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Binocular Vision Problems in Refractive Surgery Patients: Vision Therapy Case Reports

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ABSTRACT

Background: Some post-LASIK patients complain of blurry distance vision months after refractive surgery, despite good corneal healing and negligible refractive error. We postulated that perceiving blur in the absence of refractive error or significant monocular aberrations might result from poor binocular control. Binocular vision testing in a series of such patients revealed convergence problems in 83% of cases.

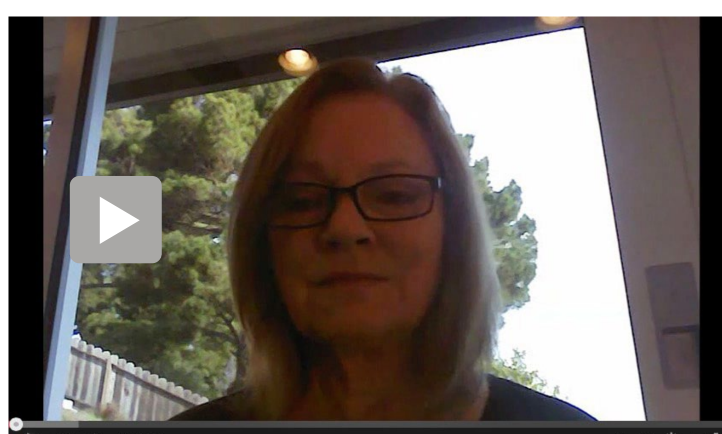
Case Reports: We report on 8 patients (average age 37.4 yrs) who completed up to 40 sessions of vision therapy (VT), either completely via computer or in a combination of computer orthoptics and office vision therapy. Seven patients had received LASIK; one had PRK. Optometric measurements and symptoms were recorded before and after VT treatment, starting at least 3 months after refractive surgery. Near point of convergence improved in 7 cases following VT, and convergence break and/or recovery improved in 6 cases. Six cases reported symptom reduction, and pre-presbyopic cases tended to improve accommodative facility. The number of binocular functions showing improvement per case correlated with the number of VT sessions completed. Convergence changes were statistically significant when pre-/post-VT data were compared for these cases as a group.

Conclusion: Patients complaining of distance blur following refractive surgery may have undiagnosed binocular vision problems. VT incorporating an internet orthoptics component improved convergence ability in the cases reported here, and most patients reported symptomatic relief.

Keywords: accommodative facility, binocular vision, computer orthoptics, convergence insufficiency, LASIK, refractive surgery, vision therapy

Introduction

Because patients elect refractive surgery to obtain clear distance vision, the pre-operative examination may not address near vision or binocular skills. The literature shows, however, that binocular problems can occur post-surgery in both strabismic and non-strabismic patients.[1-7]



If binocular vision is not tested prior to surgery, neither patients nor their doctors can know whether refractive surgery may have caused their binocular vision problem. Thus, when patients complain of blur post-surgery without a refractive explanation, surgeons can only assure the patient that his or her vision has been corrected the best it can be, optically. Yet logic dictates that post-surgery patients who complain of poor vision must have some kind of vision problem. The challenge is to determine what the problem is and then to suggest possible treatment options.

When post-refractive surgery patients at Pacific Vision Institute (PVI) in San Francisco, CA had complaints that could not be addressed with surgical enhancement, the surgeon (EF) referred them to the optometrist (GD) for a binocular vision evaluation. These patients had already been thoroughly tested for sources of monocular blur, including unresolved refractive errors, spherical aberration, and ocular health. The only remaining possible causes for their complaints were therefore either psychological dysfunction (e.g., hypochondria or malingering), which we did not assess, or binocular vision dysfunction.

Binocular vision testing revealed a pattern of relatively weak nearpoint skills in all cases. Most had ortho- to low exophoria in the distance and high exophoria at near (Duane-White classification Type I)[8] with low compensating vergence skills, and all either failed Sheard's criterion (base out break less than 2x the heterophoria)[9] or had noticeably low base out recovery at near, indicating poor stamina for binocular fusion.

These findings were equally surprising to both optometrist and patient, because even though the patients were complaining about symptoms in the distance, the only weaknesses found on examination were in their nearpoint visual skills. After seeing several such patients, we hypothesized that the patients' inaccurate control of their accommodative/convergence system resulted in perceived blur in the distance. In the absence of pre-operative binocular vision testing, there is no way to know if the convergence insufficiency (CI) observed was pre-existing or a result of the strain of adaptation to emmetropia post-operatively.

To our knowledge, this case series is the first report of binocular vision-related measurements after refractive surgery from non-strabismic patients with good optical outcomes. The literature indicates that diplopia or other issues may arise in strabismics following refractive surgery,[2] although two patients with high anisometropia reportedly improved binocular function post-surgery.[3] A prospective study on hyperopes found that binocular symptoms emerged post-LASIK, but only in those patients with pre-existing strabismus.[4] Other work on binocular function has shown that mesopic contrast sensitivity can be affected,[5] but this may or may not be related to binocular fusion, as would be of concern here. And while it is becoming clear that differential outcomes between the two eyes post-LASIK can affect contrast sensitivity and binocular summation,[6] our patients had similar outcomes in each eye.

Case Reports

We examined 11 patients who received binocular LASIK and 1 who had binocular PRK by EF between January 2005 and June 2007; all were subsequently referred to GD. Eleven (including the PRK patient) complained of unresolved distance blur and were identified with binocular vision disorders during post-op follow-up exams three months or more following surgery. The 12th patient did not complain specifically of distance blur but had complaints of headache and visual fatigue at near. Binocular vision testing revealed that 10 of the 12 (83%) had vergence problems, and we offered each of them vision therapy (VT). Although all initially accepted the invitation, the results from only eight cases appear in this paper because the others did not participate in a sufficient number of VT sessions to allow interpretation. All patients read and signed an informed consent form, and all procedures were approved by the PVI Institutional Review Board.

Patients could elect either in-office vision therapy (OVT), computer visual skills training via internet (CVST), or both. All elected to enroll in CVST, which consisted of thirty 15-minute sessions covering focusing, oculomotor, and fusional skills (Gemstone's Dynamic Vision Training program, Rodeo, California; described in Powers, 2006).[10] Three participated in OVT as well as CVST.

In-Office Vision Therapy (OVT)

Some patients had OVT prior to starting the computer program, and some patients needed and were offered in-office sessions at the conclusion of the computer program for optimal outcome (most did not accept the offer). OVT consisted of a variety of procedures typical for OVT, such as monocular and binocular accommodative procedures, Brock string, eccentric circles, clear and opaque Lifesaver cards, and polarized fusion targets. For a full description, see reference 9, pp. 505-538. Each patient's OVT program was individually designed by the optometrist according to that patient's visual skill level.

Computer Visual SkillsTraining (CVST)

Patients were given red-blue color separation filters in spectacle frames and a set of accommodative training lenses designed specifically for computer therapy (Optego Vision, Ontario, Canada). Patients accessed the computer program[10] via internet either at home or in their own offices, or wherever the internet was routinely available to them. Several used the program from a variety of locations (e.g., while on vacation).

The computer program[10] is a series of game-like modules, each of which trains a specific visual skill: accommodative facility, smooth pursuit, saccadic tracking, convergence break and recovery, and divergence break and recovery. Although these adult patients did not have symptoms of oculomotor dysfunction, the author (GD) generally ensures equality of monocular skills (usually with monocular home activities) as a foundation for binocular fusion.[11] Some patients did monocular accommodation activities, and all attempted the bi-ocular accommodative facility computer module. Two patients over the age of 40 were allowed to skip that module (Case #2 and Case #3).

The patient logged on to his or her own website, which connected with a secure remote server in Oakland, CA where data are stored. Upon presentation of red or blue stimuli (intended to stimulate either the left or right eye for accommodative facility and tracking modules, or, in the case of random dot stereograms in convergence and divergence modules, both eyes simultaneously), the patient indicated the orientation or location of the stimulus by pressing one of the four arrow keys. For example, in the convergence module, a diamond-shaped stereo image produced by random dots could appear either at the top, bottom, right, or left of a background field. When it appeared, the patient's task was to press the up, down, left, or right arrow key that corresponded to the location of the image. As soon as the patient answered, the location changed for the next trial, simultaneously moving either closer or farther (requiring either more or less convergence) according to whether the response on the previous trial was correct or not. This four-alternative forced-choice procedure allows collection of objective data regarding subject performance,[10,12] even when patient and doctor are separated geographically.[13] The investigators accessed information on patient progress via separate internet connection with the server. This connection allowed immediate access to data indicating the date and time of each session and optometric levels attained for each module.

Measurements

The following measurements were taken on patients before and after they completed (or quit) the 30-session computer program:

Table 1: Patient characteristics, post-operative refractive surgery binocular vision diagnosis, and treatment

Case #	Age at Surgery	M/F	Pre-Op Ametropia	Post-Op DVA	Post-Op Manifest Rx	Post-Op Cycloplegic Rx	BV Dx	CVST+OVT Sessions	Post-VT Manifest Rx	Post-VT DVA
1	40.7	F	High Myope, Astigmat	OD: 20/40- OS: 20/25+	-0.75 DS -0.25 DS	+0.50+0.50 x005 +0.25+0.50 x169	CI	30 + 10	-0.75 DS -0.25 DS	20/25- 20/15-
2	43.4	F	High Myope, Astigmat	OD: 20/200- OS: 20/200-	-2.75 DS -2.75+0.50 x085	-2.00 DS -2.00+0.50 x08	CI	30 + 0	-2.75+0.50 x080 -2.50+0.50 x070	20/200- 20/200-
3	46.3	M	Moderate Myope, Astigmat	OD: 20/40+ OS: 20/30+	-1.00 DS -1.00+0.50 x090	*	CE	30 + 0	-0.50+0.25 x060 -0.50 DS	20/20- 20/20-
4	36.5	F	Moderate Myope, Astigmat	OD: 20/15- OS: 20/15-	-0.75+0.50 x055 -0.50+0.50 x098	-0.50+0.25 x055 0.25+0.25 x098	CI	15 + 1	-0.25 DS -0.25 DS	20/20+ 20/20+
5	34.8	M	High Myope, Astigmat	OD: 20/15- OS: 20/15	-0.25 DS -0.25 DS	**	CI	18 + 6	-0.25 DS -0.25 DS	20/15- 20/15-
6	30.3	M	Moderate Myope, Astigmat	OD: 20/20 OS: 20/20-	-0.50+0.25 x177 -0.50+0.25 x158	-0.50+0.25 x177 -0.50+0.25 x158	CI	17 + 0	-0.25 DS -0.75 DS	20/15- 20/25-
7	36.3	F	Moderate Myope, Astigmat	OD: 20/15- OS: 20/15-	0.00+0.25 x097 0.00 DS	**	CI	7 + 0	-0.25+0.25 x090 0.00 DS	20/15- 20/15
8	31.2	F	Moderate Myope, Astigmat	OD: 20/20- OS: 20/25-	-0.50 DS -1.25+0.50 x083	+0.25 DS -0.50+0.50 x083	CI	7 + 0	-0.50 DS -0.50 DS	20/15- 20/30+

* No post-LASIK cyclo Rx because of accommodative spasm 8,17 had been noted at pre-op.
** No post-LASIK cyclo Rx because manifest Rx was not sufficient to justify surgical enhancement.

- Cover test at distance and near, using accommodative target
- Near point of convergence (NPC), mean of 3 times
- Subjective refraction
- Phoria, distance and near, in phoropter
- Divergence at near: blur, break, and recovery, in phoropter
- Convergence at near: blur, break, and recovery, in phoropter
- Accommodative facility, 30 or 60 sec test with +/-1.50 DS
- Convergence Insufficiency Symptom Survey (CISS)[14,15]

Individual Cases

The surgeon referred to the optometrist any post-LASIK patient who complained of distance blur in the presence of good refractive results. One patient's distance blur complaints were to be expected because she was awaiting surgical enhancement (Case #2). Another patient (Case #7) was referred due to headaches and trouble focusing rather than distance blur. Case #3 had PRK rather than LASIK but is included in the series because of similarities in complaints and results to the LASIK cases.

When the optometric examination revealed binocular vision disorders, the optometrist offered participation in the case series. If the patient was interested, he or she was asked to sign an informed consent document. All 12 patients who were referred agreed to participate; 8 completed more than 5 sessions and are included in the series.

Table 1 lists each case considered in this report, summarizing pre-surgery ametropia; post-surgery acuities, refraction, and binocular vision (BV) diagnosis; and post-surgery vision therapy treatment. Table 1 also shows refraction and acuities after VT treatment. As Table 1 illustrates, for these cases the magnitude of cycloplegic refractive error post-surgery seems insufficient to justify the persistent complaints of distance blur. Moreover, acuities post-surgery were typically in the excellent range.

We therefore speculated that the complaints expressed by these patients were the result of poor binocular control. This hypothesis only emerged post-surgery, because BV examinations had not been done pre-operatively on these patients. Below are details of each case.

#1. 40-yr-old Asian female (occupation: buyer), had high myopia and astigmatism pre-LASIK. Post-LASIK, she complained of distance blur at the end of the work day. A BV examination 10 months post-LASIK found fatigue upon repeated near point convergence testing and poor convergence ability in phoropter. Findings included: distance visual acuity (DVA) 20/20, 3 prism diopters exophoria at distance (3 XP), 12 prism diopters exophoria at near (12 XP'), and near point compensating vergence ranges of base out (BO) blur/break/recovery (expressed in prism diopters) = x/12/0. Diagnosis: Convergence insufficiency (CI), based on Duane-White classification Type I and failure of Sheard's criterion. She had 10 OVT sessions prior to CVST and then completed 30 CVST sessions starting 20 months post-LASIK. After VT, her visual skills had improved, and the patient felt that her vision had stabilized.

#2. 43-yr-old Caucasian female (occupation: recruiter), had high myopia and astigmatism pre-LASIK. Myopia remained post-LASIK, and patient wanted enhancement but needed to wait for sufficient corneal healing. There was noticeable difference between her cycloplegic and manifest refractions pre-op. A BV examination one month post-LASIK found poor near point of convergence and poor convergence ability at near in phoropter (BO x/6/3, base in (BI) 10/18/12; 2 XP distance, 12 XP' near). Diagnosis: CI, based on Duane-White classification Type I and failure of Sheard's criterion. The patient was highly motivated to improve vision and elected to start VT while awaiting enhancement surgery. She completed 30 sessions CVST starting 4 months post-LASIK. Her binocular skills improved, vision stabilized, and the patient was happy post-enhancement.

#3. 46-yr-old Caucasian male (occupation: consultant), had moderate myopia and high astigmatism pre-PRK. He complained post-PRK that distance vision was still blurry but tended to clear up after he was outside for a while. On BV examination 1 month post-PRK, the patient could converge at near with effort (8 cm on first trial, then to nose subsequently) and nearpoint convergence recovery was poor (BO x/30/12, BI 12/16/14). He showed 5 EP with 1 pd hyperphoria OS in the distance, 8 XP' at near. Diagnosis: Convergence excess (CE), based on Duane-White classification Type II. These findings satisfy Sheard's criterion but the low BO recovery indicates poor stamina for binocular fusion. The patient started CVST 3 months post-PRK, completed 30 CVST sessions, and reported "not noticing problems" after VT.

#4. 36-yr-old Caucasian female (occupation: event planner), had moderate myopia and moderate astigmatism pre-LASIK. She complained of blurry vision at night despite 20/15 visual acuity post-LASIK. On BV examination 15 months post-LASIK, she was found to have poor convergence ability at near in phoropter (BO x/6/0, BI x/16/14). She also showed 3 XP distance, 12 XP' near. Diagnosis: CI, based on Duane-White classification Type I and failure of Sheard's criterion. The patient had 1 OVT then completed 14 CVST, starting 20 months post-LASIK; she reported "vision better" after VT.

#5. 34-yr-old Asian male (occupation: software engineer), had high myopia and astigmatism pre-LASIK. Post-LASIK he complained of distance vision being blurry when working in the office but better when away from the office more than 3 days. Distance VA post-LASIK and post-enhancements on both eyes was 20/15. BV examination 3 months after the last enhancement found 2 XP distance, 9 XP' near, and borderline convergence ability at near in phoropter (BO x/24/14, BI x/24/14). Diagnosis: CI, based on Duane-White classification Type I. The findings satisfy Sheard's criterion, but he had low BO recovery, indicating poor stamina for binocular fusion. The patient had 6 OVT prior to completing 12 sessions of CVST, which he began 13 months post-LASIK. He reported "less fluctuation" in his vision after VT.

#6. 30-yr-old African American male (occupation: software programmer), had moderate myopia and astigmatism pre-LASIK. He complained post-LASIK of distance blur, especially at night, as well as eye fatigue and headaches that "come and go during computer work." Distance VA was 20/15. On BV examination 16 months post-LASIK, the patient was found to have poor near point of convergence (25 cm), 1 XP distance, 12 XP' near, with poor compensating vergence (BO x/14/12, BI 16/22/18). Diagnosis: CI, based on Duane-White classification Type I and failure of Sheard's criterion. He began CVST 16 months post-LASIK and completed 17 CVST sessions. Due to the severity of his symptoms, the patient was prescribed a computer Rx of +0.50 DS OU to provide short-term relief while doing VT. Post-VT, he reported that distance vision was still a problem in low light, but the Rx computer glasses helped prevent fatigue. Note: this patient's accommodative facility improved from 2 cycles/30 seconds to 7 cycles/30 seconds post-VT, yet he still preferred using the low plus lenses. It is possible that the patient might have been able to improve his stamina for binocular vision with more VT and perhaps not need computer glasses after a full course of VT (more CVST and/or more OVT). However, the patient liked the computer Rx, and he chose not to continue with VT.

#7. 36-yr-old Caucasian female (occupation: attorney), had moderate myopia and astigmatism pre-LASIK. Distance visual acuity was 20/15 post-LASIK, but she complained of headaches and trouble focusing up close. BV examination 2 months post-LASIK found 3 XP distance, 9 XP' near and weak recovery from both convergence and divergence testing at near in phoropter (BO 18/30/12, BI 6/22/6). Diagnosis: CI, based on Duane-White classification Type I. These ranges satisfy Sheard's criteria, but the low BO recovery indicates low stamina for binocular fusion. She started CVST 14 months post-LASIK and had completed only 7 sessions CVST by the end of the study period. She reported fewer headaches and said she wanted to continue with OVT in-office but never did.

#8. 31-yr-old Caucasian female (occupation: fundraising), had moderate myopia and astigmatism pre-LASIK. Post-LASIK, she complained that distance vision got blurry after reading or computer work. BV examination 5 months post-LASIK found fatigue upon repeated near point convergence testing and poor convergence recovery at near in phoropter (BO 10/24/8, BI 8/10/8). She showed ortho distance, 10 XP' near. Diagnosis: CI, based on Duane-White classification Type I and failure of Sheard's criterion. The patient started CVST 5 months post-LASIK and had completed 7 CVST sessions by the end of the study period. BV skills somewhat improved, but the patient did not continue VT.

Summary Data

Results for individual cases are in Tables 2 for convergence, 3 for phoria, and 4 for accommodative facility. Because we took the same measures on each patient pre- and post-VT, we can compare the change in group averages to see whether a pattern emerges. Caution must be used in interpreting these findings because they only summarize case findings without a comparison group. We present them nonetheless because several measures that would be expected to be affected by vision therapy did change significantly. We used a one-tailed paired t statistic to evaluate significance because the direction of effect (improvement)

Table 2: Convergence Signs and Symptoms before and after VT treatment

Case #	Convergence Near Point (cm)		Convergence Break (pd)		Convergence Recovery (pd)		Symptom Score (CISS)	
	Pre VT	Post VT	Pre VT	Post VT	Pre VT	Post VT	Pre VT	Post VT
1	4	0	12	22	0	19	40	9
2	25	0	6	16	3	11	12	12
3	3	0	30	30	12	28	16	10
4	8	8	6	22	0	6	8	6
5	6	0	24	30	14	28	4	3
6	25	3	14	30	12	26	26	28
7	9	0	30	30	12	12	40	26
8	11	10	24	20	8	8	25	24
Mean	11.4	2.6*	18.3	25.0*	7.6	17.3*	21.4	14.8

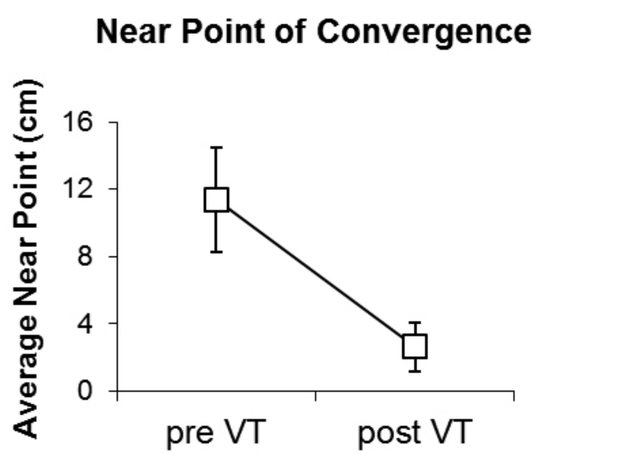


Figure 1: *Near point of convergence improved following vision therapy (p < .02, one-tailed paired t-test). Mean data for 8 cases +/- 1 standard error of the mean are shown. Individual data are in Table 2.*

Table 3: Phorias pre- and post-VT

Case #	Distance Phoria (pd)		Near Phoria (pd)	
	Pre VT	Post VT	Pre VT	Post VT
1	3XP	3XP	12XP′	12XP′
2	2XP	2EP	12XP′	8XP′
3	5EP	2EP	8XP′	3XP′
4	3XP	3XP	12XP′	12XP′
5	2XP	3XP	9XP′	7XP′
6	1XP	2XP	12XP′	5XP′
7	3XP	2XP	9XP′	12XP′
8	0	0	10XP′	6XP′

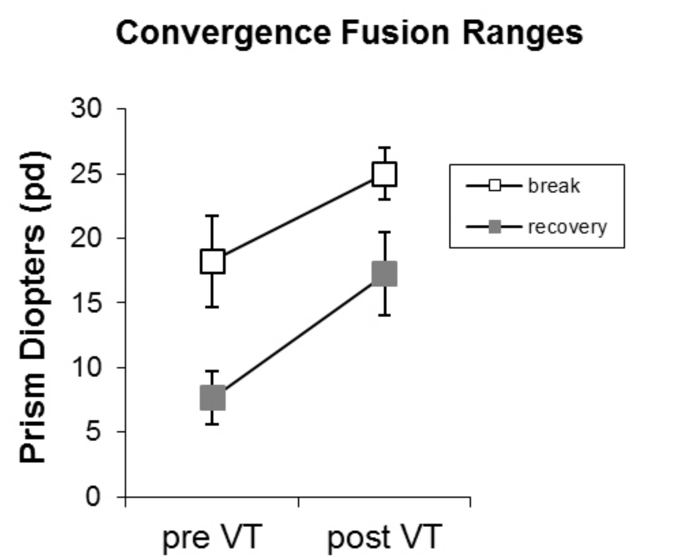


Figure 2: *Convergence break and recovery improved following vision therapy. Break improved by 6.7 pd (p < .02, one-tailed paired t-test) and recovery from 9.7 pd (p < .005, one-tailed paired t-test). Mean data for 8 cases +/- 1 standard error of the mean are shown. Individual data are in Table 2.*

was predicted before treatment, and because each case served as its own comparison in the pre-/post-VT measures. When correlations (r values) are reported, probabilities are also based on one-tailed distributions.

Convergence

Near point of convergence improved in 7 out of the 8 cases (88%; see Table 2). The value for each case in Table 2 is the average of 3 measurements. In Case #1 and Case #8, pre-VT testing revealed a near point that receded in space with each successive measurement, indicating low stamina. Post-VT revealed good stamina for both cases, with near point at the nose for every measurement. Figure 1 shows that on average across cases, near point improved by 8.8 cm, from 11.4 cm to 2.6 cm, following VT ($p < .02$).

Convergence break and/or recovery improved in 6 out of 8 cases (75%). In one case where no improvement was noted, values were good prior to VT (convergence break, Case #7), and this patient improved NPC from 9 cm to 0 cm with VT. In another case (#3) the patient was CE. In both cases where convergence ability did not improve (#7 and #8), only 7 sessions of the computer program were completed, and there were no office visits (see Table 1). Figure 2 shows that, on average, convergence break improved 6.7 pd and convergence recovery improved 9.7 pd with VT. Both changes were

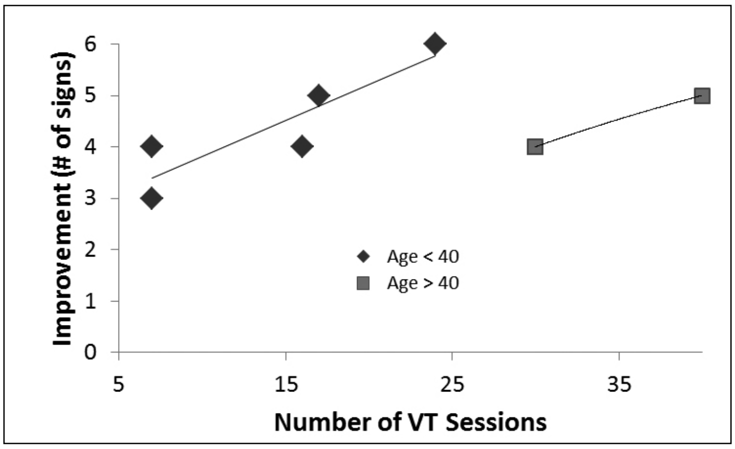


Figure 3: *For subjects under age 40, the number of convergence signs (near point, base out break, base out recovery, and near phoria) that improved depended on the number of sessions completed (r = .625, p < .02). Each point is from one case. Age > 40 cases are shown to illustrate that change did occur in presbyopes, but more sessions were required.*

statistically significant (p < .02 for break and p < .005 for recovery).

Consistent with the lack of complaints about near vision, only 2 of the 8 cases reported blur before break during convergence measurements. Five reported blur before break on divergence measurement. Little change occurred in divergence measurements, probably because most cases were exophoric at near prior to starting VT.

Phoria values are shown in Table 3 at far and near. Distance phoria did not change systematically over these cases (p > .05). However, near phoria decreased in 5 of 8 cases following VT, with a significant mean decrease over all cases of 2.5 pd (p<.05).

The number of signs that improved following VT can be considered an indicator of progress due to VT. Examination of the data in Tables 2 and 3 will show that all but one case where 16 or more sessions were completed (refer to Table 1 for number of sessions) improved in at least 3 of the 4 measures of convergence (near point, base out break, base out recovery, phoria), while those with fewer sessions improved in only 1 or 2 signs. This difference was statistically significant (mean number of signs improved with 16 or more sessions (n=6) = 3.9 compared to mean for 7 sessions completed (n=2) = 1.5; p < .02, binomial test). Moreover, the correlation between number of sessions completed (Table 1) and number of convergence signs that improved was also significant for pre-presbyopic patients (see Figure 3; r=.625, p < .02 Pearson correlation).

Table 4: Accommodative Facility pre- and post-VT

Case #	Presbyope?	Accommodative Facility (cpm)		Difference Pre-Post (cpm)	Mean Difference (cpm)
		Pre VT	Post VT		
1	Y	6.0	6.5	0.5	.02
2	Y	4	4	0	
3	Y	0	0	0	
4	N	0	6	6	3.1
5	N	1.5	9	7.5	
6	N	2	7	5	
7	N	5	6	1	
8	N	6	2	-4	

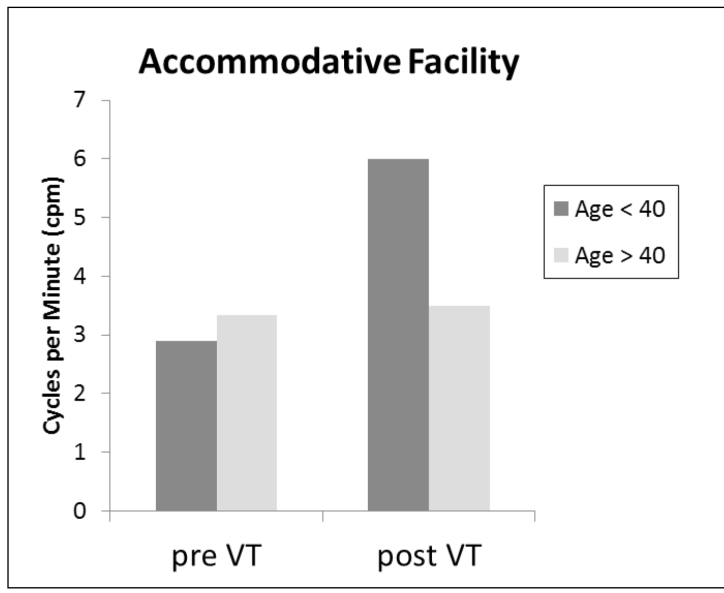


Figure 4: *Accommodative facility improved minimally in presbyopic cases (light bars), 2 of whom did not participate in accommodative facility skill practice, but patients under 40 did practice and improved on average from 2.9 cpm to 6 cpm.*

Accommodative Facility

Accommodative facility improved in four of the five pre-presbyopic cases from pre- to post-VT, but the average change did not reach statistical significance (p=.09, see values in Table 4). Measurements from the subset of three cases presumed to be presbyopic (age >40) improved only 0.2 cpm on average, which is not surprising because in addition to being older, Case #2 and Case #3 elected not to do accommodative facility training. However, the subset of five pre-presbyopic cases (age <40) improved 3.1 cpm (Figure 4). Figure 4 shows that among those younger than 40, the amount of change in accommodative facility was strongly correlated with the number of sessions completed, whether via CVST ($r=.903$, $p < .02$) or CVST+OVT ($r=.889$, $p < .05$).

Symptoms

The average score on the Convergence Insufficiency Symptom Survey (CISS)[14] for the cases in this series was 21.4 after LASIK surgery and before VT. In adults, a score above 21 indicates probable CI,[15] so these patients were, on average, barely into the symptomatic range according to this instrument. Following VT, the average CISS score for this same group was reduced to 14.8, which is clearly in the asymptomatic range.[15] Although 6 of the 8 patients did reduce their symptom score, and the average score for all cases post-VT is in the asymptomatic range, suggesting success in relieving symptoms, the treatment difference before and after VT did not reach statistical significance ($p=.07$). Notably, the 3 cases (#6, #7, #8) that remained symptomatic (with scores greater than 21) were patients who completed the fewest number of VT sessions.

Discussion

Relationship between Distance Blur and CI

Even though GD eventually diagnosed CI, nearly all of these patients complained only about distance blur during routine post-LASIK visits. With probing questions during binocular evaluation, two patients did report symptoms at near.

From the patient's perspective, they came to the laser center to get "20/20 vision," and they assumed that seeing 20/20 meant seeing clearly everywhere. Patients are literally focused on the eye chart; they do not have the conceptual framework to understand any difference that might occur due to using two eyes or to looking near vs far. After discovering that the patient had binocular vision problems at near point, the OD's task was to explain to the patient that vision is more than 20/20. How we use our eyes together, as a team, affects the ability to see clearly in the distance.

Some of the patients did note that their distance vision was blurry after they had been working in the office, and one person noticed that his distance vision was better after he had been away from the office for a few days. Thus, indirectly, these patients were connecting distance and near vision, even though they did not report blur at near. The connection was the prolonged nearwork.

The series thus suggests that the absence of near complaints does not rule out CI or accommodative problems. The connection between near and far vision in our cases is that these patients work at near for intense periods of time, resulting in contamination of far vision by near vision issues. Birnbaum[16] states that accommodative and convergence insufficiency can be adaptations to near point stress in myopia. We would postulate that removing the myopia via LASIK or other refractive surgery leaves such patients with their original adaptations to near point stress, with no way to resolve the stress.

The results strongly suggest that when patients continue to complain of blur after all refractive explanations have been exhausted, their complaints must be considered to be potentially attributable to binocular vision problems. Weak binocularity can interfere with patients' ability to apply their good refractive results, so that slight mismatches of fusion may produce a perception that they can only identify as "blur." Perhaps post-refractive surgery patients actually may have had weak convergence and/or fusion skills prior to surgery, and the presence of excellent refraction merely uncovered those poor skills. Whatever the mechanism, the patients with binocular vision disorders post-refractive surgery who participated in VT improved their vision, supporting the general hypothesis that distance blur can result from poor binocular control.

A key predictor of distance blur post-op was a difference between cycloplegic and manifest refraction during the pre-operative exam. This was a potential indicator of accommodative spasm.[8,17] As a result of PVI staff observations and subsequent quantitative chart research, PVI modified the pre-op exam form to include notation whenever pre-op cycloplegic and manifest refraction differed by more than a half diopter, and the patient is now routinely advised pre-op of possible need for vision therapy post-op. Identifying problems and solutions pre-surgery helps to manage patient expectations. From a practical point of view, it makes sense to identify and to inform those patients most at risk, and to refer for BV evaluation on an as-needed basis.

Vision Therapy

The ideal vision therapy program presented to all of the patients was in-office procedures with the optometrist combined with CVST to reinforce the skills learned in office. These adult patients could choose any combination of OVT and CVST that would fit into their busy lives. For some patients, CVST was the only way to squeeze any VT into their hectic schedule. Fortunately, adult patients seem to progress quickly through VT because they understand how and why they are doing a procedure and therefore get meaningful learning out of the experience.

Computer-based programs can be an effective tool for patients with binocular vision complaints following refractive surgery; however, some patients may need traditional in-office procedures as well to resolve their binocular vision problems fully. For those patients who did CVST + OVT, computer orthoptics reinforced the skills patients were learning in office, and patients found CVST to be a convenient and interesting way to practice visual skills training at home or on break in the workplace. Being able to do CVST in any location was made possible by the internet availability of the program we used. Some patients who initially elected CVST only, but who still had some challenges, could return to the office for a few sessions to address areas of concern, e.g. divergence training.

In general, the more VT sessions patients completed, the more CI improved. We used the total number of VT sessions for data analysis purposes, rather than separating out OVT versus CVST, because every session completed represented some work done by the patient. Case #1, who had the largest number of in-office sessions and who also completed the full course of CVST, arguably had the best overall results. She had very large improvements in convergence ability post-VT (Table 2) and the most symptomatic relief from a score of 40 pre-VT to 9 post-VT on the CISS. Other cases who completed CVST had similar CI results without OVT, but their CI and associated symptoms were not as extreme as Case #1. Thus, even though computer programs offer certain advantages for patients, they cannot completely replace activities done in free space or the guidance of an experienced therapist.[18]

Seven out of eight cases of binocular vision disorder identified post-refractive surgery showed improved binocular vision (BV) after vision therapy. To the extent that BV problems interfere with patients' appreciation of the refractive effects of refractive surgery, identifying and treating BV problems is important. Many reduced their symptoms, and most expressed greater satisfaction with their vision overall. Prior evidence suggests that patient satisfaction with refractive surgery is closely related to perceived improvements in their vision.[19] Our results show that addressing patients' BV problems can help them achieve what they consider to be clear vision post-refractive surgery. Because that was their goal prior to surgery, attaining it (by whatever means) would seem important to all clinicians.

This group of patients presented special challenges in that they came to the surgeon for refractive surgery and did not expect to need vision therapy as well. The sooner such patients are made aware of their binocular vision weakness, the more willing they will be to address the problem with VT in addition to surgery, and the less likely to blame surgery for their vision problems. In addition, these adult patients generally seem to want to discontinue vision therapy as soon as they achieve symptom relief rather than when they achieve the "normal" binocular vision skills toward which doctors work with typical vision therapy patients. The post-therapy evaluations for this case series are similar to a typical vision therapy patient progress check rather than an end-of-therapy result, and the optometrist would generally have liked the patient to continue VT in order to stabilize their skills before dismissal. However, even though the cost of vision therapy was included in their surgery fee, the patients in this case series chose to stop treatment when they were satisfied rather than when the optometrist was.

Finally, we speculate that refractive surgery patients may offer a unique opportunity to study the relationship between binocular vision conditions and myopia. The patients presented here typically felt that their symptoms were caused by the surgery, yet there is no way to know whether this was true in the absence of binocular vision measurements pre-surgery. A large scale study examining patients' binocular status pre- and post-surgery would need to be done to know whether the convergence insufficiency we found was a pre-existing condition or not. It is possible that, as Finlay[20] postulates, refractive surgery may "upset a tenuous balance" within the binocular system. Perhaps the patients were relying on the accommodative support of their minus lenses to stimulate their convergence, and thus their exophoria became symptomatic without their refractive correction. Maybe these patients were in the habit of associating any symptom of blur with the need for new glasses or contact lenses, and after surgery, there was nothing left to correct except binocular skills.

Conclusion

When patients report blur after LASIK, PRK, or similar procedures and there is no refractive explanation, doctors should check for binocular vision problems. When BV problems occur, VT can help even if only via computer. The progress made in improving CI is related to the number of sessions completed. Future research should develop predictors for emerging BV problems following refractive surgery so that patients can be fully informed.

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