ORIGINAL ARTICLE

Visual rehabilitation in patients with myopic maculopathy: our experience

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ABSTRACT • RÉSUMÉ

Objective: To evaluate the efficacy of the MP-1 microperimeter (Nidek Technologies Srl, Padova, Italy) and Visual Pathfinder (LACE Inc) in improving visual function of patients with myopic maculopathy.
Design: Prospective, nonrandomized, interventional case series.
Participants: Seventeen patients (34 eyes) between 36 and 58 years of age with myopic maculopathy and central retinal scotomas.
Methods: After a complete eye examination, all patients underwent 10 training sessions with MP-1 biofeedback (7 minutes) and Visual Pathfinder (3 minutes) for each eye once a week. Statistical analysis was performed with Student *t* test. The *p* values less than 0.05 were considered statistically significant.
Results: The mean best corrected visual acuity increased from 0.64 ± 0.22 to 0.38 ± 0.20 logMAR at the end of follow-up ($p = 0.03$); visual-evoked potential P100 amplitude increased from 3.54 ± 1.90 to 6.64 ± 2.91 μV at the end of follow-up ($p = 0.04$); average retinal sensitivity, calculated in the 12 degrees of the central retina, increased from 6.6 ± 2.6 to 14.6 ± 3.6 dB ($p = 0.03$). Fixation behaviour in the 2 degrees of the central retina increased from 45% ± 17% to 75% ± 23% ($p = 0.04$). The bivariate contour ellipse area (95%) increased from 10.34 ± 3.11 to 7.64 ± 2.71 square degrees ($p = 0.04$).
Conclusions: The combination of acoustic biofeedback training with MP-1 and Visual Pathfinder offers a reasonable improvement of visual function in patients with myopic maculopathy. This method might be considered as a rehabilitative strategy as a "therapeutic option" in these patients for whom most treatments usually do not work.

Objet : Évaluation de l'efficacité de la micropérimétrie MP-1 (Nidek Technologies) et du « Visual Pathfinder » (Lace Inc.) pour améliorer la fonction visuelle chez les patients ayant une maculopathie myopique.
Nature : Prospective non randomisée d'une série de cas d'intervention.
Participants : Dix-sept patients (34 yeux) de 36 à 58 ans ayant une maculopathie myopique et des scotomes de la rétine.
Méthodes : Après un examen oculaire complet, les patients ont tous suivi 10 séances hebdomadaires de développement par biofeedback avec le MP-1 (7 minutes) et le Visual Pathfinder (3 minutes) dans chaque œil. L'analyse statistique a été effectuée avec un test Student t. Les valeurs p inférieures à 0,05 ont été considérées comme étant statistiquement significatives.
Résultats : La moyenne de meilleure acuité visuelle corrigée (MAVC) avait augmenté, passant de 0,64 ± 0,22 à 0,38 ± 0,20 logMAR à la fin du suivi ($p = 0.03$); l'amplitude P100 du potentiel visuel évoqué (PVE) avait augmenté de 3,54 ± 1,90 à 6,64 ± 2,91 μV à la fin du suivi ($p = 0,04$); la moyenne de sensibilité rétinienne, calculée dans les 12 degrés au centre de la rétine, avait augmenté de 6,6 ± 2,6 dB à 14,6 ± 3,6 dB ($p = 0.03$). Le comportement de la fixation dans les deux degrés de la rétine centrale avaient augmenté de 45 ± 17% à 75 ± 23% ($p = 0,04$). La « zone élliptique du contour bivarié (« BCEA ») a augmenté de 10,34 ± 3.,11 à 7,64 ± 2,71 degrés carrés ($p = 0,04$).
Conclusions : La combinaison de la formation par biofeedback acoustique avec le MP-1 et le Visual Pathfinder (VPF) offre une amélioration raisonnable de la fonction visuelle chez les patients ayant une maculopathie myopique. Cette méthode pourrait être considérée comme premier choix thérapeutique pour ces patients.

Biofeedback techniques have been used for more than 40 years to alter brain activity, blood pressure, muscle tension, heart rate, and other bodily functions that are not under voluntary control.[1–3]

In the past, different biofeedback training approaches have been proposed for visual rehabilitation.[1,4–12] Accomotrack Vision Trainer has been used to modulate the accommodative tone[4]; Improved Biofeedback Integrated System (Ibis), based on infrared photostimulation and foveal flicker, has been used to improve visual function in patients with low vision[1,5]; Vision Restoration Therapy (VRT), a software-based visual training program, has been shown to improve visual deficits after prechiasmatic and postchiasmatic injury[6]; Visual Pathfinder (VPF; Lace Inc) has been found useful to ameliorate visual performance in children with amblyopia[7,8]; and MP-1 microperimeter (Nidek Technologies), both with acoustic and with pattern stimulus, has been found effective in improving visual function in age-related macular degeneration (AMD) and hereditary retinal dystrophies.[9–12] Little is still known about the potential of biofeedback techniques applied to the visual system. As in previously published articles, the biofeedback rationale is to train the new preferential retinal location in several diseases characterized by central retinal damage such as AMD or inherited retinal diseases such as Stargardt disease

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or cone dystrophy. Our interest in high myopia is due to our belief that myopic eyes have spared retina surrounding geographic atrophy with often bridges of normal retina that allows with search better performances that are not useful in normal life due to very high instability of fixation, as demonstrated in several reports and in our patients. Hence we pointed our attention to this type of patient in an attempt to improve fixation performances. Surprisingly, we also report a very clear improvement in whole visual function described in this case series.

We wanted to evaluate the effectiveness of improving visual performance with biofeedback training by means of both MP-1 microperimeter and VPF on myopic maculopathy.

Methods

We enrolled 17 patients (34 eyes; age range, 36–58 years; 10 women, 7 men) with myopic maculopathy and central retinal scotomas on visual field. The diagnosis of pathologic myopia was based on fundus appearance, a refractive error greater than –8.00 D or axial length more than 26.5 mm. All patients had patchy chorioretinal atrophy as described in Tokoro's classification.[13]

We have excluded patients with other eye diseases (glaucoma, AMD, retinal detachment, among other), uncooperative patients, and persons with opacity of the dioptric media. Informed consent to participate in the study was obtained from all patients. The Ethics Committee of our institution approved the study protocol. All procedures adhered to the tenets of the Declaration of Helsinki.

Rehabilitation protocol

All patients underwent the same rehabilitation protocol that consisted of the following:

- Measurement of best corrected visual acuity (BCVA) evaluated in logMAR. Early Treatment Diabetic Retinopathy Study (EDTRS) tables were used by the means of computerized projector cofocused with the patient (MAV SIFI Catania Italy). Visual acuity was expressed in logMAR.
- Reading speed test: The reading speed for each eye was measured by reading black letters on a white background (Times New Roman font) obtained by Limoli-Vingolo text tables from Virtual-IPO system (Eye.com, Palermo, Italy) at 30-cm distance with an appropriate addition. Subjects were asked to read aloud as quickly as possible without skipping words (the size of the press corps has been adapted to the patient's visual acuity and was measured in electronic points). The sentences contained words that occur frequently in Italian and had no punctuation; value was measured in words per minute. The virtual-IPO software generates randomly and prints tests from a web-based text database so that in each session, text was chosen of the same reading difficulty but of different arguments. Visual acuity was tested with same low-vision aid and at same distance that the patient performed at baseline control.
- Microperimetry with MP-1 microperimeter: a cross of 2-degree diameter circle or 1-degree diameter circle was used for the test before the training; after the training, a cross of 1-degree diameter circle was used for all patients. An automated program macula 12 (60 stimuli) and 4-2 strategy was used. Retinal sensitivity was measured in all patients using Goldmann III aim with a stimulus intensity ranging from 0 to 20 dB. Each patient was informed about the examination and was submitted to a visual adaptation before the test could start. Each eye was analyzed separately for fixation behaviour, the location of the functional retinal locus,[14] scotoma size and density, and central retinal sensitivity was calculated on 12 degrees. Microperimetric acoustic biofeedback was performed with patterned stimulation chosen in relation to the smallest checkerboard seen by the patient. Same characteristics were used for fixation target and red cross size; obviously with better performances the cross became thinner, but this did not affect correct running of the biofeedback sessions because fixation red cross indicates a general target for the patient, whereas the eye-tracker assures the correct presentation of acoustic and visual biofeedback. For statistical purposes, bivariate contour ellipse area (BCEA) was calculated on 95% of fixation points data.
- Microperimetric re-examination was performed using follow-up tools of MP-1 device.
- Assessment of pattern reversal visual-evoked potentials (VEP) was performed by Metrovision System (Clermond Ferrant Fra) and was carried out according to the International Society for Clinical Electrophysiology of Vision (ISCEV) standard.[15] Black and white checkerboard patterns with check sizes of 30° of visual angle served as the stimulus.
- After selection of the functional retinal locus to be trained, 10 training sessions of 10 minutes each for each eye were performed in sequence once a week using MP-1 (7 minutes) and VPF by the means of VPF A10 (3 minutes; Ingenesi, Rome Italy). For the MP-1, patients were asked to move their eyes according to an audio feedback that advised them whether they were getting closer to the desired final fixation position. For the VPF, patients were asked to look at a red cross in the centre of a black and white checkerboard. A sound that increased in tone was connected with the amplitude of the P100 wave to stimulate the patients to maintain the highest sound (allowed by their clinical condition) and consequently the highest VEP amplitude. The checkerboard size used for the biofeedback training was visual acuity dependent, so that a higher visual acuity led to a higher frequency to be used.

- After 10 weeks of training, all patients were again subjected to the measurement of BCVA, reading speed test, VEP pattern reversal measurements, and microperimetry in the same manner as described earlier. Microperimetry was repeated with the follow-up tool that allows retesting of the same points of the reference microperimetry. The reason that both biofeedback systems were used was that usually microperimetric biofeedback stimulates a more stable fixation, training the retina to maintain a target retinal location, whereas VPF A10 presents an iterative stimulation that forces the number of ganglion cell and receptive fields to improve axonal transmission through the geniculate body and brain.

Functional retinal locus

The functional retinal locus to be trained with biofeedback examination was a 1-degree diameter circle, if possible on the superior retinal field with an appropriate retinal sensitivity to ensure the reinforcement of fixation behaviour and fluent reading. It has been demonstrated that reading speed improves if a newly trained retinal locus is established in an area that is more favourable for reading.[16] With the aid of the virtual-IPO system, the retinal locus was chosen by the ophthalmologist, who paid particular attention to the horizontal width of the retinal area (for fluent reading, patients must be able to read correctly at least 4 letters) and to its single-point sensitivity.[16] If this locus was already in the area that would have been chosen by the ophthalmologist, it was decided to reinforce the fixation behaviour and not to change the location.[16] All patients presented PRLs in different positions in each eye because of chorioretinal atrophy.

Table 1—Visual acuity, retinal sensitivity, fixation behaviour, visual-evoked potential P100 amplitude, bivariate contour ellipse area, and reading speed observed before and after biofeedback rehabilitation (mean ± 1 SD logMAR)

	Pre	Post	*p*
BCVA	0.64 ± 0.22	0.38 ± 0.20	0.03
VEP P100 amplitude (μV)	3.54 ± 1.90	6.64 ± 2.91	0.04
Retinal sensitivity (dB)	6.6 ± 2.6	14.6 ± 3.6	0.03
Fixation (%)*	45 ± 17	75 ± 23	0.04
BCEA	10.3 ± 3.1	7.6 ± 2.7	0.04
Reading speed (**words read per minute**)	54 ± 9.38	88 ± 8.55	0.02

Pre, before treatment; Post, after rehabilitation; BCVA, best corrected visual acuity; BCEA, bivariate contour ellipse area.

*Percentage of fixations points within the 2-degree diameter circle.

Statistical analysis was performed using Student *t*-test. The *p* values less than 0.05 were considered statistically significant because of the preliminary nature of this study.

Results

All patients (100%) were satisfied after the training, and they reported a subjective improvement in their visual function evaluated by asking them what happened in their visual performances after the biofeedback (improved, stable, or worsened), being able to read faster and smaller character sizes, and reporting to move better even in their familiar environment.

Mean data and relative statistical analysis of functional parameters are shown in Table 1. Figures 1 and 2 show examples of retinal sensitivity and BCEA improvement.

Notably, functional results demonstrate a significant increase of visual acuity, despite a very compromised retinal situation; several patients could notice a surprising improvement in lock-on procedure to identify letters in EDTRS charts. This was also evaluated by increase in reading speed

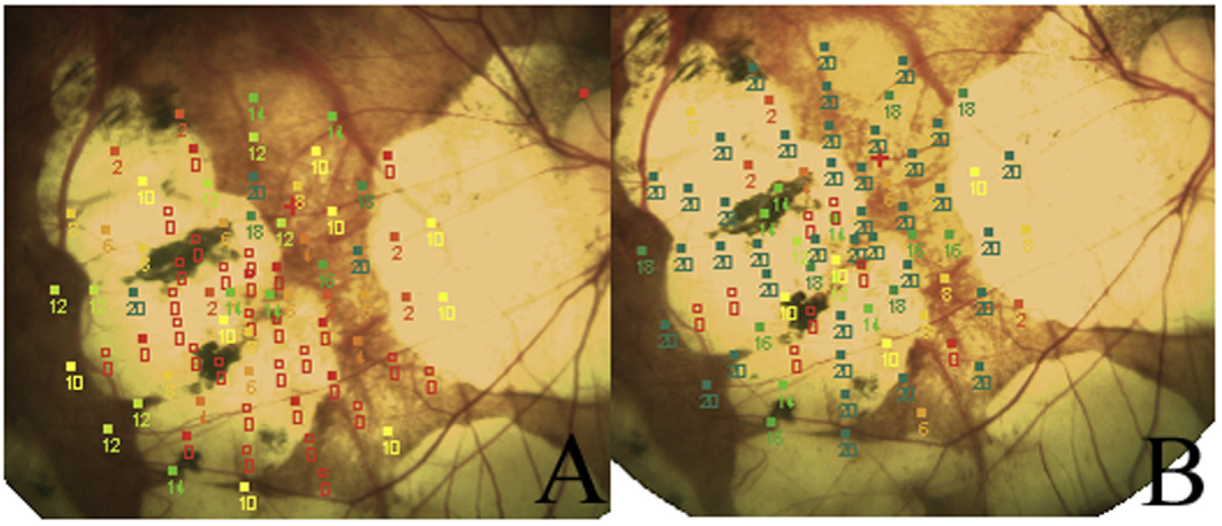

Fig. 1—A, Retinal sensitivity of the right eye of 1 patient at baseline. Patchy chorioretinal atrophy of a 50-year-old woman, right eye, refraction, –13.0 D, axial length, 30.6 mm. Mean retinal sensitivity 5.9 dB, mean defect –11 dB. B, Retinal sensitivity of the right eye of the same patient at the rehabilitation. The retinal sensitivity map shows a dramatic improvement. Mean retinal sensitivity 14.5 dB, mean defect –3.5 dB.

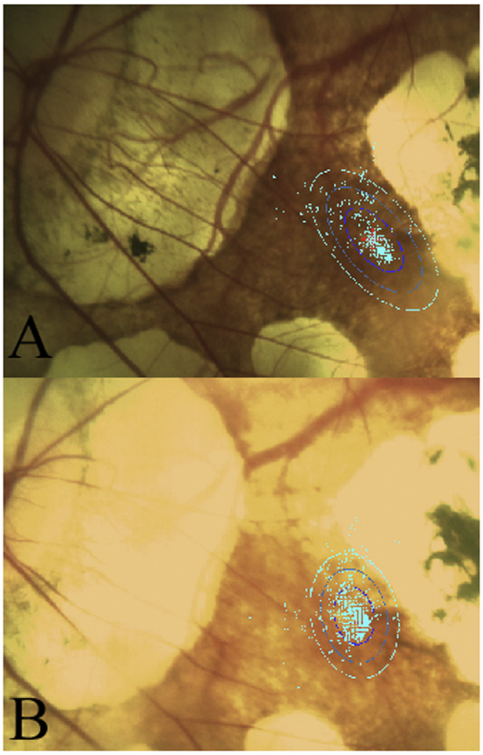

Fig. 2—A, Bivariate contour ellipse area (BCEA) of the same patient as in Figure 1, left eye. BCEA before rehabilitation 12.6 square degrees. B, BCEA after rehabilitation 9.6 square degrees.

after retinal stimulation. The sample size is not large enough to allow statistical inference on correlations between different parameters to evaluate which of them was most important in determining the functional increase.

Discussion

This pilot study allowed for the evaluation of the efficacy of visual rehabilitation with MP-1 and VPF. For the first time, these techniques were applied to the treatment of myopic maculopathy, and our results demonstrated an improvement of BCVA, retinal sensitivity, fixation behaviour, VEP P100 amplitude, and grossly on patient satisfaction.

Some hypotheses can be made to explain the mechanism by which this technique acts in improving visual performance. First, it is possible that both MP-1 and VPF act on the oculomotor performance of patients with myopic maculopathy, which might be deficient when they attempt to redirect incoming images to land on the area with the highest retinal sensitivity. We decided to train eccentric retinal areas hosting the preferred retinal locus used for fixation, as well as the closest retinal locus with highest retinal sensitivity offering best potential visual acuity (functional retinal locus).[14,21] Even if it cannot be proved at this time, these techniques might increase the number of correct fixation saccades and re-reference the oculomotor system to functional retinal locus.

Second, the possibility of a cortical reorganization secondary to local retinal dysfunction has been demonstrated.[17] Structured stimulation with VPF might act on integrative processes at the inner retinal layers, allowing optimization of the recognition of the stimulus, its processing, and its transmission to the visual cortex, thus inducing a cortical reorganization.[18] Henriksson et al.[19] also showed that patients with homonymous hemianopia often have some residual sensitivity for visual stimuli in their blind hemifield and demonstrated that intensive training with flicker stimulation of a blind hemifield in the chronic stage of stroke can induce cortical reorganization in an adult patient.

Furthermore, connections between visual acuity, central retinal sensitivity, and fixation stability have been demonstrated.[19] A correlation between reading ability and fixation stability in patients with macular disease has also been found.[20]

Although there is no validated scientific theory about the real mechanism of action of biofeedback training, the results obtained in this study were highly encouraging, and significantly contribute to the clinical practice and research work in patients with myopic maculopathy. Regarding our data on AMD reported in 2007, our present group of myopic eyes shows an improvement in visual performances. In our opinion, this could be due to the fact that, as in previously published articles, the biofeedback rationale is to train the new preferential retinal location in several diseases characterized by central retinal damage with disruption of retinal architecture as in AMD or inherited retinal diseases, such as Stargardt disease or cone dystrophy, and consequent dysfunction.

We directed our attention to myopic cases in an attempt to improve fixation performances. Surprisingly, we also saw a very clear improvement in whole visual function described in this case series. In fact, in Figure 1, from a clinical point of view, optical coherence tomography scans demonstrated a very small area not interested by the geographic atrophy, so that this highly responsive point in our opinion was in the first examination masked by a lower fixation stability (15% before and 46% after the biofeedback), and this is clear at a careful examination of the images that show a very thin retinal strip inside the atrophy.

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