

Electroretinogram changes after scleral buckling surgery of retinal detachment

Yuanyuan Gong · Xingwei Wu ·
Xiaodong Sun · Xi Zhang · Ping Zhu

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Abstract *Objective* To observe changes in visual function after a single scleral buckling surgery for rhegmatogenous retinal detachment (RD) by using ERG (electroretinogram). *Methods* One eye from 56 patients with rhegmatogenous RD was chosen. Forty-three corresponding normal fellow eyes from these patients were chosen as controls. Single scleral buckling surgery was carried out and a full-field ERG was performed before the surgery, and 1 and 6 months after surgery. *Results* The mean amplitude of ERG decreased and the latency (except for the *a*-wave) was delayed in the eye with a retinal detachment, and wavelets of the oscillatory potential decreased or were completely lacking. One month after surgery, the amplitudes of the *a* and *b* waves were noticeably improved (except for the 30 Hz flicker responses), but the latency (except for the *a*-wave) was still delayed. The ratio of *b/a* (mixed response) increased 1 month after surgery, with no further changes thereafter. The amplitude of the scotopic *b* wave was 58.1% of the control eyes, while the 30 Hz flicker responses was only 45.8% of controls; the difference between the two responses was significant ($P < 0.001$). The number of oscillatory potential wavelets increased, but the total

amplitude of the oscillatory potentials did not exhibit any obvious changes during the follow-up period ($P = 0.20$). In the 41 patients whose detachment involved the macula preoperatively, the amplitude of the 30 Hz flicker responses improved significantly after surgery ($P = 0.037$). Six months after the operation, the wave amplitudes were not significantly different from 1 month after surgery, but there was a tendency toward a decrease in the latency. *Conclusions* After reattachment of the retina, visual function showed dramatic improvement 1 month after the surgery. The postreceptoral responses recovered more than the *a*-wave. The rod system recovered more quickly and completely than the cone system during the follow-up period. The incomplete recovery observed by using ERGs indicates that there is irreversible damage that likely occurs following retinal detachment and surgery.

Keywords Rhegmatogenous retinal detachment · Electroretinogram · Visual function · Scleral buckling

Introduction

Retinal detachment (RD) is the separation of retinal pigment epithelium and neural epithelium, and is a serious eye disease that can induce blindness. Rhegmatogenous detachment is the most common form of

Y. Gong · X. Wu (✉) · X. Sun · X. Zhang · P. Zhu
Department of Ophthalmology, The First People's
Hospital Affiliated Shanghai Jiaotong University,
Wujin Road No. 85#, Shanghai 200080, China
e-mail: xingweiwu@yahoo.com

RD observed in the clinic, and is treated by reattachment via simple sclera buckling surgery [1, 2]. However, recovery of visual function does not always correlate with anatomical reattachment [1, 3–7]. Even after successful retinal reattachment surgery, defects in visual function usually occur in the affected eye to some extent [3, 4, 7, 8], and it has been suggested that a defective blood supply in the retina following surgery may underlie these problems [9, 10]. However, detailed information about these effects is lacking according to the ISCEV standards of electroretinogram (ERG) for assessing retinal functional changes following reattachment. Moreover, because of the complexity and diversity of RD and different recording parameters, conclusions about postoperative retinal function recovery are not very consistent [3–6, 11–14].

ERG is a useful tool to objectively assess retinal function in the clinic, and can be used to analyze visual function in different layers of the retina. Among the different variables that can be observed using ERG are oscillatory potentials (OPs), which can sensitively reflect the state of microcirculation in the retina [15, 16]. The present study examined changes in ERG after retinal reattachment to assess visual function. In order to provide a more objective evaluation of single successful scleral buckling surgery and reduce clinical heterogeneity and confounding factors, we selected a large number of patients with similar conditions, and performed the same type of reattachment surgery. Our study may provide useful information that can improve patient care in the clinic.

Materials and methods

Patient information

Fifty-six patients (mean age: 43 years, range: 18–68 years; 26 male and 30 female) with primary RD were selected for the study from hospitalized patients (at the First People's Hospital, affiliated Shanghai Jiaotong University in China). Among these patients, there were no other obvious ophthalmopathies or systemic diseases (such as diabetes or hypertension), except for refractive errors. Thirty-one left eyes and 25 right eyes were included in this study. The period between RD and surgery ranged from 3 to 20 days

(macula detached, $n = 41$; macula attached, $n = 15$). The extent of the detachment ranged between 2 and 6 clock hours in 40 eyes, and more than 6 clock hours in 16 eyes. The best-corrected visual acuity was between 0.01 and 0.6. The diopter correction was between -1.0 D to -8.0 D. Sixteen eyes (28.6%) had high myopia (-6.0 D to -8.0 D), 24 eyes (42.9%) had medium myopia (-3.0 to -6.0 D) and 16 eyes (28.6%) had low myopia (<-3.0 D). Patients with macular holes, chorioretinal degeneration, media opacity, and proliferative vitreoretinopathy grade C or D were excluded. In addition, patients who had undergone more than one surgery on the eye, or who had not received follow-up examinations for more than 6 months were excluded. During the follow-up period, eyes with serious cataracts, re-detachment, macular edema or surface membrane were also excluded. Forty-three normal fellow eyes from these patients (20 males and 23 females) were chosen as controls, and the best-corrected visual acuity was not less than 1.0. The average age of the control patients was 45 years, and none of the controls had any history of eye surgery or ophthalmopathy.

All patients underwent the same basic procedure, including routine cryoretinopexy, the encircling procedure, and silicone scleral buckling. Silicone explants were used to cover the retinal tear(s). Where appropriate (31 eyes), subretinal fluid was drained through a scleral incision during surgery. Neither air nor any another gas was used in any of the patients during the surgery. All patients signed informed consent forms, and all aspects of the study were in compliance with the Helsinki Declaration. The study protocol was approved by our local Institutional Review Board/ethics committee.

Examination by ERG

ERG was performed within 2 days before the surgery, then again 1 and 6 months following the operation. An UTAS-E 2000 electrophysiology testing instrument (LKC, Technographics, USA) was used. Before ERG recording, the pupils were dilated with 1% tropicamide and 10% phenylephrine to obtain the maximum dilatation and then the eyes were adapted to darkness for 30 min. Under superficial anesthesia with 0.5% decicaine, the ERG JET contact lens electrode was used as the recording electrode and

0.5% methyl cellulose was deposited into its concavity, then the reference silver–silver chloride electrode was placed in the center of the forehead, and the grounding electrode was attached to the ear lobe under a dim red light. Five responses were recorded in turn following ISCEV standards [17]: the rod-driven *b* wave of dark adapted eye (rod-*b*), the maximal *a* and *b* waves (max-*a*, max-*b*), the total amplitude of oscillatory potential (OPs), the cone-driven *b* wave (cone-*b*) and 30 Hz flicker response (flicker) were all recorded and analyzed. Responses were obtained with a band filter (0.3 and 500 Hz), stimulating with a single blue full-field flash (Wratten filter Blue #47B) and white full field flash (2.13 cd s/m²). OPs were extracted between 75 ~ 500 Hz and averaged four times (interval 15 s). Cone-driven responses were obtained after 10 min of light adaptation to background illumination (25.3 cd/m²) on the Ganzfeld screen, and 30 Hz flicker responses with the background light on, averaged over 20 sweeps.

Data and statistical analysis

SAS statistical software was used to perform statistical analysis, and repeated measures ANOVA, Student's *t*-test, and the Wilcoxon tests were applied for analyses of differences among various groups.

Results

Comparison with control group before surgery

As illustrated in Table 1, the ERG amplitude of eyes with retinal detachment was significantly decreased or completely lacking, and the latency (except for the *a* wave) was delayed compared to the control eyes.

ERG amplitude increases following surgery

All of the retinas in the affected eyes were successfully reattached, and the intraocular pressure was normal during the follow-up period. The amplitudes of the *a* and *b* waves were dramatically improved 1 month after the operation, although there were no significant differences in the amplitudes of the oscillatory potentials (Table 2). The amplitude of

Table 1 Comparison of ERG amplitudes and latencies from retinal detachment eyes and controls prior to surgery (mean ± SD) (*t*-test)

		Control group	Before surgery	<i>P</i> -value
Amplitude (μV)	Rod- <i>b</i>	267.7 ± 66.1	109.7 ± 71.7	<0.001
	Max- <i>a</i>	175.1 ± 40.4	66.8 ± 42.3	<0.001
	Max- <i>b</i>	366.6 ± 71.7	140.3 ± 86.4	<0.001
	<i>b/a</i>	2.2 ± 0.6	2.1 ± 1.1	0.66
	OPs	203.1 ± 53.1	78.0 ± 37.0	<0.001
	Cone- <i>b</i>	41.5 ± 16.6	17.5 ± 11.3	<0.001
Latency (ms)	Flicker	31.7 ± 10.6	12.3 ± 6.5	<0.001
	Rod- <i>b</i>	57.7 ± 5.0	60.6 ± 6.5	0.02
	Max- <i>a</i>	22.2 ± 1.3	22.8 ± 3.1	0.21
	Max- <i>b</i>	42.7 ± 2.5	44.3 ± 4.3	0.03
	Cone- <i>b</i>	26.9 ± 1.3	28.5 ± 2.5	<0.001
	Flicker	27.6 ± 1.3	30.5 ± 2.7	<0.001

the 30 Hz flicker responses did not improve significantly ($P = 0.20$), but the improvement was significant in patients who had a preoperatively detached fovea ($P = 0.037$, $n = 41$). The results of statistical analyses of the latencies of various ERG waves before and after surgery are shown in Table 3. The representative wave changes of one patient after surgery are shown in Fig. 1.

Changes in the *b/a* ratio after surgery

As shown in Table 1 and 2, the *b/a* ratios 1 month after surgery (the ratio of *a* and *b* amplitudes of maximal response) were significantly improved compared to the ratios obtained before surgery ($P < 0.01$). However, there were no further improvements observed 6 months after surgery.

Changes in the wavelets of oscillatory potentials

The changes in wavelets of OPs following surgery were examined using the Wilcoxon test. The average number of wavelets before reattachment surgery was 2.06, compared to 3.44 one month after the operation. This difference indicates that the surgery made a significant difference in oscillatory potentials ($P < 0.01$). There was also a tendency toward an

Table 2 Statistical analysis of amplitudes (μV) of ERG before and after the surgery (repeated measures ANOVA)

Compared to before surgery, ** $P < 0.01$, * $P < 0.05$; No significant differences were noted between 1 and 6 months after surgery

	Before surgery	1 month after surgery	6 months after surgery	<i>P</i> -value
Rod- <i>b</i>	109.7 \pm 71.7	155.6 \pm 51.2**	152.4 \pm 43.7**	<0.001
Max- <i>a</i>	66.8 \pm 42.3	82.6 \pm 36.0**	76.8 \pm 30.7*	0.02
Max- <i>b</i>	140.3 \pm 86.4	208.3 \pm 58.1**	208.9 \pm 59.3**	<0.001
<i>b/a</i>	2.1 \pm 1.1	2.8 \pm 1.0**	3.1 \pm 1.4**	<0.001
OPs	78.0 \pm 37.0	79.7 \pm 33.0	85.3 \pm 36.0	0.20
Cone- <i>b</i>	17.5 \pm 11.3	27.7 \pm 9.1**	26.5 \pm 8.4**	<0.001
Flicker	12.3 \pm 6.5	14.5 \pm 5.3	14.0 \pm 5.9	0.20

Table 3 Statistical analysis of latencies (ms) of ERG waves before and after surgery (repeated measures ANOVA)

	Before surgery	1 month after surgery	6 months after surgery	<i>P</i> value
Rod- <i>b</i>	60.6 \pm 6.5	67.0 \pm 8.3**	65.6 \pm 8.5**	<0.001
Max- <i>a</i>	22.8 \pm 3.1	23.8 \pm 2.4	23.4 \pm 2.4	0.11
Max- <i>b</i>	44.3 \pm 4.3	48.4 \pm 3.8**	46.8 \pm 4.4**##	<0.001
Cone- <i>b</i>	28.5 \pm 2.5	30.7 \pm 2.7**	29.9 \pm 2.9**#	<0.001
Flicker	30.5 \pm 2.7	33.1 \pm 2.9**	32.7 \pm 2.5**	<0.001

Compared to before surgery, ** $P < 0.01$, * $P < 0.05$;
Compared to 1 month after surgery, ## $P < 0.01$, # $P < 0.05$

increase in amplitude, but this was not statistically significant ($P > 0.05$).

Rod and cone system responses

The percentages of the response amplitudes of rod-*b* and 30 Hz flicker responses in RD eyes compared to control eyes are shown in Fig. 2. The difference between rod-*b* and flicker were significant in each time point. ($P < 0.001$, *t*-test).

Discussion

Although retinal detachment can be successfully treated by scleral buckling surgery, there is usually visual damage following anatomic reattachment, even when a long period of time has elapsed post-surgery [2, 18]. The results of our study indicate that, despite a partial recovery of the amplitude of ERG waves after retinal reattachment, they are still lower than those recorded from control eyes. Moreover, the *b* wave latencies are postponed, and there are differences in the recovery of the *a* and *b*

waves, indicating that there are differences in the functional recoveries of different cells and regions of the retina.

Full-field ERG amplitudes were decreased in the detached retina, with improvement after reattachment [12–14]. Improvements in photoreceptors can be observed by electron microscopy 24 h after retinal reattachment, and only 1 month after reattachment, the ultra-structure of photoreceptors recovers completely [11, 19, 20]. Moreover, most of the outer segments recover their normal appearance within 2 weeks. However, there are often still defects in outer segments, especially the outer segments of cone cells. Our present study indicates that, 1 month after surgery, the waves of ERG tend to rise, although there is no obvious improvement during the next 6 months recovery time, which is consistent with observations in animals [21].

Recovery of the potential amplitude (rod-*b*) demonstrated a higher level than that of the 30 Hz flicker response (flicker) at each time point. These differences were significant. This indicates that the rod system is repaired more completely, suggesting that certain functional disorders may exist more in the cone system [8, 22]. In support of this, Schatz et al. reported that in a group of patients with preoperative detachment of the fovea ($n = 8$), rod system function was significantly improved at follow-up, while the single flash white light response and cone amplitudes with 30 Hz flicker did not improve to the same extent [14]. However, the lack of significant improvement in the two responses may be due to the small sample size. In our study, there was a significant improvement in the amplitude with 30 Hz flicker response in patients with preoperative macular involvement ($n = 41$). On the other hand, patients in this group had a greater extent of preoperative detachment, and the detachment involved the periphery in most RD

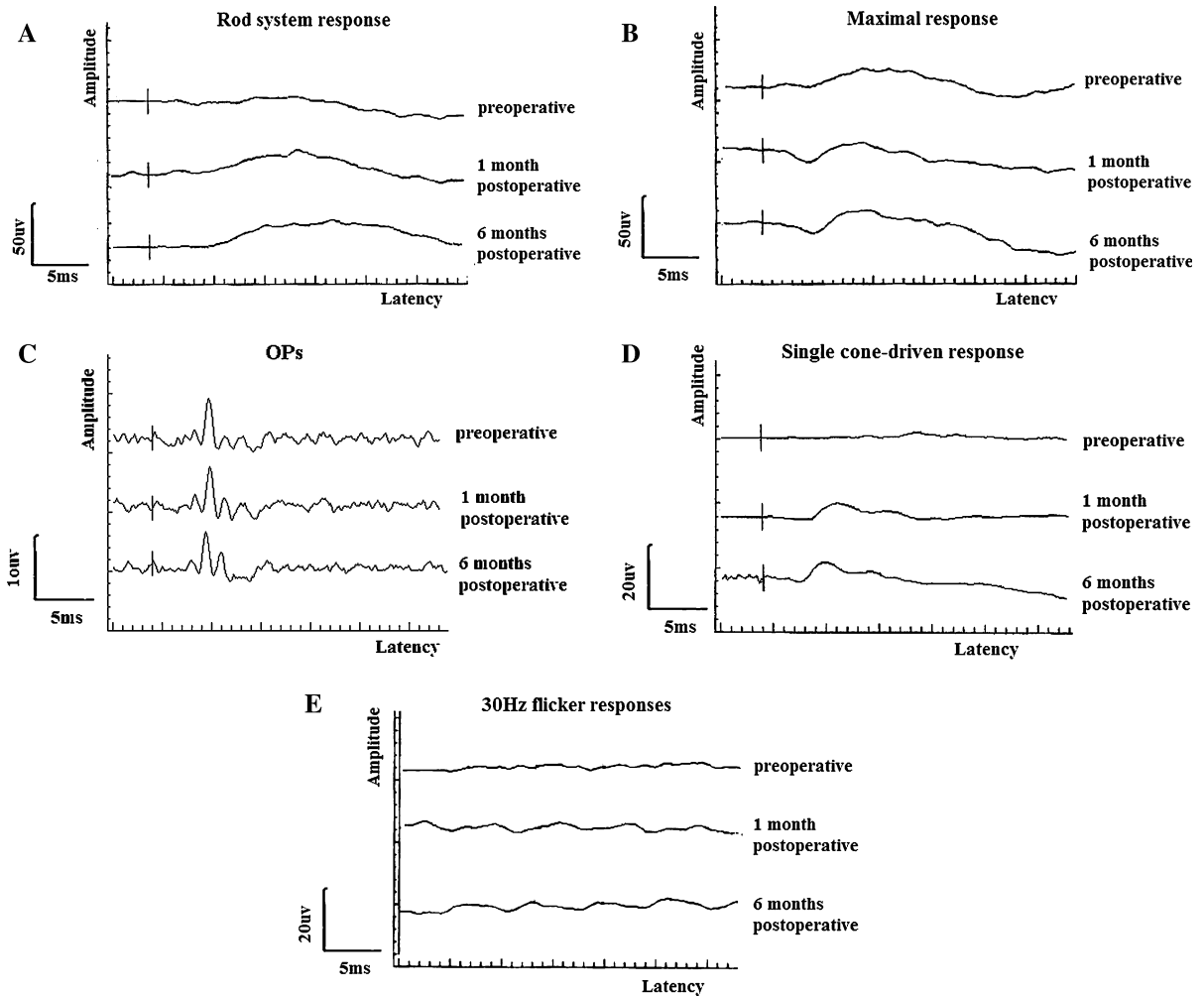


Fig. 1 Representative changes in ERGs after reattachment of the retina (a male patient aged 38 with myopia -5.0 D; the extent of RD was 6 clock hours with macular involvement; the period of RD before surgery was 10 days). (a) Rod system

response; (b) maximal response; (c) oscillatory potentials (OPs); (d) single cone-driven response; (e) 30 Hz flicker responses

eyes, which may explain the better improvement in rod system function.

Cone system dysfunction may still be detected even long intervals after retinal reattachment, independent of the presence of a preoperative macular RD [23]. It also has been shown that there is a significant correlation between outer nuclear layer (ONL) cell count and flicker ERG amplitude in the reattached retina [24]. Thus, flicker ERG may be a better method to assess retinal function following RD surgery. In our study, the improvement of single cone-driven response was greater than that of 30 Hz flicker responses, which had not been discussed earlier. The photopic white stimulus is designed to suppress rod

system participation, and the 30 Hz flicker stimulus is too fast for the rods to follow; therefore, the flicker response consists of an isolated cone system response. The single cone-driven response may mix rod system response to some degree. Moreover, there may also be some unknown mechanism(s) that influence cone system responses after retinal reattachment, especially in that of 30 Hz flicker responses after light adaptation [25].

Because the *b/a* wave amplitude ratio is believed to correlate with the total number of functioning retinal elements, it is useful in evaluating retinal function [26]. The value of the *b/a* ratio tends to increase with time following surgery. This indicates

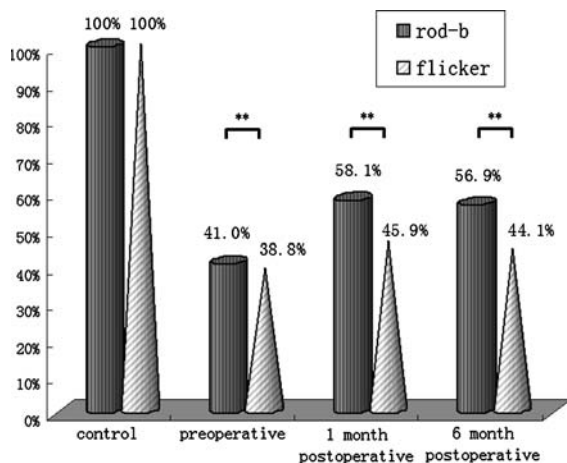


Fig. 2 Percentages of amplitudes of rod system response and 30 Hz flicker responses compared to the control values before and after surgery (%) (** $P < 0.001$)

that after surgery the recovery of the *b* wave is greater than that of the *a* wave, which is consistent with animal experiments carried out by Kamei et al. [27]. The increase in the amplitude following reattachment suggests that the functions of the inner layer are improved, which reflects the degree of repair and reconstruction of internal structures.

OPs are a group of rhythmic small waves added on the rising phase of the *b* wave. Various wavelets may originate from different levels of the retina, and they are closely related to the microcirculation in the inner retina [15, 16]. Previous studies [9, 10] indicated that several parameters, such as blood flow rate and priming volume of the chorioid and retina, and the vascular diameter, decrease after scleral buckling surgery. It was believed that these effects were responsible for the long-term defects in visual function even after successful retinal reattachment. Schepens [28] proposed that the intra-ocular pressure during or after surgery influences retinal reattachment and the recovery of visual function after scleral buckling. In our study, the observed ocular pressure was within the normal range, and no ischemic symptoms or signs were found. However, the changes in OPs after surgery suggest that the microcirculation does not recover to the same extent in the various levels of the inner layer. A previous study [13] showed that OPs including the amplitude of O1 and the sum amplitude had a significant postoperative improvement. One reason for these improvements was that more than half

of these patients received the segmental scleral buckle procedure. A better improvement of the *a*-wave and *b*-wave were also observed in this group of patients. It is possible that in our study, the persistent reduction of OPs may be due to the encircling band, which was placed in all of our patients. Although the encircling circumferential buckle procedure can relieve the traction between the vitreous and the retina in the periphery and simplify the operation, it may be a factor that influences the postoperative recovery of retinal function.

Cryoretinopexy in the operation also produces a certain amount of damage to the retina. It has been indicated that the retina becomes thin in the operated region, and as the internal limiting membrane is lost, pigments accumulate under the retina. This leads to atrophy of the pigment epithelium, thinning of the chorioid, and a decrease in vessel number [29]. These changes are often still present even a year after cryoretinopexy. In addition, the adherence between the pigment epithelium and the sensory layer is different from normal adherence, and changes can be observed in the retina after electric or laser coagulation [30]. These changes may be important factors that influence the recovery of visual function after surgery.

In summary, our results indicate that after retinal reattachment surgery, visual function underwent an incomplete recovery during follow-up period. This indicates that there may be irreversible damage that occurs following retinal detachment and surgery. These results provide a basis for future, larger scale clinical studies.

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References

1. Kreissig I (1977) Prognosis of return of macular function after retinal reattachment. *Mod Probl Ophthalmol* 18: 415–429
2. Tani P, Robertson DM, Langworthy A (1981) Prognosis for central vision and anatomic reattachment in rhegmatogenous retinal detachment with macula detached. *Am J Ophthalmol* 92:611–620
3. Chisholm IA, McClure E, Foulds WS (1975) Functional recovery of the retina after retinal detachment. *Trans Ophthalmol Soc UK* 95:167–172

4. Foulds WS, Reid H, Chisholm IA (1974) Factors influencing visual recovery after retinal detachment surgery. *Mod Probl Ophthalmol* 12:49–57
5. Friberg TR, Eller AW (1992) Prediction of visual recovery after scleral buckling of macula off retinal detachments. *Am J Ophthalmol* 114:715–722
6. Gundry MF, Davies EWG (1974) Recovery of visual acuity after retinal detachment surgery. *Am J Ophthalmol* 77:310–314
7. Ueda M, Adachi-Usami E (1992) Assessment of central visual function after successful retinal detachment surgery by pattern visual evoked cortical potentials. *Br J Ophthalmol* 76:482–485
8. Yamamoto S, Hayashi M, Takeuchi S (1998) Cone electroretinograms in response to color stimuli after successful retinal detachment surgery. *Jpn J Ophthalmol* 42:314–317
9. Ogasawara H, Fake GT, Yoshida A, Milbocker MT, Weiter JJ, McMeel JW (1992) Retinal blood flow alterations associated with scleral buckling and encircling procedures. *Br J Ophthalmol* 76:275–279
10. Regillo CD, Sergett RC, Brown GC (1993) Successful scleral buckling procedures decrease central retinal artery blood flow velocity. *Ophthalmology* 100:1044–1049
11. Guerin CJ, Lewis GP, Fisher SK, Anderson DH (1993) Recovery of photoreceptor outer segment length and analysis of membrane assembly rates in regenerating primate photoreceptor outer segments. *Invest Ophthalmol Vis Sci* 34:175–183
12. Karpe G, Rendahl I (1969) Clinical electroretinography in detachment of the retina. *Acta Ophthalmol* 47:633–641
13. Kim IT, Ha SM, Yoon KC (2001) Electroretinographic studies in rhegmatogenous retinal detachment before and after reattachment surgery. *Korean J Ophthalmol* 15: 118–127
14. Schatz P, Holm K, Andreasson S (2007) Retinal function after scleral buckling for recent onset rhegmatogenous retinal detachment: assessment with electroretinography and optical coherence tomography. *Retina* 27:30–36
15. Hancock HA, Kraft TW (2004) Oscillatory potential analysis and ERGs of normal and diabetic rats. *Invest Ophthalmol Vis Sci* 45:1002–1008
16. Wachtmeister L (1998) Oscillatory potentials in the retina: what do they reveal. *Prog Retin Eye Res* 17:485–521
17. Marmor MF, Holder GE, Seeliger MW, Yamamoto S (2004) Standard for clinical electroretinography (2004 update). *Doc Ophthalmol* 108:107–114
18. Ross WH (2002) Visual recovery after macula-off retinal detachment. *Eye* 16:440–446
19. Anderson DH, Guerin CJ, Erickson PA, Stern WH, Fisher SK (1986) Morphological recovery in the reattached retina. *Invest Ophthalmol Vis Sci* 27:168–183
20. Macheimer R, Steinhorst UH (1993) Retinal separation, retinotomy, and macular relocation: I: experimental studies in the rabbit eye. *Graefes Arch Clin Exp Ophthalmol* 231:629–634
21. Imai K, Hayashi A, De-Juan E Jr (1998) Method and evaluation of experimental retinal detachment. *Nippon Ganka Gakkai Zasshi* 102:161–166
22. Hayashi M, Yamamoto S (2001) Changes of cone electroretinograms to colour flash stimuli after successful retinal detachment surgery. *Br J Ophthalmol* 85:410–413
23. Montrone L, Ziccardi L, Stifano G, Piccardi M, Molle F, Focosi F, Fadda A, Falsini B (2005) Regional assessment of cone system function following uncomplicated retinal detachment surgery. *Doc Ophthalmol* 110:103–110
24. Sakai T, Calderone JB, Lewis GP, Linberg KA, Fisher SK, Jacobs GH (2003) Cone photoreceptor recovery after experimental detachment and reattachment: an immunocytochemical, morphological, and electrophysiological study. *Invest Ophthalmol Vis Sci* 44:416–425
25. Terasaki H, Miyake Y, Suzuki T, Niwa T, Piao C-, Suzuki S, Nakamura M, Kondo M (2002) Change in full-field ERGS after macular translocation surgery with 360° retinotomy. *Invest Ophthalmol Vis Sci* 43:452–457
26. Peklman I (1983) Relationship between the amplitudes of b-and a-wave as a useful index for evaluating the ERG. *Br J Ophthalmol* 67:443–448
27. Kamei S (1992) The recovery of the local ERG recorded from reattached retina after retinal detachment. *Nippon Ganka Gakkai Zasshi* 96(6):776–783
28. Schepens CL, Gardner TW, Quillen D, Blankenship GW, Marshall W (1994) Increased intraocular pressure during scleral buckling(letter). *Ophthalmology* 101:417
29. Wilson DJ, Green WR (1987) Histopathologic study of the effect of retinal detachment surgery on 49 eyes obtained post mortem. *Am J Ophthalmol* 103:167–179
30. Van Lith GHM, Van Der Torren K, Vijfvinkel-Bruinenga S (1981) ERG and VECPS in retinal detachment. *Doc Ophthalmol* 50:291–297