ORIGINAL ARTICLE

Treatment of Accommodative Dysfunction in Children: Results from a Randomized Clinical Trial

Mitchell Scheiman*, Susan Cotter†, Marjean Taylor Kulp†, G. Lynn Mitchell‡, Jeffrey Cooper§,
Michael Gallaway‖, Kristine B. Hopkins¶, Mary Bartuccio**, Ida Chung‖,
and the Convergence Insufficiency Treatment Trial Study Group

ABSTRACT

Purpose. To report the effectiveness of various forms of vision therapy/orthoptics in improving accommodative amplitude and facility in children with symptomatic convergence insufficiency (CI) and co-existing accommodative dysfunction.
Methods. In a randomized clinical trial, 221 children aged 9 to 17 years with symptomatic CI were assigned to one of four treatments. Of the enrolled children, 164 (74%) had accommodative dysfunction; 63 (29%) had a decreased amplitude of accommodation with respect to age, 43 (19%) had decreased accommodative facility, and 58 (26%) had both. Analysis of variance models were used to compare mean accommodative amplitude and accommodative facility for each treatment group after 4, 8, and 12 weeks of treatment.
Results. After 12 weeks of treatment, the increases in amplitude of accommodation [office-based vergence/accommodative therapy with home reinforcement group (OBVAT) 9.9 D, home-based computer vergence/accommodative therapy group (HBCVAT+) 6.7 D, and home-based pencil push-up therapy group (HBPP) 5.8 D] were significantly greater than in the office-based placebo therapy (OBPT) group (2.2 D) (p-values ≤0.010). Significant increases in accommodative facility were found in all groups (OBVAT: 9 cpm, HBCVAT+: 7 cpm, HBPP: 5 cpm, OBPT: 5.5 cpm); only the improvement in the OBVAT group was significantly greater than that found in the OBPT group (p = 0.016). One year after completion of therapy, reoccurrence of decreased accommodative amplitude was present in only 12.5% and accommodative facility in only 11%.
Conclusions. Vision therapy/orthoptics is effective in improving accommodative amplitude and accommodative facility in school-aged children with symptomatic CI and accommodative dysfunction.
(Optom Vis Sci 2011;88:1343–1352)

Key Words: accommodative dysfunction, accommodative amplitude, accommodative facility, accommodative insufficiency, convergence insufficiency, vision therapy, orthoptics, vergence/accommodative therapy, HTS

Accommodative disorders are commonly encountered in pediatric eye care practices,[1,2] and the two most common accommodative disorders are accommodative insufficiency and accommodative infacility.[3–5] Accommodative insufficiency is a condition in which the amplitude of accommodation is less than expected for a nonpresbyopic patient's age,[5] whereas accommodative infacility is a condition in which the latency and speed of the accommodative response are abnormal compared with normative clinical data.[5] Associated signs and symptoms are usually related to reading and other close work activities and include blurred vision at near, intermittent blurred vision when looking up from near work, headaches, watering or burning of the eyes, tired eyes, loss of concentration, and avoidance of near activities.[6–9]

The most commonly prescribed treatments for accommodative dysfunction are a plus lens addition at near or vision therapy/orthoptics.[4,5,10–13] Although plus lenses worn for near activities may improve symptoms for some patients, vision therapy/orthoptics has the potential to eliminate the accommodative dysfunction rather than solely providing symptomatic relief.[5]

Studies have shown that voluntary control of accommodation can be learned and transferred to a variety of conditions,[14,15] and

*OD, FAAO
†OD, MS, FAAO
‡MAS, FAAO
§MS, OD, FAAO
‖OD, FAAO
¶OD, MPH, FAAO
**OD

Pennsylvania College of Optometry at Salus University, Philadelphia, Pennsylvania (MS, MG), Southern California College of Optometry, Fullerton, California (SC), The Ohio State University College of Optometry, Columbus, Ohio (MTK, GLM), State University of New York, College of Optometry, New York, New York (JC, IC), University of Alabama at Birmingham College of Optometry, Birmingham, Alabama (KBH), and NOVA University College of Optometry, Ft. Lauderdale, Florida (MB).

A listing of the writing committee and investigators who participated in the study appears in the Acknowledgments.

objective improvements in the dynamics[16] and accuracy of accommodation after vision therapy have been documented.[17,18]

Although clinical studies have reported success rates for the treatment of accommodative dysfunction as high as 96%,[10–13,19,20] methodological limitations have prevented definitive conclusions from being made. A more rigorous scientific base, ideally a randomized controlled trial, is needed to evaluate the effectiveness of vision therapy/orthoptics for the treatment of accommodative dysfunction in children.

The Convergence Insufficiency Treatment Trial (CITT),[21,22] a large-scale, randomized clinical trial evaluating vision therapy/orthoptics modalities for children with symptomatic convergence insufficiency (CI), enrolled 164 children with concomitant deficiencies in accommodative function. Accommodative amplitude and facility measures were prospectively collected using standardized methods. These data provide an opportunity to determine the effectiveness of vision therapy/orthoptics for accommodative dysfunction. Herein, we report the effectiveness of office-based vergence/accommodative therapy (OBVAT), home-based computer vergence/accommodative therapy plus pencil push-ups (HBCVAT+), home-based pencil push-up therapy (HBPP), and office-based placebo therapy (OBPT or placebo therapy) for improving accommodative amplitude and accommodative facility in school-aged children with symptomatic CI and accommodative dysfunction.

PATIENTS AND METHODS

The institutional review boards of all participating centers approved the protocol and informed consent forms. The parent or guardian of each participant gave written informed consent, and each participant gave assent to participate. Health Insurance Portability and Accountability Act authorization was obtained, and the tenets of the Declaration of Helsinki were followed. Oversight was provided by an independent data and safety monitoring committee (see Acknowledgments). This study is registered at ClinicalTrials.gov as the Convergence Insufficiency Treatment Trial (NCT00338611).

Patients

Enrolled children at the nine CITT clinical sites (see Acknowledgments) met the following major eligibility criteria: age 9 to 17 years, near exophoria at least 4Δ greater than far, receded nearpoint of convergence break (6 cm or greater), and insufficient positive fusional vergence at near [PFV; i.e., failing Sheard's criterion[23] (PFV less than twice the near phoria) or minimum PFV of 15Δ base-out blur or break], a Convergence Insufficiency Symptom Survey (CISS) score of ≥16,[24,25] and monocular accommodative amplitude of >5.00 diopters (D). An optical correction was required for refractive error (cycloplegic refraction) of ≥1.50 D hyperopia, ≥0.50 D myopia, ≥0.75 D astigmatism, ≥0.75 D of spherical equivalent anisometropia, or ≥1.50 D of meridional anisometropia. Full correction of myopia, astigmatism, and anisometropia was required. Investigators were permitted to symmetrically decrease the prescription for hyperopia if they believed full correction would have a negative effect on distance visual acuity or treatment. A complete listing of eligibility and exclusion criteria has been reported previously.[21,22]

Measurement of Accommodative Function

Monocular (right eye) accommodative amplitude and accommodative facility were measured with spectacle correction at baseline and all protocol-specified visits. Amplitude of accommodation was measured by the push-up method using a moveable target of 20/30 letters on the Astron Accommodative Rule (Gulden Ophthalmics, Elkins Park, PA).[22] Decreased accommodative amplitude was defined as >2.00 D below the lowest expected amplitude based on the Hofstetter's formula of 15 to 1/4 age.[26,27] Accommodative facility was the speed at which the patient could see 20/30 letters at 40 cm clearly through alternating +2.00 D and −2.00 D lenses, measured in cycles per minute (cpm) (i.e., of +2.00 D and −2.00 D). Decreased accommodative facility was defined as <6 cpm, which is 1 SD below the normative value of 11 cpm for school-age children.[7,28,29] Details of the testing protocols for accommodation can be found at http://optometry.osu.edu/research/CITT/4363.cfm

Randomization

Patients were randomly assigned (using a permuted block design stratified by site) with equal probability via the CITT web site to OBVAT, HBCVAT+, HBPP, or placebo. Randomization was achieved using a secure web site created and managed by the Data Coordinating Center.

Treatment Protocols

Home-Based Pencil Push-Ups

The pencil push-ups procedure used a pencil with 20/60 size letters and a white index card placed in the background to provide a suppression check by using physiological diplopia awareness. The goal of the procedure was to move the pencil to within 2 to 3 cm of the brow, just above the nose on each push up while trying to keep the target single and clear. Patients were instructed to perform the pencil push-ups procedure 15 min per day, 5 d per week.

Home-Based Computer Vergence/Accommodative Therapy and Pencil Push-Ups

Patients in this group were taught to perform the aforementioned pencil push-up procedure as well as procedures on the Home Therapy System (HTS) (www.visiontherapysolutions.com) computer software. Using this program, they performed fusional vergence and accommodative therapy procedures (vergence base-in, vergence base-out, auto-slide vergence, and jump- ductions vergence) using random dot stereopsis targets. The accommodative rock program was used for accommodative therapy. Patients were instructed to do pencil push-ups 5 min per day and the HTS software program for 15 min per day, 5 d per week.

Office-Based Vergence/Accommodative Therapy with Home Reinforcement

The office-based vergence/accommodative therapy group received a weekly 60-min in-office therapy visit with additional pro-

cedures prescribed to be performed at home for 15 min a day, 5 d per week. The therapy procedures are described in detail elsewhere.[30] At each office-based therapy session, the patient performed four to five procedures with supervision and guidance from a therapist.

Office-Based Placebo Therapy

Patients in the office-based placebo therapy group received therapy during a weekly 60-min office visit and were prescribed procedures to be performed at home for 15 min per day, 5 d per week. The placebo therapy program consisted of 16 in-office therapy procedures and 4 home therapy procedures, which were designed to look like real vergence/accommodative therapy procedures yet not stimulate vergence, accommodation, or fine saccadic eye movement skills beyond normal daily visual activities. Five procedures were performed during each office therapy visit and two procedures were assigned for home therapy each week.

The OBVAT and HBCVAT+ included specific accommodative therapy procedures in addition to vergence procedures, such as clearing progressively greater amounts of plus and minus. The pencil push-up procedure performed by the HBPP and HBCVAT+ groups created a progressive change in stimulus to accommodation as the patient slowly moved the pencil toward his or her face while trying to keep a 20/60 size letter on the pencil single and clear. Full details of the treatment protocols have been described[22] and can be found at http://optometry.osu.edu/research/CITT/4363.cfm.

Per protocol, masked examiners evaluated all participants after 4, 8, and 12 weeks of therapy (hereafter referred to as week 4, week 8, and week 12 examinations, with the latter being the primary outcome examination). Although not feasible to mask the therapists to patients' assigned treatment, the therapists followed well-defined, sequential treatment protocols. Patients receiving office-based treatment were masked regarding whether they were assigned to OBVAT or placebo therapy.

Long-Term Follow-Up

At completion of the 12-week treatment programs, patients were classified as either asymptomatic (CISS score <16) or symptomatic (CISS score ≥16). Symptomatic patients were offered alternative treatment at no cost. Asymptomatic patients were assigned home maintenance therapy for 15 min per week for the initial 6 mo after treatment discontinuation; no therapy was prescribed between the 6- and 12-mo follow-up visits. This maintenance schedule was consensus-based and was used in our earlier pilot study.[31] A masked examiner performed a sensorimotor examination including accommodative amplitude and facility testing and administered the CISS at the 6- and 12-mo follow-up visits. Long-term stability of treatment effectiveness was assessed by comparing accommodative amplitude and facility measures from treatment completion to those at the 12-mo follow-up examination. Patients with decreased accommodative amplitude and/or facility at treatment completion or who were classified as symptomatic and underwent subsequent treatment were excluded from the long-term analyses.

Statistical Methods

Because the treatments used in the CITT were not specifically designed as primary treatments for accommodative dysfunction, we compare each of the three therapy groups (OBVAT, HBCVAT+, and HBPP) to placebo treatment rather than comparing the three treatments to each other. Changes across visits (baseline, week 4, week 8, and week 12) for each treatment group were compared using a 4 group × 4 time-point analysis of variance model. A 4-group × 3 time-point analysis of covariance model was used to compare mean accommodative amplitude and facility for each treatment group at the 4, 8, and 12-week examinations while controlling for differences at baseline. Tukey's method was used to control the overall error rate (alpha level) for post hoc pair-wise comparisons. A one-sample t-test was used to compare the mean long-term change in accommodative amplitude and facility to zero. Models for accommodative amplitude and accommodative facility included only those patients with decreased accommodative amplitude and decreased accommodative facility, respectively. Analysis of variance and chi-square tests were performed to compare baseline demographics between the four treatment groups.

The original CITT sample size was determined to ensure 90% power to detect treatment group differences with respect to CISS score, nearpoint of convergence, and positive fusional vergence at near. Post hoc calculations were performed to assess the power to detect between-group differences in total change (baseline to week 12) of both accommodative amplitude and facility. Estimates of variability were obtained from a previous pilot study.[31] Because the treatment groups for this analysis were of unequal size, a conservative estimate of power was determined using the placebo group sample size and the smallest sample size of the three active treatment groups. Using only the patients with decreased accommodative amplitude, this study has 82% power to detect a 4 D difference in total amplitude improvement and 81% power to detect a 5 cpm difference in total facility improvement. All analyses were performed using SAS version 9.2 (Cary, NC) following the intention-to-treat principle and using an alpha level of 0.05 to assess statistical significance.

RESULTS

Between July 2005 and October 2006, 221 patients were enrolled. The number of patients enrolled at the nine sites ranged from 14 to 35 (median = 25). Sixty were assigned to OBVAT, 53 to HBCVAT+, 54 to HBPP, and 54 to placebo therapy. Baseline demographic and clinical data have been reported previously. Retention was excellent with 219 of the 221 patients remaining in the study through the week 12 examination (99%). Two children missed their week 4 examination (1 HBCVAT+ and 1 OBVAT) and 1 child (OBVAT) missed the week 12 examination. Less than 2% of all study visits through week 12 were missed. Of the enrolled children, 164 (74%) had accommodative dysfunction; 63 (29%) had a decreased amplitude of accommodation, 43 (19%) had decreased accommodative facility, and 58 (26%) had both. Among the 121 (63 + 58, 55%) with decreased amplitude, 36 were assigned to OBVAT, 30 to HBCVAT+, 27 to HBPP, and 28 to OBPT. Of the 101 (43 + 58, 46%) with decreased accommodative facility, 23 were assigned to OBVAT, 30 to HBCVAT+, 22 to

TABLE 1.

Mean (95% CI) for accommodative amplitude (D), by treatment group and time for those patients with decreased accommodative amplitude at baseline (n = 121)

Treatment group	Time				Total change
	Baseline	Week 4	Week 8	Week 12	
OBVAT (n = 36)	7.7 (7.2, 8.2)	12.1 (10.4, 13.6)	14.9 (13.2, 16.6)	16.9 (15.2, 18.6)	9.9 (8.2, 11.7)
HBCVAT+ (n = 30)	6.9 (6.4, 7.5)	11.7 (9.9, 13.5)	11.8 (10.0, 13.7)	13.8 (12.0, 15.7)	6.7 (4.8, 8.6)
HBPP (n = 27)	7.1 (6.5, 7.7)	11.7 (9.8, 13.6)	13.1 (11.2, 15.0)	13.1 (11.2, 15.0)	5.8 (3.9, 7.8)
OBPT (n = 28)	7.0 (6.5, 7.6)	8.9 (7.1, 10.8)	9.5 (7.7, 11.4)	9.5 (7.6, 11.4)	2.2 (0.3, 4.2)

TABLE 2.

Mean (95% CI) for accommodative facility (cpm), by treatment group and time for those patients with decreased accommodative facility at baseline (n = 101)

Treatment group	Time				Total change
	Baseline	Week 4	Week 8	Week 12	
OBVAT (n = 23)	2.3 (1.5, 3.1)	7.0 (5.1, 8.8)	11.4 (9.2, 13.6)	12.1 (9.8, 14.4)	9.4 (7.1, 11.8)
HBCVAT+ (n = 30)	2.8 (2.0, 3.5)	6.0 (4.5, 7.6)	8.0 (6.0, 9.9)	9.7 (7.7, 11.7)	7.0 (4.9, 9.1)
HBPP (n = 22)	3.0 (2.2, 3.8)	4.5 (2.6, 6.3)	6.6 (4.4, 8.8)	7.7 (5.3, 10.0)	5.0 (2.6, 7.4)
OBPT (n = 26)	2.7 (2.0, 3.5)	5.5 (3.8, 7.2)	6.7 (4.6, 8.8)	8.2 (6.0, 10.4)	5.5 (3.3, 7.7)

HBPP, and 26 to OBPT. There was no statistically significant difference in the proportion of children in each treatment group with decreased accommodative amplitude or facility (p-values >0.20), or in mean accommodative amplitude or facility at baseline (p-values >0.15) among the four treatment groups (Tables 1 and 2). For both patients with decreased accomodative amplitude and those with decreased accomodative facility, there were no significant treatment group differences in baseline characteristics.

Results for Accommodative Amplitude

Within-Group Comparisons: Change in Accommodative Amplitude between Examinations by Treatment Group

The mean increase in accommodative amplitude (range of 4.5 to 4.7 D) from baseline to week 4 for the active therapy groups was significantly greater than zero (p-values <0.0001), whereas the change in the placebo group was not (1.8 D, p = 0.057; Table 3). Between weeks 4 and 8, only the OBVAT group showed a significant improvement in accommodative amplitude (2.8 D, p < 0.001), whereas in the 8- to 12-week interval, both the OBVAT and HBCVAT+ groups showed significant improvements (2.0 D, p = 0.02 and 2.0 D, p = 0.037, respectively).

Increased Accommodative Amplitude: Vision Therapy/ Orthoptics Therapy Compared with Placebo Therapy

Significant treatment group differences in mean accommodative amplitude were present only at weeks 8 and 12 (p < 0.001 and p < 0.0001, respectively; Fig. 1). At the 8-week visit, the mean accommodative amplitude of the OBVAT group was approximately 5 D greater than that of the placebo group (p < 0.0001),

with the difference increasing to more than 7 D at week 12 (p < 0.0001; Table 1). The improvement in accommodative amplitude for the HBCVAT+ group was significantly different from that of the placebo group only at week 12 (difference = 4.3 D, p = 0.002), while the HBPP group showed a significantly greater mean amplitude (difference = 3.6 D) at both weeks 8 and 12 (p = 0.009 and p = 0.010, respectively) when compared with placebo.

At study completion, the mean increases in accommodative amplitude (9.3 D for OBVAT, 6.8 D for HBCVAT+, and 5.9 D for HBPP) were significantly greater than the 2.4 D gain found for the placebo group (p-values ≤ 0.01; Table 1; Fig. 2). A decreased amplitude of accommodation was no longer present in 91.4% (32/35) of the patients in OBVAT, 79.3% (23/29) in HBCVAT+, and 74.1% (20/27) in HBPP, compared with 35.7% (10/28) of those assigned to placebo treatment (p < 0.003).

Of the patients who no longer had a decreased amplitude of accommodation at treatment completion (n = 85) and did not undergo subsequent treatment during the 1-year follow-up period (n = 44), the mean decrease in accommodative amplitude was 1.4 D (p = 0.044). A recurrence of decreased accommodative amplitude occurred in 11% (5/44) (4 of 12 in HBPP, 1 of 21 in OBVAT, 0 of 9 in HBCVAT+ and 0 of 2 in placebo).

Accommodative Facility

Within-Group Comparisons: Change in Accommodative Facility between Examinations by Treatment Group

The OBVAT group showed significant improvement in accommodative facility (4.4 cpm, p < 0.0001) from baseline to 4 weeks and between 4 and 8 weeks (4.4 cpm, p < 0.0001), with no significant improvement between 8 and 12 weeks (0.8 cpm, p = 0.39; Fig. 3). The HBCVAT+ group showed significant improve-

TABLE 3.
Treatment group differences at successive examinations

Comparison	Difference	95% CI	p-value
Accommodative amplitude (D) for OBVAT			
Week 4—baseline	4.5	2.8, 6.2	<0.0001
Week 8—week 4	2.8	1.4, 4.3	<0.001
Week 12—week 8	2.0	0.3, 3.7	0.020
Accommodative amplitude (D) for HBCVAT+			
Week 4—baseline	4.7	2.9, 6.5	<0.0001
Week 8—week 4	0.1	−1.5, 1.7	0.91
Week 12—week 8	2.0	0.1, 3.9	0.037
Accommodative amplitude (D) for HBPP			
Week 4—baseline	4.6	2.6, 6.5	<0.0001
Week 8—week 4	1.4	−0.3, 3.1	0.11
Week 12—week 8	−0.02	−2.0, 1.9	0.99
Accommodative amplitude (D) for OBPT			
Week 4—baseline	1.8	−0.1, 3.7	0.057
Week 8—week 4	0.6	−1.1, 2.3	0.48
Week 12—week 8	−0.01	−1.9, 1.9	0.99
Accommodative facility (cpm) for OBVAT			
Week 4—baseline	4.4	2.5, 6.2	<0.0001
Week 8—week 4	4.4	3.0, 5.8	<0.0001
Week 12—week 8	0.8	−1.0, 2.5	0.39
Accommodative facility (cpm) for HBCVAT+			
Week 4—baseline	3.3	1.7, 4.9	<0.0001
Week 8—week 4	2.0	0.7, 3.2	0.002
Week 12—week 8	1.7	0.2, 3.2	0.029
Accommodative facility (cpm) for HBPP			
Week 4—baseline	1.7	−0.2, 3.6	0.072
Week 8—week 4	2.1	0.7, 3.6	0.004
Week 12—week 8	1.1	−0.7, 2.8	0.23
Accommodative facility (cpm) for OBPT			
Week 4—baseline	2.8	1.1, 4.5	0.002
Week 8—week 4	1.2	−0.1, 2.5	0.075
Week 12—week 8	1.5	−0.1, 3.1	0.075

ments from baseline to week 4 (3.3 cpm, p < 0.0001) and showed smaller but statistically significant improvements of approximately 2 cpm between weeks 4 to 8 (p = 0.002) and 8 to 12 (p = 0.029). The HBPP group only showed significant gains between weeks 4 and 8 (2.1 cpm, p = 0.004). The placebo group showed significant improvements only at week 4 (2.8 cpm, p = 0.002).

Active Vision Therapy/Orthoptic Therapies Compared with Placebo Therapy after 4, 8, and 12 weeks of Treatment

There was no difference in mean accommodative facility between treatment groups at week 4 (p = 0.30); however, significant differences were found at weeks 8 (p = 0.010) and 12 (p = 0.037) (Fig. 3; Table 2). Compared with the placebo group, only the OBVAT group's mean accommodative facility was significantly better at the 8-week visit (mean difference of 4.7 cpm; p = 0.003) and the 12-week visit (mean difference of 3.9 cpm; p = 0.016).

At treatment completion, accommodative facility increased by 9.5 cpm in the OBVAT group, 7.0 cpm in the HBCVAT+ group,

4.9 cpm in the HBPP group, and 5.5 cpm in the placebo group (Table 2). Only the OBVAT group showed a significantly greater improvement in accommodative facility than the placebo group (p = 0.016) (Fig. 4).

After 12 weeks of treatment, decreased accommodative facility was no longer present in 87% (20/23) of OBVAT patients, 70% (21/30) of the HBCVAT+ patients, and 63.6% (14/22) of the HBPP patients, when compared with 57.7% (15/26) of those assigned to placebo treatment (p = 0.15).

Long-Term Results

Among the patients who did not have reduced accommodative facility at week 12 (n = 70) and performed no other treatments during subsequent 1-year follow-up period (32, 46%) there was a small, non-significant decrease in facility found at the 12-mo follow-up visit (−0.7 cpm, range −12.0 to 9.5 cpm, p = 0.41). Of these 32 patients, 4 (12.5%) regressed sufficiently to be diagnosed with deficient accommodative facility (1/11 OBVAT, 2/7 HBPP, 0/8 HBCVAT+, and 1/6 OBPT).
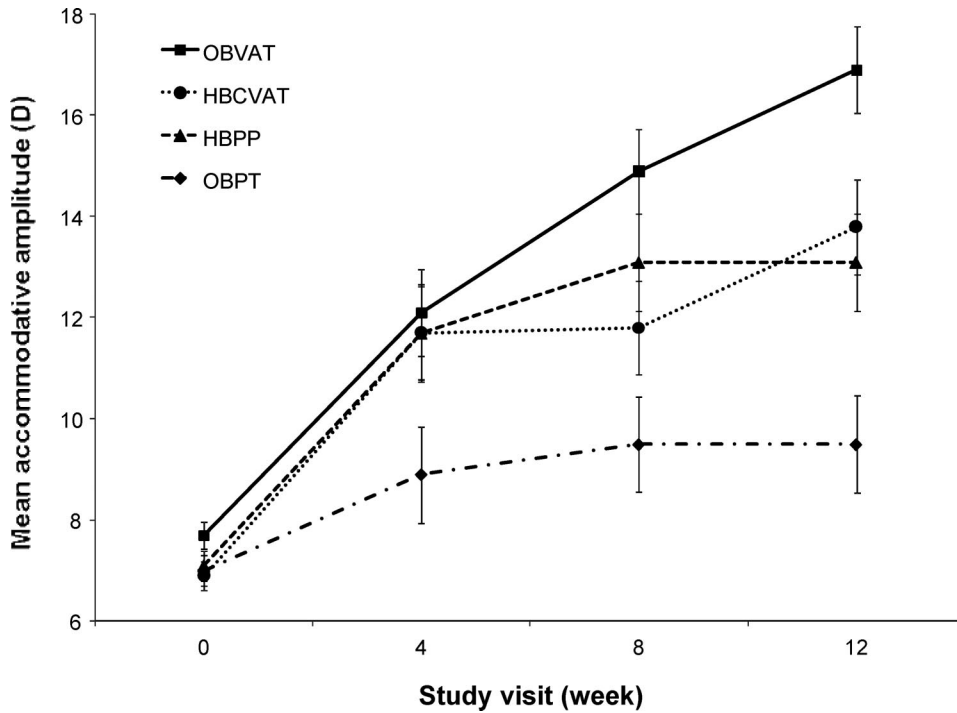
FIGURE 1.

Mean accommodative amplitude (D) for patients with decreased accommodative amplitude, by study visit and treatment group.
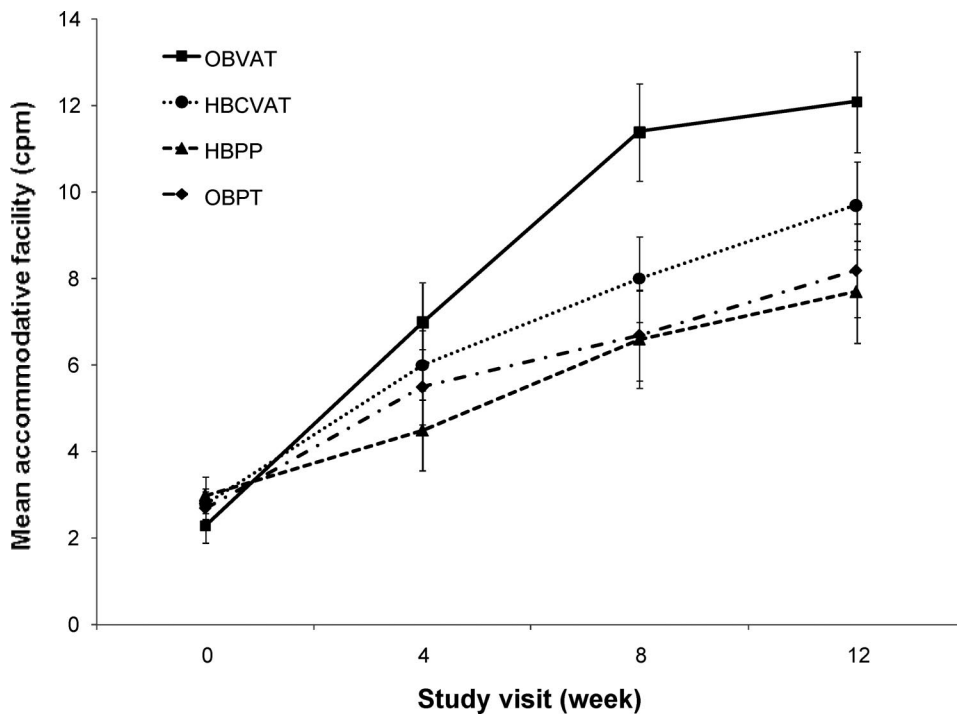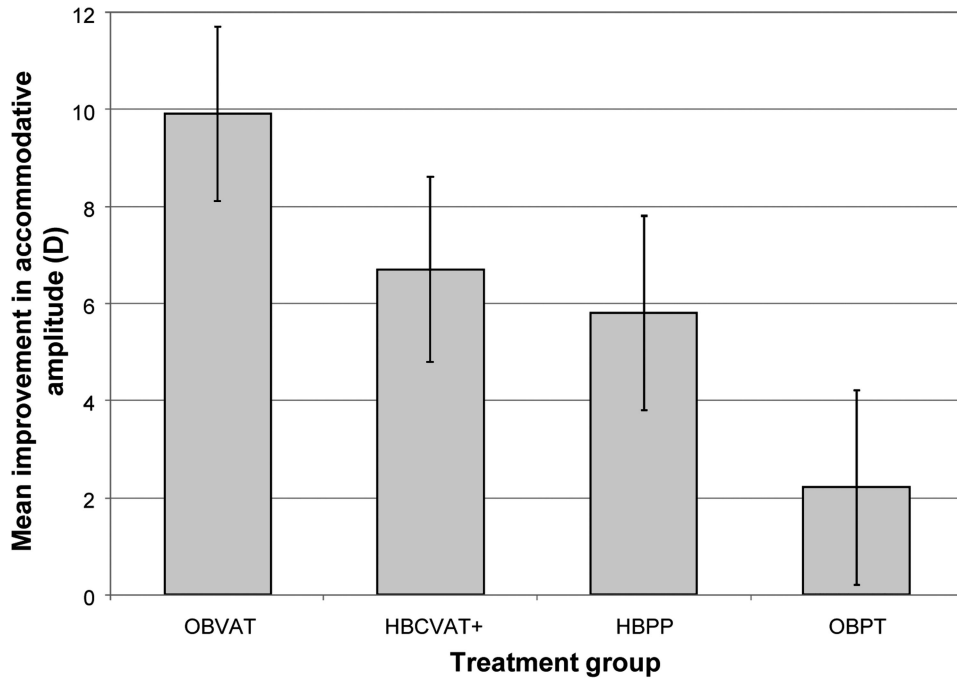

FIGURE 2

Mean improvement in accommodative amplitude (D) for patients with decreased accommodative amplitude, by treatment group.

Adverse Events

There were six vision- or eye-related events among the 221 patients enrolled in the study. All were unexpected and further evaluations determined that all six were not serious and unrelated to the study treatment.

DISCUSSION

We compared the effectiveness of OBVAT, HBCVAT+, and HBPP to office-based placebo therapy for improving accommodative amplitude and facility in children with both symptomatic CI and accommodative dysfunction who were

FIGURE 3.

Mean accommodative facility (cpm) for patients with decreased accommodative facility, by study visit and treatment group.
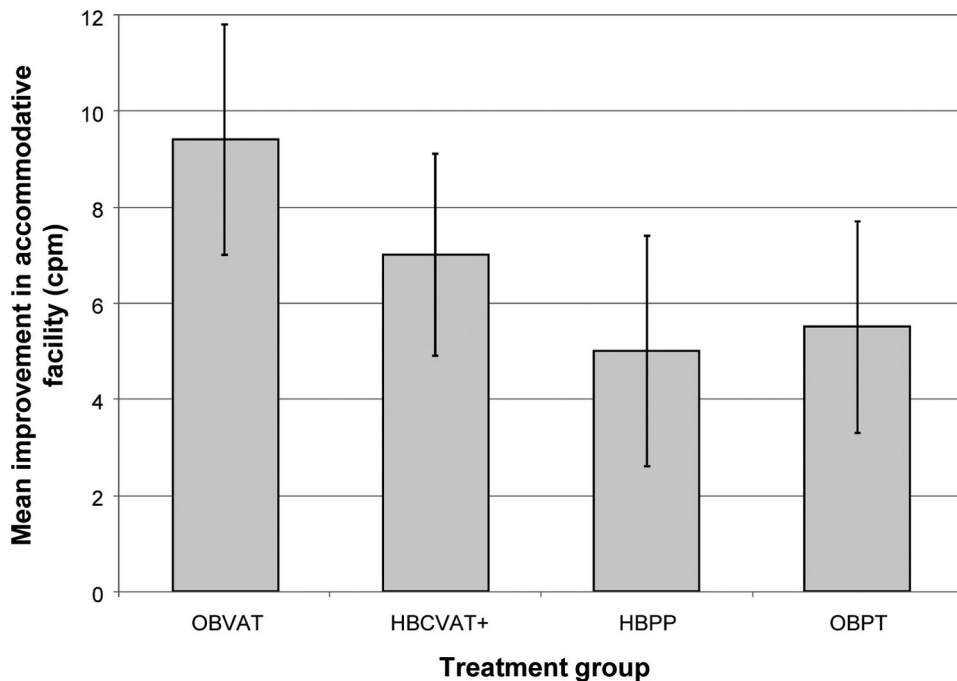
FIGURE 4.

Mean improvement in accommodative facility (cpm) for patients with decreased accommodative facility, by treatment group.

enrolled in the CITT. Although the primary objective of the study was the comparison of the effectiveness of active treatments for symptomatic CI, accommodative function was measured at baseline and at all subsequent study visits, and each active therapy program included accommodative therapy. This allowed us to evaluate the kinetics of change in accommodative function and the effectiveness of the three therapy modalities in improving accommodative amplitude and facility.

All three of the vision therapy/orthoptic treatments were significantly more effective than placebo therapy for improving accommodative amplitude in patients with decreased accommodative amplitude while only OBVAT was significantly more effective than placebo therapy in improving accommodative facility in patients. In addition, at the end of the 12-week treatment period, significantly fewer patients had a decreased amplitude of accommodation or subnormal accommodative fa-

cility in the active therapy groups compared with the placebo. Finally, the gains demonstrated at 12 weeks were still present in the majority (>87%) of patients after 1-year off treatment.

Although all three active treatment modalities included some form of accommodative therapy, there were differences in the type of the accommodative procedure, format of the therapy (monocular, biocular, and binocular), and time spent performing the therapy. Accommodative therapy for accommodative insufficiency and infacility traditionally includes procedures designed to increase both the amplitude of accommodation and the dynamics of the accommodative response.[5] The objectives of the latter type of accommodative therapy, also referred to as accommodative facility therapy, are to decrease the latency and increase the speed of the accommodative response. Procedures designed to increase the amplitude of accommodation use an accommodative stimulus that is increased in a slow, gradual manner while procedures used to improve the dynamics of the accommodative response alter the accommodative stimulus in large discrete steps. Generally, accommodative amplitude procedures are emphasized initially and once the amplitude normalizes, facility procedures are introduced. In addition, accommodative therapy is generally sequenced so that accommodative function is improved and equalized in each eye monocularly before beginning binocular accommodative therapy.[5] Of the three active treatments used in this study, only OBVAT incorporated both accommodative amplitude and facility procedures and used a monocular to binocular therapy sequence. The OBVAT treatment sequence used monocular accommodative amplitude and facility techniques during the first 8 week, and binocular accommodative facility techniques between weeks 8 and 12. The HBCVAT+ group performed biocular (both eyes open, but no fusion) accommodative facility therapy for the entire treatment period. Although there was no specific accommodative therapy procedure per se for the HBPP group, pencil push-up therapy involved maintaining clarity as the accommodative target was moved toward the child's eyes and thus can be considered a binocular accommodative amplitude procedure. These differences in therapy may explain some of the apparent differences in effectiveness.

In terms of the kinetics of change in accommodative amplitude during the 12-week treatment program, there was a significant improvement in amplitude from baseline to week 4 in all groups except the placebo group but only the OBVAT group demonstrated continued improvements between weeks 4 and 12. For accommodative facility, most improvements occurred during the first 8 week of therapy for all three active therapy groups. The treatment kinetic data reported herein provide guidance regarding the timing of follow-up visits. Because the largest changes in both accommodative amplitude and facility occurred by 4 weeks for all three treatment groups, 4 weeks appears to be an appropriate time for a progress evaluation. Absence of any improvement after 4 weeks of treatment might suggest poor adherence to therapy or cast doubt on the accuracy of the diagnosis.

Although previous studies have reported that active vision therapy is an effective treatment for accommodative dysfunction, these studies suffer from a variety of design limitations including retrospective design,[10,19,20] small sample size,[12,20,32] lack of a placebo group,[10,19,20] and use of unmasked examiners.[10,12,19,20,32] In addition, some of the studies used adult patients[17,19] and only investigated home-based therapy.[12,19] Thus, there are no other data from well-designed, randomized clinical trials showing the effectiveness of vision therapy/orthoptics compared with a placebo control group for accommodative dysfunction in children.

The strengths of our study include its prospective design, adequate sample size, randomization of patients, having a placebo control for the OBVAT group, evidence of successful masking of examiners and patients in the OBVAT and OBPT groups, and outstanding follow-up.[22] Because the study was not designed specifically to investigate the effectiveness of therapy for accommodative function, one might argue that the data do not demonstrate whether office- or home-base therapy are effective for patients with accommodative dysfunction alone. However, because the therapy procedures that would be prescribed for children with accommodation dysfunction alone would actually be more extensive, there is good reason to believe that the results of this study may underestimate the potential for success. Only approximately half of the subjects could be included in the analyses of long-term follow-up because subjects had to be both asymptomatic and have normal accommodative function. We are also unable to comment about the effect of therapy on symptoms related to accommodative problems because the patients all had CI as well. Because a natural history group was not included in the study, it is unknown if the small and generally nonsignificant improvements in the placebo group were due to placebo effect or regression to the mean. We can conclude, however, that meaningful and significantly greater improvements in accommodative amplitude and facility can be achieved using vision therapy/orthoptics and that the gains cannot be attributed to the placebo effect. Furthermore, these gains are maintained for a least a year in the majority of subjects. Future studies should consider including objective measures of accommodative function and additional studies are necessary to compare office-based vs. home-based treatments specifically designed to address accommodative dysfunction. Our data demonstrate improvement of accommodative function in children with poor accommodative amplitudes or facility and should be the impetus for a new randomized clinical trial studying the effectiveness of various therapies for the treatment of symptomatic accommodative dysfunction in children.

CONCLUSIONS

In this first, large-scale randomized clinical trial in children with CI and accommodative dysfunction, vision therapy/orthoptics was effective for improving decreased accommodative amplitude and accommodative facility. Further study is required to determine the most effective treatment approach (office-based vs. home-based), most effective therapy procedures, effect of accommodative therapy on symptoms in patients with symptomatic accommodative dysfunction alone, and the optimum duration of therapy.

and location. Personnel are listed as (PI) for principal investigator, (SC) for coordinator, (E) for examiner, and (VT) for therapist.

REFERENCES

1. Scheiman M, Gallaway M, Coulter R, Reinstein F, Ciner E, Herzberg C, Parisi M. Prevalence of vision and ocular disease conditions in a clinical pediatric population. J Am Optom Assoc 1996; 67:193–202.
2. Borsting E, Rouse MW, Deland P. Evaluation of symptoms in school-aged children with accommodative insufficiency. Optom Vis Sci 1999;76(Suppl):205.
3. Abrams D. Duke-Elder's Practice of Refraction, 10th ed. Edinburgh: Churchill Livingstone; 1993.
4. Rouse MW. Management of binocular anomalies: efficacy of vision therapy in the treatment of accommodative deficiencies. Am J Optom Physiol Opt 1987;64:415–20.
5. Scheiman M, Wick B. Clinical Management of Binocular Vision: Heterophoric, Accommodative and Eye Movement Disorders, 3rd ed. Philadelphia, PA: Lippincott, Williams and Wilkins; 2008.
6. Daum KM. Accommodative dysfunction. Doc Ophthalmol 1983; 55:177–98.
7. Hennessey D, Iosue RA, Rouse MW. Relation of symptoms to accommodative infacility of school-aged children. Am J Optom Physiol Opt 1984;61:177–83.
8. Levine S, Ciuffreda KJ, Selenow A, Flax N. Clinical assessment of accommodative facility in symptomatic and asymptomatic individuals. J Am Optom Assoc 1985;56:286–90.
9. Hoffman LG, Rouse M. Referral recommendations for binocular function and/or developmental perceptual deficiencies. J Am Optom Assoc 1980;51:119–26.
10. Wold RM, Pierce JR, Keddington J. Effectiveness of optometric vision therapy. J Am Optom Assoc 1978;49:1047–54.
11. Cooper J, Feldman J, Selenow A, et al. Reduction of asthenopia after accommodative facility training. Am J Optom Physiol Opt 1987;64: 430–36.
12. Sterner B, Abrahamsson M, Sjostrom A. The effects of accommodative facility training on a group of children with impaired relative accommodation—a comparison between dioptric treatment and sham treatment. Ophthal Physiol Opt 2001;21:470–6.
13. Sterner B, Abrahamsson M, Sjostrom A. Accommodative facility training with a long term follow up in a sample of school aged children showing accommodative dysfunction. Doc Ophthalmol 1999; 99:93–101.
14. Cornsweet TN, Crane HD. Training the visual accommodation system. Vision Res 1973;13:713–5.
15. Provine RR, Enoch JM. On voluntary ocular accommodation. Percept Psychophys 1975;17:209–12.
16. Bharadwaj SR, Vedamurthy I, Schor CM. Short-term adaptive modification of dynamic ocular accommodation. Invest Ophthalmol Vis Sci 2009;50:3520–8.
17. Bobier WR, Sivak JG. Orthoptic treatment of subjects showing slow accommodative responses. Am J Optom Physiol Opt 1983;60: 678–87.
18. Liu JS, Lee M, Jang J, Ciuffreda KJ, Wong JH, Grisham D, Stark L. Objective assessment of accommodation orthoptics. I. Dynamic insufficiency. Am J Optom Physiol Opt 1979;56:285–94.
19. Daum KM. Accommodative insufficiency. Am J Optom Physiol Opt 1983;60:352–9.
20. Hoffman L, Cohen AH, Feuer G. Effectiveness of non-strabismus optometric vision training in a private practice. Am J Optom Arch Am Acad Optom 1973;50:813–6.
21. Convergence Insufficiency Treatment Trial Investigator Group. The convergence insufficiency treatment trial: design, methods, and baseline data. Ophthalmic Epidemiol 2008;15:24–36.
22. Convergence Insufficiency Treatment Trial Investigator Group. Randomized clinical trial of treatments for symptomatic convergence insufficiency in children. Arch Ophthalmol 2008;126: 1336–49.
23. Sheard C. Zones of ocular comfort. Am J Optom 1930;7:9–25.

24. Rouse M, Borsting E, Mitchell GL, Cotter SA, Kulp M, Scheiman M, Barnhardt C, Bade A, Yamada T. Validity of the convergence insufficiency symptom survey: a confirmatory study. Optom Vis Sci 2009; 86:357–63.

25. Borsting EJ, Rouse MW, Mitchell GL, Scheiman M, Cotter SA, Cooper J, Kulp MT, London R. Validity and reliability of the revised convergence insufficiency symptom survey in children aged 9 to 18 years. Optom Vis Sci 2003;80:832–8.

26. Hofstetter HW. Useful age-amplitude formula. Opt World 1950;38: 42–5.

27. Hofstetter HW. A comparison of Dunae's and Donders' tables of the amplitude of accommodation. Am J Optom Arch Am Acad Optom 1944;21:345–63.

28. Kulp M, Mitchell GL, Borsting E, Scheiman M, Cotter S, Rouse M, Tamkins S, Mohney BG, Toole A, Reuter K. Effectiveness of placebo therapy for maintaining masking in a clinical trial of vergence/accommodative therapy. Invest Ophthalmol Vis Sci 2009;50:2560–6.

29. Kulp MT, Borsting E, Mitchell GL, Scheiman M, Cotter S, Cooper J, Rouse M, London R, Wensveen J. Feasibility of using placebo vision therapy in a multicenter clinical trial. Optom Vis Sci 2008;85:255–61.

30. Scheiman M, Wick B. Clinical Management of Binocular Vision: Heterophoric, Accommodative and Eye Movement Disorders, 2nd ed. Philadelphia, PA: Lippincott, Williams and Wilkins; 2002.

31. Scheiman M, Mitchell GL, Cotter S, Cooper J, Kulp M, Rouse M, Borsting E, London R, Wensveen J A randomized clinical trial of treatments for convergence insufficiency in children. Arch Ophthalmol 2005;123:14–24.

32. Weisz CL. Clinical therapy for accommodative responses: transfer effects upon performance. J Am Optom Assoc 1979;50:209–16.

Mitchell Scheiman
Pennsylvania College of Optometry at Salus University
1200 West Godfrey Avenue
Philadelphia, Pennsylvania 19141
e-mail: mscheiman@salus.edu