded stereo, all of whom had onset of their strabismus either congenitally or in childhood. The 13 patients with 40 seconds of stereo preoperatively and postoperatively (Table IIIB) had postoperative improvement in diplopia (9 patients), head position (3 patients), and torsion (1 patient). Those patients with intermediate amounts of stereo (range, 50 seconds to 400 seconds) are summarized in Table IIIC. In two of these patients, head position improved. Two had their diplopia eliminated, one had a decrease in her esotropia angle, and one had persistent asthenopic symptoms.

Table IV summarizes the four patients with decreased stereo acuity. We have not seen patient 14 since her 6-week postoperative visit, and her stereo may have improved. Patients 16 and 29 have had ongoing ocular

TABLE III: BINOCULAR FUNCTION UNCHANGED

N = 38	
No stereo	19
40 seconds stereo	13
Intermediate	6

TABLE IIIA: BINOCULAR FUNCTION UNCHANGED NO STEREO

N = 19	
Esotropia	11
Exotropia	5
Third nerve palsy	1
Congenital cataract	1
Retinal	1 (congenital stationary night blindness)

TABLE IIIB: 40 SECONDS STEREO

N = 13	
Superior oblique palsy	6 (3 congenital, 2 motor vehicle accident, 1 childbirth)
Graves	3
Esotropia	1 (trauma: fall at age 12)
Partial third nerve palsy	1
Hypertropia	1
Intermittent exotropia	1

TABLE IIIC: INTERMEDIATE STEREO

N = 6		
Graves	2	(60 sec, 80 sec)
Pseudophakia	1	(50 sec)
Lasik	1	(200 sec)
Asthenopia	1	(50 sec)
Convergence excess	1	(400 sec)

problems since the time of their surgery, and patient 60 had 50 seconds of stereo preoperatively, 80 seconds at 6 weeks, and 60 seconds on the final visit. She wore a toric contact lens. Although she had a mild decrease in her final stereo, she demonstrated an improvement in her diplopia.

DISCUSSION

The goal of adult strabismus surgery is not cosmetic, but rather to correct or revise a pathologic condition.[4] The literature has reported on the psychosocial implication of strabismus surgery in adults and expanded binocular visual fields following adult strabismus surgery.[1-3] Binocular function is a quantifiable and very desirable result of strabismus surgery in adults as well. The literature describes improvement in diplopia, motor fusion, binocularity as measured by Bagolini lenses, develoment of the monofixation syndrome, and stereo acuity in a

TABLE IV: POSTOPERATIVE DECREASE IN STEREO ACUITY

PT NO.	PREOPERATIVE STEREO	POSTOPERATIVE STEREO	HYPOTHETICAL REASON FOR DECREASE
14	Surgery 1: 40 sec Surgery 2: 40 sec	Surgery 1: 40 sec (15 mo) Surgery 2: 60 sec (6 wk)	 Conjunctival wound dehiscence Suture irritation/tearing
16	Surgery 1: 80 sec 400 sec (6 mo) Surgery 2: 0	Surgery 1: 80 sec (6 wk), Surgery 2: 400 sec (6 wk)	Progressive Graves' ophthalmopathy
29	50-60 sec	50 sec (4 mo) 40 sec (12 mo) 400 sec (>6 yr)	s/p CE/IOL s/p IOL exchange s/p trabeculotomy s/p blebitis/endophthalmitis/uveitis
60	50 sec	80 sec (6 wk) 60 sec (5 mo)	Toric contact lens

CE, cataract extraction; IOL, intraocular lens.

select group of patients.[5-9]

Scott and associates[7] studied 892 patients whose age at surgery ranged from 9 to 89 years. This large series divided patients into two groups: (1) before visual maturity, with 21% having preoperative diplopia, and (2) after visual maturity, with 81% having preoperative diplopia. Both groups showed only 2% of patients with postoperative diplopia.

Pratt-Johnson[8] reported two adult patients with acquired fusion disruption and intractable diplopia from long-standing occlusion from acquired cataracts. Both of these patients preoperatively experienced vertical bobbing, typical of fusion disruption in free space and on the synoptophore. Several months after surgical alignment, both patients no longer experienced vertical bobbing and demonstrated motor fusion on the synoptophore. Kushner and Morton[5] studied a selected group of typical strabismus patients (those whose postoperative measurement was within 10 diopters of orthotropia), who were 21 years and older at the time of surgery and whom they measured with Bagolini lenses. In this select group of surgical results, 86% of patients demonstrated binocularity by 6 weeks postoperatively; the highest percentage of binocularity was found in patients with primary exotropia (92%), and the lowest was found in patients with hypertropia (58%).

Morris and associates[6] studied consecutive esotropic patients (onset within 2 years of age) with no history of alignment until 8 years or older and no fusion demonstrated preoperatively by red glass test, Worth 4-dot test, or Titmus test. Of these 24 patients, 50% developed the mono fixation syndrome postoperatively. O'Neal and associates[9] studied a select group of 20 intermittent exotropic patients (aged 54 years to 87 years) who underwent strabismus surgery and measured Titmus at near and Mentor B-vat stereo testing at distance. Stereo acuity improved in 75% of patients at near and 45% at distance. We tested 72 consecutive surgical patients 16 years and older preoperatively and postoperatively for binocularity by synoptophore, Worth 4-dot testing, and Titmus testing. Of these, 30 (42%) improved in their stereo acuity. Thirty-eight (53%) remained the same, but of these, 19 (50%) had no recordable stereo preoperatively or postoperatively and had probably never developed the capacity for binocularity. Thirteen (34%) had 40 seconds of stereo preoperatively and therefore could not improve by our criteria. (They did improve by the criteria of head position, diplopia, and torsion.) If you excluded these 32 patients who had no capacity for improvement in stereo acuity postoperatively, and look only at the 40 surgical patients who could improve postoperatively, 30 (75%) did improve.

Clearly, whether measured by improvement of diplopia, development of motor fusion, Bagolini lens sensory function, or stereo acuity (the most quantifiable and the most highly developed type of sensory binocular function), adult strabismus surgery can improve binocular function. In our study, improvement occurred in 42% of patients as measured by the Titmus stereo acuity test.

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DISCUSSION

Dr Susan H. Day. The authors address an important aspect of strabismus surgery in adults–binocular function–which is of paramount importance in managing childhood strabismus, but which is assumed to be of less importance in adults. From many presentations at this 139th meeting of the AOS, we have learned a new respect for differences in how we think about common ophthalmic conditions; this theme continues in this manuscript.

The authors' retrospective review is over a long period–10 years–with one tester of binocular function (BAH) and one surgeon (MBM). Unfortunately, 36 of 112 patients who underwent surgery as adults either were not tested (N=24) or had no charts (N=16) for review. It would be very helpful to know why the 24 patients were not tested, and further chart review might elucidate this.

The method of binocular testing was also variable, with either the Titmus, Worth 4 dot, or synoptophore techniques. Criteria for choice among these were not mentioned. Notably, two different binocular functions–stereopsis and fusion–were tested.

Despite the limitations of study design, the results nevertheless support our concepts of binocular vision development as occurring at a very early time in a person's life, and one that is linked to orthophoria. Early-onset and constant strabismus results in altered development of binocular function; intermittent strabismus even during childhood may be consistent with normal stereopsis. Adult-onset strabismus results in abnormal binocular function–diplopia–with the expectation that restoration of straight eyes will result in return of normal binocular function.

The authors appropriately review the literature pertinent to this study, and thus this manuscript is a contribution to growing literature that supports strabismus surgery as having the potential to improve binocular function.

There are unanswered questions regarding this manuscript which might be addressed either by further review of the data or by the design of a prospective study:

1. When did the insult to binocular function occur? At the root of the oversimplified approach to discerning the etiology of strabismus is a fundamental nature versus nurture question, elucidated by Worth and by Donders. In my experience, this question is exceedingly difficult to answer, since one cannot rely upon parents' judgment of eye alignment or prompt examination to confirm such finding by an ophthalmologist.
2. When was binocular function restored? Without a prospective model, only inferences can be made. Resolution of this issue also begs the question as to how binocular function is tested and defined.
3. Were there any surprises? In large part, the authors obtained improvement in binocular function in patients who had adult-onset strabismus or intermittent childhood strabismus.
4. Is a 42% improvement valid? Data was not available for an additional 36 individuals. Conceivably, the 24 whose charts were available but who did not have binocular testing had no binocular tests because the examiner did not sense that binocular function would be present. Assuming none of these had binocular function, one would certainly increase the percentage of patients with "same" binocular function from 53% to 68%, and reduce the "improved" category to 31%. More optimistically, if all 24 had improvement, then the 42% improvement would increase to 56%. With inclusion of those whose charts were not available, further speculation as to its influence on such data will not be made.
5. Did patients experience any subjective improvement vis á vis binocular function? What matters the most is our ability to help our patients enjoy their lives more. Clearly, adult strabismus surgery that eliminates diplopia and restores normal binocular function is an appreciated gift. I question whether a patient would notice, however, a subtler shift in stereopsis and wonder its relative value to the patient in comparison to improvement of visual fields and restoration of a more normal appearance.

In summary, this paper defines improvement of binocular function as a goal of surgery, concludes that many do improve, and validates that adult surgery is more

than cosmesis. The predominant limitations occur as a result of the retrospective study design and the exclusion of nearly one-third of the adults who did have such surgery. The question that is asked of strabismologists is, "Will binocular function improve after adult strabismus surgery?" In large part, this is answered by taking a very careful history of vision development, of timing of onset of strabismus, and of treatment intervention. I encourage the authors and others to address these important historical issues prospectively, and predict that these nuances are of essential importance in counseling any individual patient preoperatively.

Dr Douglas D. Koch. I assume that all the preoperative testing was done with prismatic correction. However, that raises the issue about whether just having prisms present could create optical changes that could reduce stereopsis; this alone might account for the postoperative improvement in stereopsis. There's also a testing-retesting phenomenon, which is well known and occurs, for example, with visual field and contrast sensitivity testing. Either of these factors could result in better test scores postoperatively.

Dr Malcolm R. Ing. I would think there should be a correlation of the motor angle result and the visual acuity. All of us who deal with adult strabismus would love to predict whether a patient would possibly have a good functional result. Although some patients come only for the cosmetic improvement, we are sometimes suddenly surprised that these patients actually do fuse and regain some binocularity we thought they would never have. Was there any possibility of correlating a synoptophore or fusion test prior to surgery with the end result? Or was there a test you could have for predictability?

Dr Irene H. Ludwig. There are some adult patients with long standing strabismus who do not have stereopsis the first few months, even though they are aligned. A year later they then demonstrate stereopsis. Have you checked the long-term stereopsis results in your patients?

Dr Henry S. Metz. Many of our adult strabismus patients come to us with complaints of diplopia and if you can resolve that they're very pleased, whether they end up with good binocularity as we measure or not. Do you have any data on whether your patients had diplopia when they came, and had resolution of the diplopia following strabismus surgery? I think that would be a very important outcome.

I wonder if you have any data on those with good binocularity, regardless of how they got it, either because they had it when you first saw them, or because you were able to achieve improvement of binocularity, had better long-term stability in terms of their deviation.

Dr Edward L. Raab. As Dr Metz mentioned, most of the adult patients I see have some functional stake in having a better alignment such as eliminating diplopia. By inference, if their surgery results in improvement in their diplopia, it is because they are fusing better. If they were fusing beforehand they wouldn't have had diplopia. So while we talk about stereoacuity as the gold standard of sensory determination, I think that the more useful test is the result on diplopia. If you were ever to design this prospectively for this outcome, for me the best single test for fusion ability preoperatively, with or without prism correction, would be Bagolini glasses, without paying attention to whether there is a central scotoma or whether they have ARC because they shift with cover.

Dr David R. Stager, Sr. The term "cosmetic" is something that makes a normal situation look better. In other words, a face-lift. If you are doing reconstructive surgery, it's converting an abnormal situation to a more normal situation. So I think we ought to get rid of the term cosmetic since this is really reconstructive surgery.

Dr Burt Kushner had an article last fall regarding the problem of diplopia post-op in strabismus patients who did not have diplopia preoperatively. The people who do not have diplopia have a .7 percent incidence of persistent diplopia. So it's a very small percentage of people who will wind up with complaints of diplopia. Many of these patients who do have diplopia really have rapid alternation of their vision. They are sometimes been told by orthoptists that they need to appreciate the two images. So they rapidly alternate and they interpret that as being double vision when it's really rapid alternation.

There is a socio-economic impact of strabismus surgery. Drs Paysee and Coats in Houston did a paper that reported that it really does impact the employability, particularly of women. Eye contact is an important function of communication and I think that having fairly straight eyes in an important aspect.

Dr Edward L. Raab. With regard to the comment of Dr Stager, instead of "reconstructive," I would suggest that he employ the word "restorative."

Dr Marilyn B. Mets. The word "cosmetic" will not appear in the manuscript. Dr Day: the 24 patients were eliminated from the database because there were not pre- and post-operative measurements of binocularity. Twelve of them had either hand motion or count fingers vision in one eye. So binocular testing had not been done on them. They may have been improved by the surgery but they

were not pertinent to this data because they didn't meet the criteria. There were another 12 patients in whom we did not have follow-up data for various reasons. I assume that if binocularity came back that it wasn't really delayed, but that it had developed. If it didn't come back then, at least in some of those cases, binocular function had not developed well.

Dr Koch's comment about testing and retesting is certainly a valid one and could confound the data. Dr Ing: certainly the vision that wasn't in the presentation is present in the manuscript so you can find visual correlation. I don't have a magic test for telling ahead of time who would have a good functional result. A Worth 4-dot and the stereo is done on everyone unless they have very poor vision. When I'm planning on surgery on an adult, I ask for a synoptophore examination. If it's a horizontal deviation, I want to know what the horizontal vergence amplitudes, or the vertical amplitudes so I know what range I am dealing with. I want to know about binocular function. If it looks like they're alternating back and forth as Dr Stager mentioned, then these images are not going to go together, I attempt to increase the range and the field over which they can use both eyes together. With the congenital superior oblique palsies, my goal here is to increase the field over which you can use two eyes together.

On Dr Raab's and Dr Metz's question with regard to diplopia data, we can certainly pull that historically, but it is less quantifiable and a softer end point. Dr Henry Metz referred to looking at long-term stability. We have the data and will, for the patients that we can get to come back in the office, have longer-term data on stability of alignment. Drs Stager and Raab, we certainly will not use the word cosmetic in the manuscript. The points made about eye contact are very important. It impacts greatly on patient's socioeconomic capabilities and is an important improvement that comes from adult strabismus surgery.

Dr Ludwig, we have not, as yet, checked the long-term stereopsis results in our patients, but your experience is also my experience, and I think our data, therefore, may be an underestimate.