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RESCUE OF RETINAL FUNCTION BY MACULAR TRANSLOCATION SURGERY IN AGE-RELATED MACULAR DEGENERATION AND OTHER DISEASES WITH SUBFOVEAL CHOROIDAL NEOVASCULARIZATION

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ABSTRUCT

Age-related macular degeneration (AMD) is the leading cause of legal blindness among the elderly. In AMD and some other macular diseases, subfoveal choroidal neovascularization (CNV) damages the underlying retinal pigment epithelium (RPE), and because retinal function is dependent on a healthy RPE, vision is markedly reduced by a subfoveal CNV.

To treat such CNVs, macular translocation surgery has been performed to move the sensory retina from the damaged RPE to healthier RPE. At present, this surgery is the only possible treatment to improve the visual acuity of patients with subfoveal CNV.

Macular translocation surgery involves the detachment of the entire retina from the RPE by a subretinal infusion of fluid and creating a 360° circumferential retinotomy followed by the rotation of the retina. Severe postoperative complications such as recurrent retinal detachment have been reported in about 30% of the cases after macular translocation.

To determine the efficacy of this surgery, it is necessary to demonstrate an improvement in macular and overall retinal function objectively as well as subjectively. To this end, we have assessed the changes in visual function by measuring the visual acuity subjectively, and the macular function objectively by focal macular ERGs (FERGs). We shall show that there is an improvement in the FERGs in most patients after retinal translocation surgery but the full-field ERGs were reduced by about 30%. Thus, macular translocation surgery with 360-degree retinotomy may be feasible for macular function, although some degree of peripheral retinal function is lost.

Key words: Age-related macular degeneration, high myopia, choroidal neovascularization, macular translocation, vitrectomy

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INTRODUCTION

Age-related macular degeneration (AMD) is the leading cause of legal blindness among the elderly in industrialized countries. There are two types of AMD; the dry type and the exudative

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or wet type with subretinal choroidal neovascularization (CNV). In AMD, both eyes are usually affected and have poor visual acuity. Laser photocoagulation[1,2] and surgical removal of the subretinal CNV[3,4] have proved to be effective in reducing the severe loss of vision in patients with the exudative type of AMD. These treatments, unfortunately, damage the underlying retinal pigment epithelium (RPE) and choriocapillaris that can then lead to alterations of the retina and loss of reading ability following the atrophy of the RPE.

Selective photocoagulation of the CNV under the fovea by photodynamic therapy is one of the new promising methods, however, the effectiveness has been demonstrated only for a limited number of cases.[5,6]

Other major causes of subretinal CNV are high myopic chorioretinal degeneration,[7,8] idiopathic polypoidal choroidal vasculopathy[9] and angioid streaks. These diseases also resemble AMD if the CNV exists in the fovea.

Foveal or macular translocation surgery is an operation that moves the fovea from the diseased RPE to healthier RPE[10,11] and is currently the only possible treatment that offers improvements in visual acuity after the removal of subfoveal CNVs. Several small case series of macular translocation surgery have been published[12-24] with various modification of the surgical procedures first reported by Machemer in 1993.[25,26] Machemer's technique involved detachment of the entire retina from the RPE by means of subretinal infusion of fluids with a 360° circumferential retinotomy followed by the rotation of macula. During this meticulous manipulation, some retinal function may be lost although the central visual function may be saved.

To determine the efficacy of this surgical procedure and whether it should be used in selected patients, the improvement in macular and overall retinal function must be evaluated pre- and postoperatively. To date, only subjective assessments have been made with measurements of the visual acuity.

PATIENTS AND METHODS

Patients

Patients older than 60 years of age with AMD, with idiopathic polypoidal choroidal vasculopathy, and patients older than 50 years of age with high myopic chorioretinal degeneration and with new or recurrent choroidal neovascularizations (CNV) that involved the geometric center of the foveal avascular zone were enrolled for this surgery. Twenty patients have been operated on to date at the Nagoya University Hospital from March to November, 2000. The mean follow-up periods after translocation surgery ranged from 1 to 9 months.

This research was conducted in accordance with the institutional guidelines of Nagoya University and conformed to the tenets of the World Medical Association Declaration of Helsinki. An informed consent was obtained from each patient for the surgery and for the pre- and postoperative focal macular electroretinograms (FERGs) after providing information on other treatment options including photocoagulation, only removal, and observation alone.

Surgical Methods

Our technique was a modification of the 360° retinotomy method of Machemer,[25,26] with lensectomy and preservation of anterior lens capsule, complete removal of vitreous by pars plana vitrectomy, and the creation of four separate dome-shaped retinal detachment with subretinal infusion of balanced salt solution. Fluid-air exchange was performed that led to the coalescence of the detachments followed by 360° retinotomy at the ora serrata with an automated scissors. This was followed by the injection of heavy perfluorocarbon liquid, rotation of

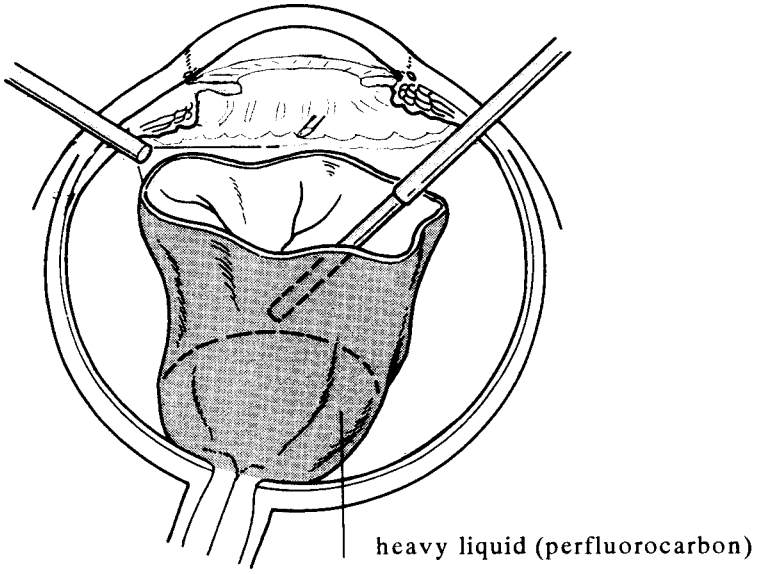

Figure 1. Macular translocation with 360° retinotomy. After the creation of retinal detachment and 360° retinotomy at the ora serrata, the whole retina was rotated around the axis of optic disc during the injection of heavy perfluorocarbon liquid.

the whole retina around the axis of optic disc with further injection of perfluorocarbon liquid during the rotation, endophotocoagulation and silicone oil injection (Figure 1). The operation time ranged 150 to 270 minutes.

After two to three months, the silicone oil was removed, and an intraocular lens was implanted in patients who requested the implantation.

Focal Macular ERGs

To evaluate macular retinal function, focal macular electroretinograms (FERGs) were elicited by a 15° stimulus under fundus monitoring with an infrared camera before, 1, and 3 months after silicon oil removal. This corresponded to 6 to 8 months after the translocation surgery in 8 patients who already had undergone silicone oil removal.

The technique of recording, analyzing, and interpreting the clinical significance the FERGs have been previously described in detail (Figure 2).[27-31] Briefly, an infrared television fundus camera installed with the stimulus light, background illumination, and fixation target, was mounted to be certain that the stimulus was centered on the macula. A Burian-Allen bipolar contact lens electrode, used for conventional electroretinographic recordings, was used. This allowed a low noise level and permitted a clear view of the fundus. After the patients' pupils were fully dilated with 0.5% tropicamide and 0.5% phenylephrine hydrochloride, FERGs were elicited by 5 Hz rectangular stimuli (100 msec on, 100 msec off). The center of the stimulus spot was on the fovea preopertively, and on the translocated fovea postoperatively. A total of 512 responses was averaged by a signal processor. A time constant 0.03 seconds with a 100-Hz high-cut filter on the amplifier was used to record a-wave, b- wave and oscillatory potentials. ERGs elicited by this stimulus have been shown to be generated by the cone system, and, for stimuli <15 degrees, are focal responses.

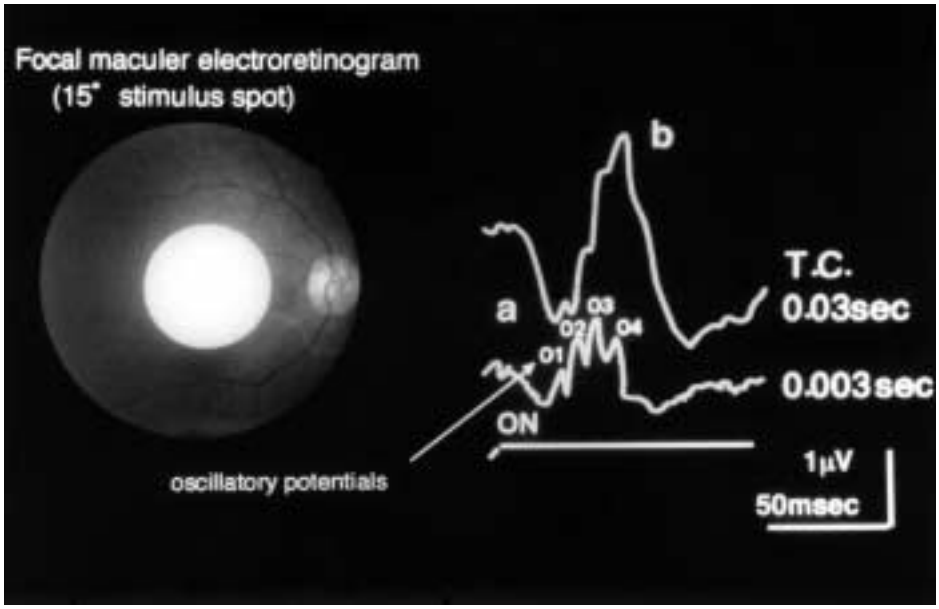

Figure 2. Focal macular electroretinograms were recorded from the geographical center of the macula before surgery. After surgery, the stimulus spot was set on the macula on new underlying RPE. Waveforms in the right were those in a normal subject.

Full-field ERGs

Because this surgery involves complex and meticulous surgical procedures, viz., creation of the retinal detachment, retinotomy at the ora serrata and the photocoagulation of the peripheral retina to reattach the retina, it was considered necessary to assess the retinal function over the entire field. To this end, conventional ganzfeld ERGs were recorded after pupil dilatation and 30 minutes of dark-adaptation in 10 consecutive patients. The rod (scotopic) ERG was recorded with a blue stimulus at an intensity of 5.2×10^{-3} cd/m^2. The rod-cone mixed single flash (bright white) ERG was recorded with a white stimulus at an intensity of 44.2 cd/m^2. The cone and the 30-Hz flicker ERG were recorded with a white stimulus intensity of 4 cd/m^2 and 0.9 cd/m^2, respectively in both light- and dark-adapted conditions.

RESULTS

Pre- and postoperative fundus photographs and optical coherence tomographic (OCT) images of the macula of a representative patient are shown in Figure 3. The subfoveal CNV was successfully removed with the rotation of the center of the fundus. The mean angles of rotation was 30.1° ± 2.7°.

Visual acuity

The preoperative best corrected visual acuity (BCVA) ranged from hand motion to 0.4, and the postoperative BCVA ranged from 0.08 to 0.4 in twelve eyes with AMD, 0.1 to 0.8 in 6 eyes with high myopic choroidal atrophy and 0.1 to 0.7 in 2 eyes with PCV (Figure 4).

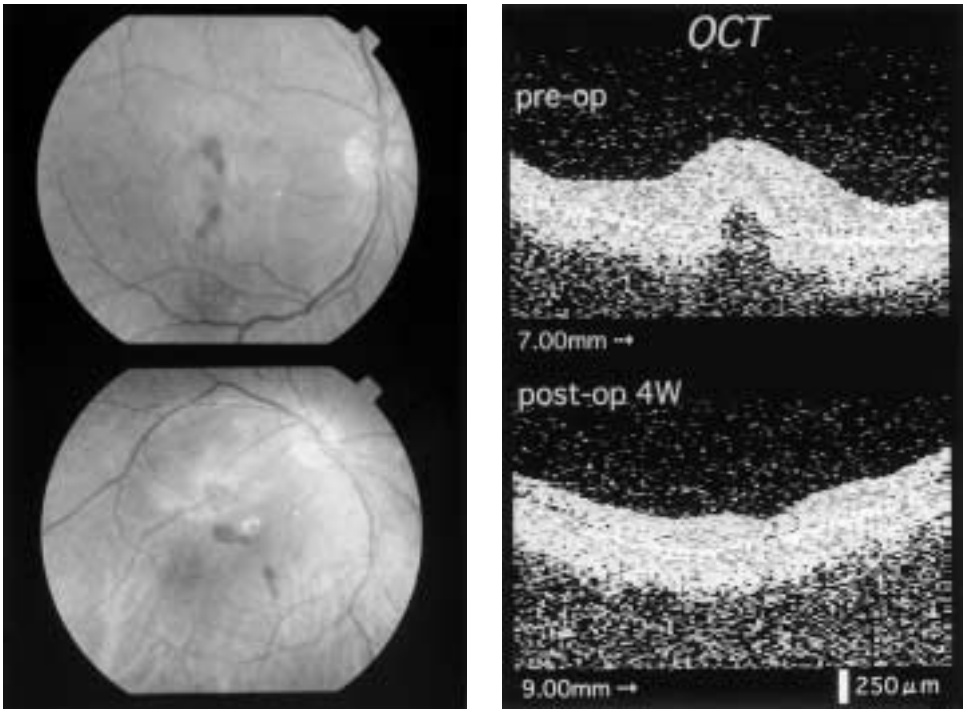

Figure 3. Fundus photograph and optical coherence tomographic (OCT) images of the macula from a representative patient with subretinal CNV which was successfully removed with the rotation of the center of the fundus. Best corrected visual acuity increased from 0.06 to 0.7.

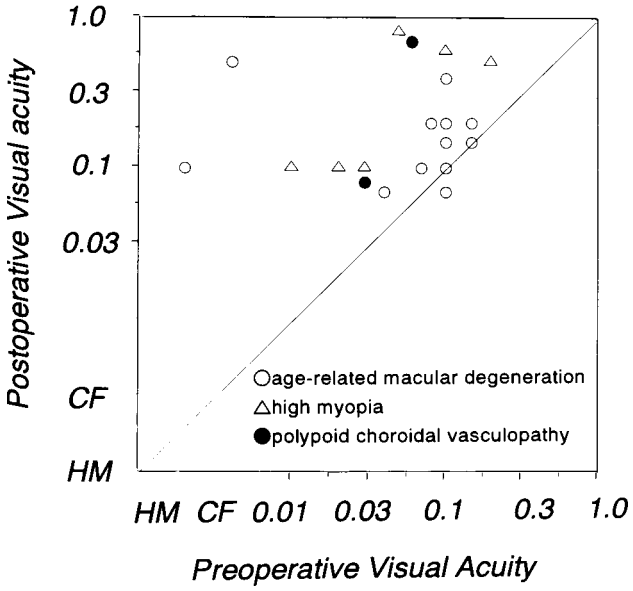

Figure 4. Pre- and post-operative BCVA. (Best corrected visual acuity)

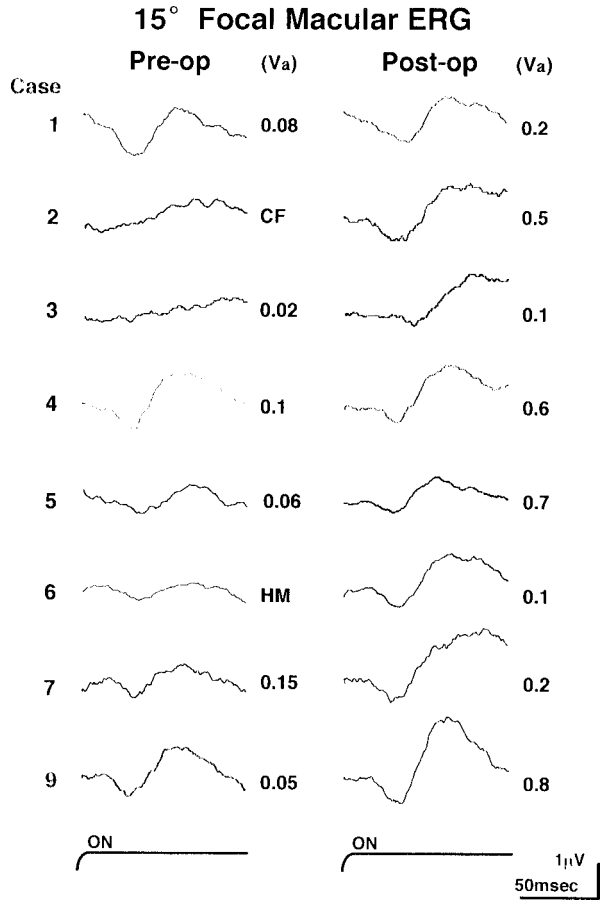

Figure 5. Increase in amplitude of a- and b- wave of focal macular ERG was demonstrated in 5 of 8 patients.

Macular retinal function

The pre-and postoperative amplitudes and implicit times of the a-, and b-waves were compared for each eye. Before the operation, the amplitude of the a- and b-waves and the oscillatory potentials (OPs) were markedly reduced compared with that of normal eyes. The implicit times were delayed for the two components of the FERGs postoperatively. The summed OP amplitudes before and after surgery were too small to evaluate.

After surgery, there was a relative increase in the amplitude of both the a- and b-waves in 5 of 8 patients (Figure 5).

Full-field Retinal ERGs

Full-field ERGs in a representative case and those in a normal subject were shown in Figure 6. The mean amplitude of the full-field ERGs was reduced after surgery by 37.2% for the rod response, by 22.2% for the mixed rod-cone response b-wave, by 33.6% for the single flash cone b-wave and by 50.1% for the 30 Hz flicker response in the light adapted state. The mean amplitude was reduced by 11.8% in single flash cone ERG b-wave, and by 33.6 % in 30 Hz

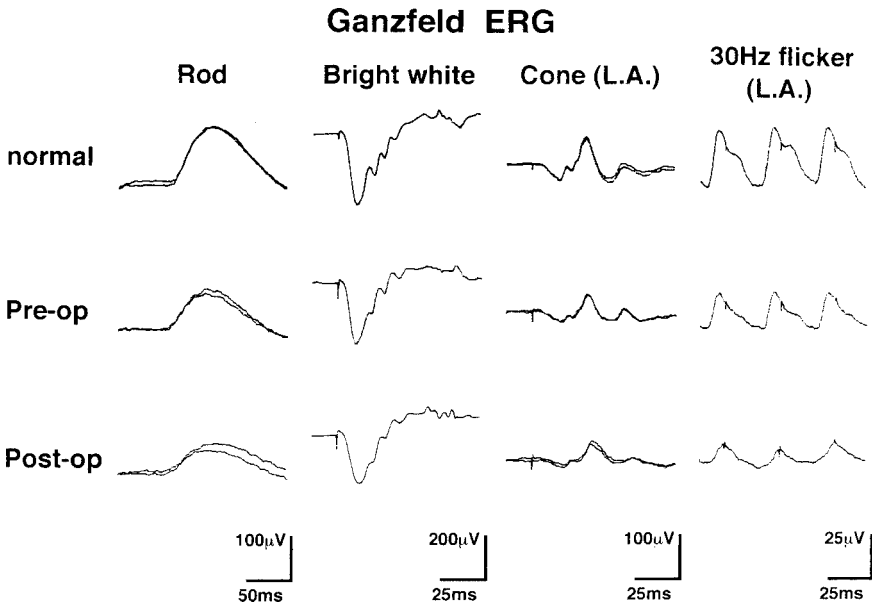

Figure 6. Full-field ERGs in a representative patient before and after macular translocation surgery and those in a normal subject. After surgery, the amplitude of the full-field ERGs was reduced by 38.1% for the rod response, by 10.8% for the mixed rod-cone response b-wave, and by 50.0% for the 30 Hz flicker response in the light adapted state. The amplitude of cone response in the light adapted state was unchanged. Implicit times in all components were delayed.

flicker response in the dark-adapted states. The implicit times was delayed for all components of the full-field ERGs postoperatively.

COMMENTS

Our results demonstrated that retinal translocation surgery preserved or improved visual acuity in 17 of 20 eyes (85%). Macular retinal function was improved in 5 of 8 eyes as shown by the FERGs elicited by a 15 degree stimulus spot which covered almost the entire macular area. The full-field retinal function, however, was reduced by 12-50% for both rod and cone functions after surgery.

Histopathologically, Machemer and Steinhorst demonstrated with scanning and transmission electron microscopic studies the remarkable intactness of the outer segments of rod and pigment epithelium after the creation of an acute retinal detachment.[25] They stated that the ultrastructural changes were different from those following a slower course of experimental detachment. Our finding of reduced peripheral retinal function may be caused partly by the loss of peripheral retina by the retinotomy and the 5 rows of endophotocoagulation to fix the peripheral retina. However, the function of the more posterior retina may be relatively well preserved in the majority of patients.

Imai et al[32] reported on the histological and electrophysiological results on rabbit eyes after limited retinal translocation. Their study demonstrated mild morphological damage to the outer retinal layers and normal morphology of the inner layers, although the results on the rabbit eye

might be exaggerated because of the avascular retina. They reported that there was some decrease in the vertical alignment of the photoreceptors, as well as some loss of their outer segment disks. The dark-adapted ERG responses suggested a transient reduction in retinal function. Their data showed a 70% reduction in the b-wave on the third postoperative day that improved to a 30% reduction on 14 postoperative day. In the vascularized retina of primates, on the other hand, there is good recovery after retinal detachment.[28] In this study, the light-adapted cone b-wave was reduced by about 30%, while the dark-adapted cone b-wave was reduced by 12% after translocation surgery. In the light-adapted state, the full-field cone ERG represents only cone function, while in the dark-adapted state, the cone function is believed to be suppressed by rod as by cone-rod interaction.[33] The difference in the reduction ratio between the light-adapted and dark-adapted states may result from a decreased suppression from the reduced rod function. The condition that both rod and cone were reduced diffusely after surgery may be the incidental clinical model that support the hypothesis of cone-rod interaction in the dark- and light-adapted states. Severe postoperative complications such as recurrent retinal detachment have been reported in about 30% of the cases after macular translocation although none of our patients had any complications. If the fetal complication is avoidable technically, macular translocation with a 360° retinotomy may be feasible from the aspect of macular retinal function, although a certain degree of peripheral retinal function will be lost.

REFERENCES

1) Macular Photocoagulation Study Group. Laser photocoagulation of subfoveal neovascular lesions in age-related macular degeneration. Results of a randomized clinical trial. Arch. Ophthalmol., 109, 1220–1231 (1991).
2) Laser photocoagulation of subfoveal neovascular lesions of age-related macular degeneration. Updated findings from two clinical trials. Macular Photocoagulation Study Group. Arch. Ophthalmol., 111, 1200–1209 (1993).
3) Thomas MA, Grand MG, Williams DF, Lee CM, Pesin SR, Lowe MA. Surgical management of subfoveal choroidal neovascularization. Ophthalmology, 99, 952–968; discussion 975–976 (1992)
4) Merrill PT, LoRusso FJ, Lomeo MD, Saxe SJ, Khan MM, Lambert HM. Surgical removal of subfoveal choroidal neovascularization in age-related macular degeneration. Ophthalmology, 106, 782–789 (1999)
5) Horle S, Postgens H, Schmidt J, Kroll P. Pigment epithelium defects after submacular surgery for choroidal neovascularization: first results.Ophthalmologica, 214, 122–125, (2000)
6) Treatment of age-related macular degeneration with photodynamic therapy (TAP) Study Group. Photodynamic therapy of subfoveal choroidal neovascularization in age-related macular degeneration with verteporfin: one-year results of 2 randomized clinical trials—TAP report. Arch. Ophthalmol., 117, 1329–1345 (1999)
7) Uemura A, Thomas MA. Subretinal surgery for choroidal neovascularization in patients with high myopia. Arch. Ophthalmol., 118, 344–50 (2000)
8) Tabandeh H, Flynn HW Jr, Scott IU, Lewis ML, Rosenfeld PJ, Rodriguez F, Rodriguez A, Singerman LJ, Schiffman J. Visual acuity outcomes of patients 50 years of age and older with high myopia and untreated choroidal neovascularization. Ophthalmology, 106, 2063–7 (1999)
9) Yannuzzi LA, Ciardella A, Spaide RF, Rabb M, Freund KB, Orlock DA. The expanding clinical spectrum of idiopathic polypoidal choroidal vasculopathy. Arch. Ophthalmol., 115, 478–485 (1997)
10) American Academy of Ophthalmology. Macular translocation. Ophthalmology, 107, 1015–1018 (2000)
11) Cekic O, Ohji M, Hayashi A, Fujikado T, Tano Y. Foveal translocation surgery in age-related macular degeneration. Lancet, 354, 340 (1999)
12) Fujii GY, Pieramici DJ, Humayun MS, Schachat AP, Reynolds SM, Melia M, De Juan E. Complications associated with limited macular translocation. Am. J. Ophthalmol., 130, 751–762 (2000)
13) Pieramici DJ, De Juan E, Fujii GY, Reynolds SM, Melia M, Humayun MS, Schachat AP, Hartranft CD. Limited inferior macular translocation for the treatment of subfoveal choroidal neovascularization secondary to age-related macular degeneration. Am. J. Ophthalmol., 130, 419–428 (2000)
14) Lin SB, Glaser BM, Gould D, Baudo TA, Lakhanpal RR, Murphy RP. Scleral outfolding for macular translocation. Am. J. Ophthalmol., 130, 76–81 (2000)

15) Wong D, Harding S, Grierson I. Foveal translocation with secondary confluent laser for subfoveal CNV in AMD: 12 month follow up. Br. J. Ophthalmol., 84, 670–671 (2000)
16) Potter MJ, Chang TS, Lee AS, Rai S. Improvement in macular function after retinal translocation surgery in a patient with age-related macular degeneration. Am. J. Ophthalmol., 129, 547–549 (2000)
17) McLeod D. Foveal translocation for exudative age related macular degeneration. Br. J. Ophthalmol., 84, 344–345 (2000)
18) Akduman L, Karavellas MP, MacDonald JC, Olk RJ, Freeman WR. Macular translocation with retinotomy and retinal rotation for exudative age-related macular degeneration. Retina, 19, 418–423 (1999)
19) de Juan E Jr, Vander JF. Effective macular translocation without scleral imbrication. Am. J. Ophthalmol., 128, 380–382 (1999)
20) Lewis H, Kaiser PK, Lewis S, Estafanous M. Macular translocation for subfoveal choroidal neovascularization in age-related macular degeneration: a prospective study. Am. J. Ophthalmol., 128, 135–146 (1999)
21) Eckardt C, Eckardt U, Conrad HG. Macular rotation with and without counter-rotation of the globe in patients with age-related macular degeneration. Graefes. Arch. Clin. Exp. Ophthalmol., 237, 313–325 (1999)
22) Wolf S, Lappas A, Weinberger AW, Kirchhof B. Macular translocation for surgical management of subfoveal choroidal neovascularizations in patients with AMD: first results. Graefes. Arch. Clin. Exp. Ophthalmol., 237, 51–57 (1999)
23) Fujikado T, Ohji M, Hayashi A, Kusaka S, Tano Y. Anatomic and functional recovery of the fovea after foveal translocation surgery without large retinotomy and simultaneous excision of a neovascular membrane. Am. J. Ophthalmol., 126, 839–842 (1998)
24) Ninomiya Y, Lewis JM, Hasegawa T, Tano Y. Retinotomy and foveal translocation for surgical management of subfoveal choroidal neovascular membranes. Am. J. Ophthalmol., 122, 613–621 (1996)
25) Machemer R, Steinhorst UH. Retinal separation, retinotomy, and macular relocation: II. A surgical approach for age-related macular degeneration? Graefes. Arch. Clin. Exp. Ophthalmol., 231, 635–641 (1993)
26) Machemer R, Steinhorst UH. Retinal separation, retinotomy, and macular relocation: I. Experimental studies in the rabbit eye. Graefes Arch. Clin. Exp. Ophthalmol., 231, 629–34 (1993)
27) Miyake Y. Studies of local macular ERG. Acta. Soc. Ophthalmol. Jpn., 92, 1418–1449 (1988)
28) Miyake Y, Shiroyama N, Ota I, Horiguchi M. Oscillatory potentials in electroretinograms of the human macular region. Invest. Ophthalmol. Vis. Sci.,29, 1631–1635 (1988)
29) Terasaki H, Miyake Y, Kondo M, Tanikawa A. Focal macular electroretinogram before and after drainage of macular subretinal hemorrhage. Am. J. Ophthalmol., 123, 207–211 (1997)
30) Terasaki H, Miyake Y, Tanikawa A, et al. Focal macular electroretinograms before and after successful macular hole surgery. Am. J. Ophthalmol., 125, 204–213 (1998)
31) Terasaki H, Miyake Y, Nomura R, Piao CH, Hori K, NiwaT, Kondo M. Focal macular electroretinograms in eyes following removal of macular internal limiting membrane during macular hole surgery. Invest. Ophthalmol. Vis. Sci., 42, 229–234 (2001)
32) Imai K. Loewenstein A. de Juan E Jr. Translocation of the retina for management of subfoveal choroidal neovascularization I: experimental studies in the rabbit eye [see comments]. Am. J. Ophthalmology., 125, 627–634 (1998)
33) Jacobi PC, Miliczek KD, Zrenner E. Experiences with the international standard for clinical electroretinography: normative values for clinical practice, interindividual and intraindividual variations and possible extensions. Doc. Ophthalmol. 85, 95–114 (1993)