CLINICAL INVESTIGATIONS

Analysis of Changes in Corneal Shape and Refraction Following Scleral Buckling Surgery

Yuichi Okada, Seigo Nakamura, Eri Kubo,
Namiki Oishi, Yukio Takahashi and Yoshio Akagi

Department of Ophthalmology, Fukui Medical University, Yoshida-gun Fukui, Japan

Purpose: A prospective study was performed to investigate changes in corneal shape and axial length following scleral buckling surgery.

Methods: We investigated the changes in corneal shape, refraction, and axial length following scleral buckling surgery in 24 patients who underwent local buckling and 14 patients who underwent encircling with additional segmental buckling. The corneal shape was determined by corneal topography and autokeratometry, refraction was measured by autorefractometry, and axial length was measured by A-mode ultrasonography before surgery, and 1, 2, and 7 days, and 1, 3, and 6 months after surgery.

Results: After local buckling, the axial length shortened and a hyperopic change was observed. After encircling with additional segmental buckling, the axial length elongated and a myopic shift was detected. The direction of the surgically induced corneal astigmatic vectors was almost identical to the direction of the buckle. There was a tendency for shorter distances between the limbus and the buckle to be associated with greater absolute values. Astigmatism gradually decreased following surgery and stabilized in about 3 months.

Conclusions: Surgeons should select a surgical procedure to ensure favorable postoperative visual acuity while minimizing changes in the shape of the cornea. **Jpn J Ophthalmol 2000;44:132–138** © 2000 Japanese Ophthalmological Society

Key Words: Axial length, corneal shape change, hyperopic change, myopic shift, retinal detachment.

Introduction

Scleral buckling surgery is one of several surgical techniques used to treat rhegmatogenous retinal detachment (RD) and is the oldest of these techniques. Except in some special cases, such as a tear near the posterior pole, scleral buckling surgery is selected to treat RD. The reattachment rate of RD is higher than 90%, and surgical results are excellent.[1] Nonetheless, even when the retina is repositioned, severe myopia or astigmatism may persist after surgery, resulting in dissatisfied patients. A myopic shift is believed to be caused by an elongation of axial length after scleral buckling surgery,[2,3] and astigmatism is thought to be due to changes in the corneal shape after scleral buckling surgery.[4–6] These refractive errors should be avoided or minimized after this surgery.

In the present study, we investigated changes in the corneal shape, refraction, and axial length after surgery for RD, and analyzed differences between local buckling and the encircling with additional segmental bucking surgical technique.

Materials and Methods

A total of 38 eyes of 38 patients who underwent scleral buckling surgery for RD were prospectively analyzed. All patients underwent scleral buckling surgery at the Fukui Medical University between October 1995 and June 1997. The patients were divided into two groups; 24 patients who underwent

Received: November 25, 1998
Correspondence and reprint requests to: Yoshio AKAGI, MD, Department of Ophthalmology, Fukui Medical University, 23-3 Shimoaizuki, Matsuoka, Yoshida-gun, Fukui, 910-1193, Japan

Jpn J Ophthalmol 44, 132–138 (2000)

Published by Elsevier Science Inc.
0021-5155/00/$–see front matter
PII S0021-5155(99)00183-5

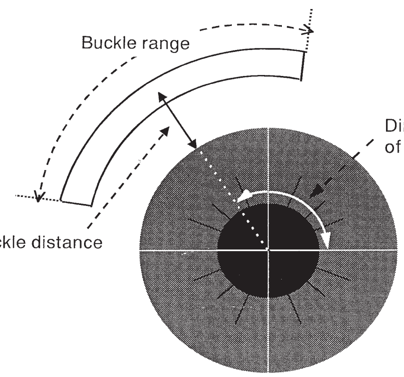

Figure 1. Definition of buckle distance, buckle range, and direction of center of the buckle. Buckle distance was defined as distance between limbus and center of scleral buckle; buckle range as the angle between both ends of scleral buckle; and direction of center of buckle was defined as the angle between 0° and center of buckle.

local buckling and 14 patients who underwent encircling with additional segmental buckling. The following types of patients were excluded: patients with a past history of scleral buckling surgery; those with corneal disease detected by slit-lamp biomicroscopy; patients in whom the results of photokeratoscopy were poor due to narrow eyelid opening; patients with macular detachment; and patients who required additional retinal detachment surgery or other intraocular surgery (eg, cataract surgery) during the present study. Only a few patients underwent encircling or scleral shortening alone, so such patients were also excluded from the present study.

All subjects were treated by the same physician and informed consent was obtained from each patient. In local buckling surgery, the sclera was buckled using a 3 × 5 mm silicone sponge (Mira 506; Mira, Waltham, MA, USA) and 4-0 Zupramido (Kono, Chiba) with a bite width of 7 mm. In the encircling with additional segmental buckling surgery, a 2.5 mm wide silicone band (Mira 240) was placed on top of a 3 × 5 mm wide silicone sponge with a groove (Mira 506G). Encircling was performed using a tube with an internal diameter of 0.75 mm (Mira 270). These exoplants were fixed by mattress sutures. Cryogenic or light coagulation was performed to close the retinal tears. Subretinal fluid was removed as follows: after performing sclerostomy and exposing the choroidal membrane, a diathermy needle was used for coagulation and hemostasis, and either the needle or an intraocular argon laser probe (Ultima

Table 1. Local Buckling Patients

Patient No.	Location of Buckle: Buckle Distance (mm)	Location of Buckle: Direction of Center of Buckle ± Buckle(°)	Changes in Axial Length (mm)	Induced Corneal Astigmatic Vector (D)/Ax(°)	Induced Refractive Astigmatic Vector (D)/Ax(°)
1	14.0	45 ± 45	−1.00	3.20/52	3.25/64
2	11.0	45 ± 45	−0.66	1.87/32	0.75/36
3	10.0	135 ± 45	−0.75	2.84/121	3.08/153
4	12.0	135 ± 45	−1.19	0.69/158	0.54/17
5	11.5	90 ± 90	−0.73	2.56/99	1.47/121
6	13.5	135 ± 45	+0.10	1.31/155	2.92/126
7	14.0	135 ± 45	−0.80	2.59/122	3.85/130
8	15.0	135 ± 45	−0.65	0.51/131	0.25/138
9	15.0	40 ± 45	−0.72	0.61/171	2.54/47
10	15.0	175 ± 95	−0.49	0.80/19	1.00/172
11	16.0	25 ± 55	−1.03	1.66/1	0.75/21
12	14.0	50 ± 60	−0.59	1.70/71	0.97/94
13	15.0	45 ± 65	−1.32	2.32/74	3.31/79
14	14.0	150 ± 60	−0.47	1.90/163	1.01/167
15	11.0	85 ± 45	−0.48	1.15/103	1.83/99
16	14.0	135 ± 60	+0.51	1.63/17	1.70/145
17	13.0	40 ± 50	+0.21	2.85/34	2.30/32
18	12.0	70 ± 30	+0.90	0.64/57	0.64/56
19	13.0	135 ± 45	−0.76	2.28/137	0.96/169
20	11.0	90 ± 30	−0.47	2.01/77	2.12/73
21	16.0	90 ± 30	+0.41	0.51/169	0.17/60
22	15.0	90 ± 45	−1.01	0.85/107	0.83/111
23	11.5	120 ± 30	+0.17	1.07/102	1.11/163
24	10.0	40 ± 40	+0.02	2.60/38	0.76/55

Jpn J Ophthalmol
Vol 44: 132–138, 2000

Table 2. Encircling With Additional Buckling Patients

Patient No.	Location of Buckle: Buckle Distance (mm)	Location of Buckle: Direction of Center of Buckle ± Buckle(°)	Changes in Axial Length (mm)	Induced Corneal Astigmatic Vector (D)/Ax(°)	Induced Refractive Astigmatic Vector (D)/Ax(°)
1	13.0	135 ± 10	+0.84	0.94/153	2.82/139
2	12.0	0 ± 45	−0.01	0.99/175	3.74/164
3	14.0	45 ± 50	−0.66	1.00/95	1.57/124
4	15.0	45 ± 45	+0.70	1.09/66	1.32/67
5	15.0	135 ± 45	+0.53	2.30/167	2.24/157
6	13.0	45 ± 90	−0.03	1.84/41	3.10/15
7	11.5	20 ± 80	+1.25	5.81/35	4.58/44
8	11.0	15 ± 45	+0.15	0.36/76	1.11/134
9	9.0	90 ± 40	+0.35	0.44/72	0.44/26
10	12.0	170 ± 90	+1.28	0.29/137	0.24/82
11	14.0	160 ± 80	+0.19	0.35/148	0.90/101
12	11.0	45 ± 90	+0.62	1.51/115	1.19/147
13	12.0	100 ± 10	−0.08	0.97/70	0.78/64
14	11.5	40 ± 40	+1.44	3.45/69	3.36/20

2000 SE; Coherent, Palo Alto, CA, USA) was used (0.5 seconds, 800 mW). Puncture wounds were sutured using 7-0 Ortho thread (Handaya, Tokyo).

Corneal shape was determined using an autokeratometer (KM-800; Nidek, Gamagori) and a photokeratoscope (SK-2000; Sun Contact Lens, Kyoto). Refraction was measured using an autorefractometer (AA-2000; Nidek), and axial length was measured by A-mode ultrasonography (ULT-1000; Storz Instrument, St. Louis, MO, USA). These measurements were taken by an independent ophthalmologist with no prior knowledge of the study. The measurements were taken before and 1, 2, and 7 days, and 1, 3, and 6 months after surgery. In addition, at each of these measurement times, the direction and size of the induced astigmatic vectors was determined by Jaffe's method.[7] Astigmatism was assessed in the left and right eyes in the same manner.

The buckle distance was defined as the distance between the limbus and the center of the scleral buckle, the buckle range as the angle between both ends of the scleral buckle, and the direction of the center of the buckle as the angle between 0° and the center of the buckle (Figure 1).

Refraction was analyzed in terms of the spherical equivalent. Photokeratoscopy was performed twice at each examination and the better image was used for analysis. Chronological shifts were analyzed in two ways: by comparing corneal topographic maps and by subtracting preoperative corneal topographic data at each measurement time.

Results

As shown in Table 1, local buckling was performed on 24 patients with a buckle distance of 10.0 to 16.0 mm. One month after surgery, the average absolute value of the induced corneal astigmatic vectors was 2.38 ± 1.96 D (maximum: 3.20 D).

As shown in Table 2, the encircling with additional segmental buckling surgery was performed on 14 patients with a buckle distance of 9.0 to 15.0 mm. The average absolute value of the induced corneal astigmatic vectors one month after surgery was 2.13 ±

Table 3. Analysis of Changes in Spherical Equivalent, Corneal Refractive Power, and Axial Length for Two Surgical Procedures

	Local Buckling	Encircling With Additional Segmental Buckling
Spherical equivalence (D)	0.54 ± 1.28	−1.75 ± 1.47
Corneal refractive power (D)	0.20 ± 0.31	0.17 ± 0.30
Eye axial length (mm)	−0.48 ± 0.49	0.47 ± 0.58

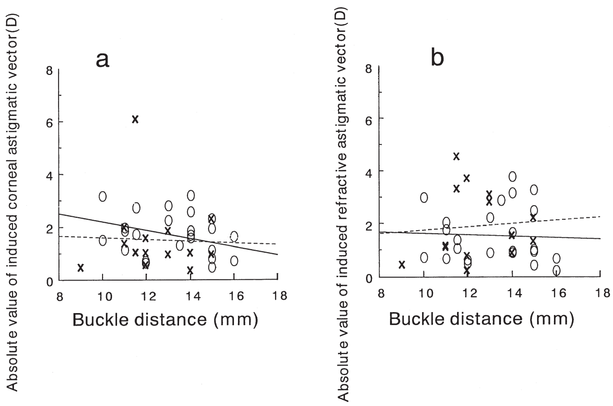

Figure 2. ○ represents local buckling. × represents encircling with additional segmental buckling. (**a**) Relationship between buckle distance and the absolute value of induced corneal astigmatic vectors. ○: $y = 3.732 - 0.156$ x: $R^2 = 0.116$ x: $y = 1.967 - 0.036$ x: $R^2 = 0.002$. Following local buckling, the shorter the buckle distance, the greater the absolute value of induced corneal astigmatic vectors. (**b**) Relationship between buckle distance and the absolute value of induced refractive astigmatic vectors. ○: $y = 1.965 - 0.029$ x: $R^2 = 0.002$. ×: $y = 1.212 + 0.06$ x: $R^2 = 0.06$. Relationship between buckle distance and absolute value of induced refractive astigmatic vectors closely resembles relationship between buckle distance and absolute value of induced corneal astigmatic vectors following local buckling.

1.58 D (maximum: 5.81 D), which was less than that following local buckling. In addition, the difference in the direction of the induced corneal astigmatic vectors and the direction of the center of the buckle was less than ±25° in 20 of the 24 patients (83.3%) who underwent local buckling and in 7 of the 14 patients (50%) who underwent encircling with additional segmental buckling (Tables 1 and 2). As a result, the direction of the induced corneal astigmatic vectors matched the direction of the center of the buckle at a higher frequency among patients who underwent local buckling.

The axial length shortened (hyperopic change) in 17 of the 24 patients (70.8%) who underwent local buckling and the corneal refractive power increased slightly (myopic shift) in 15 of the 24 patients (65.5%). On the whole, the refractive status of these patients showed a slight tendency toward hyperopia.

On the other hand, the axial length elongated in 10 of the 14 patients (71.4%) who underwent encircling with additional segmental buckling, and the corneal refractive power increased slightly in 8 of the 14 patients (57.1%). Thus, the refractive status of these patients showed a myopic shift (Tables 1–3).

The relationship between the absolute value of the induced corneal astigmatic vectors and the buckle

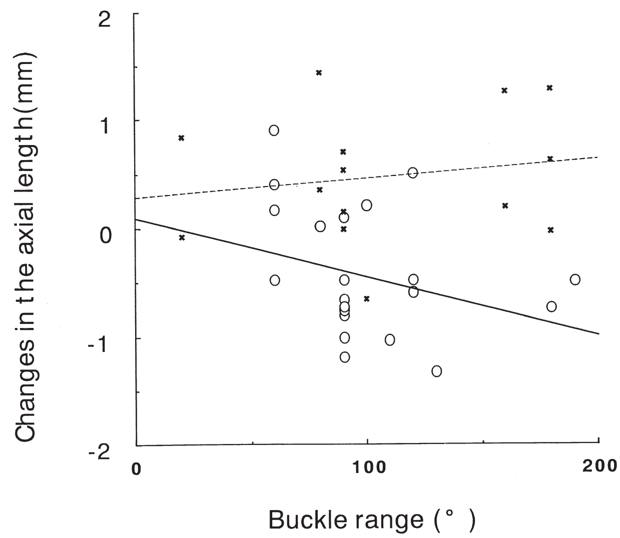

Figure 3. Relationship between buckle range and changes in axial length. ○ represents local buckling. × represents encircling with additional segmental buckling. ○: $y = 0.091 - 0.005$ x: $R^2 = 0.095$. ×: $y = 0.278 + 0.002$ x: $R^2 = 0.026$. No significant relationship was observed between postoperative changes in axial length and buckle range in the two surgical procedures.

distance was also analyzed. Among the patients who underwent local buckling, the tendency was for shorter buckle distances to be associated with greater absolute values of induced corneal astigmatic vectors (Figure 2a).

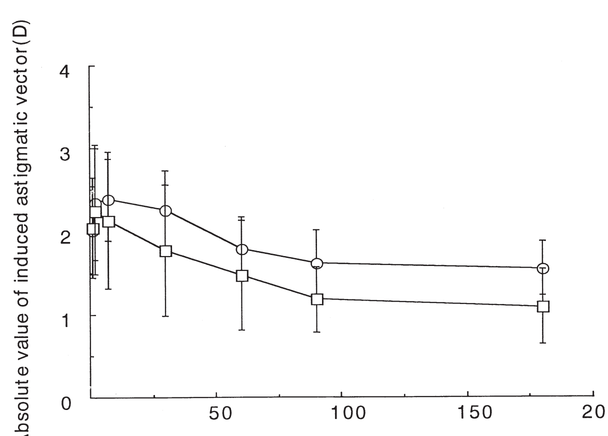

Figure 4. Chronological shifts in absolute value of induced corneal astigmatic vectors. ○ represents local buckling. □ represents encircling with additional segmental buckling. Degree of astigmatism at any time after surgery was greater following local buckling than following encircling with additional segmental buckling. Absolute value of induced corneal astigmatic vectors decreased with time, and stabilized at about 3 months after surgery.

Jpn J Ophthalmol
Vol 44: 132–138, 2000

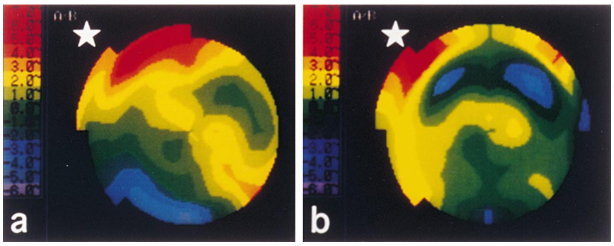

Figure 5. Chronological changes in corneal topography. (**a**) Representative local buckling case. When silicone sponge was sutured to one quadrant of superior auricle, first principal meridian shifted toward direction of buckle (indicated by white star). (**b**) Representative encircling with additional segmental buckling case. When silicone sponge with groove was sutured to one quadrant of superior auricle, first principal meridian shifted toward direction of buckle (indicated by white star).

The changes in astigmatism in terms of refractive power, analyzed using the Jaffe method, and the relationship between the buckle distance and the absolute value of induced refractive astigmatic vectors exhibited the same tendency: the shorter the buckle distance, the greater the absolute value of the induced refractive astigmatic vectors following local buckling (Figure 2b).

No significant relationship was observed between the postoperative changes in the axial length and buckle range in the two surgical procedures (Figure 3). Furthermore, the absolute value of the induced corneal astigmatic vectors was greater following local buckling than following encircling with additional segmental buckling at all measurement times (Figure 4). The absolute value of the induced corneal astigmatic vectors decreased with time and stabilized at about 3 months after surgery.

Figures 5a,b show the chronological shift in corneal topography among patients who underwent local bucking or encircling with additional segmental buckling, respectively. Regardless of the surgical technique, the first principal meridian shifted toward the direction of the buckle.

Figures 6a,b show the shift in corneal topography among the patients who underwent encircling with additional segmental buckling, before surgery and 1 day after surgery, and also before surgery and 90 days after surgery, respectively. As shown, astigmatism was induced in the direction of the buckle, and the severity of the induced astigmatism gradually decreased with time.

Discussion

The changes in corneal shape, refraction, and axial length caused by scleral buckling surgery were investigated. There have been previous reports on the changes in axial length[2,3,8,9] and in corneal shape.[6] The results of these studies and those of the present study are compared below. In the present study, the axial length elongated in 71.4% of patients who underwent encircling with additional segmental buckling, and a myopic shift was detected. We believe that this elongation in axial length was caused by encircling the equator of the eye, where the circumference is the greatest, causing the eye to be reshaped into the form of an ellipse. Hayashi et al[2] reported that, when compared to local buckling, encircling significantly elongates the axial length 3 and 6 months after surgery. They used 6 or 7 mm wide silicone tires whereas we used 3 × 5 mm wide silicone sponges with a groove. Although both the width and buckle material differed in the two studies, the results are similar in that the axial length elongated af-

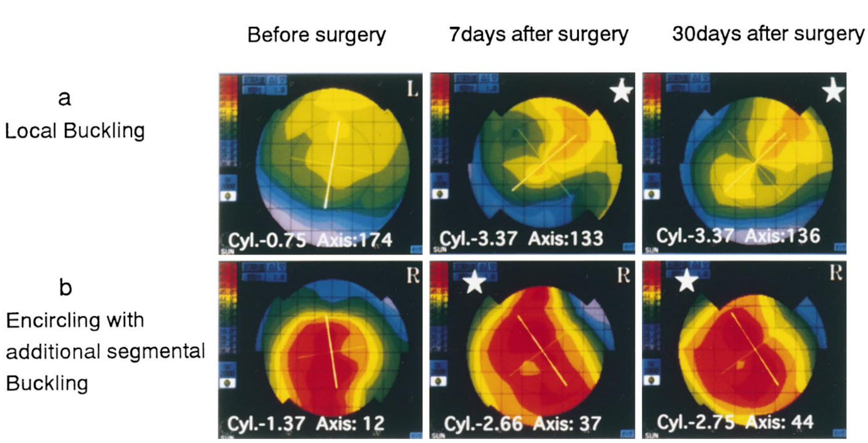

Figure 6. Differential map. (**a**) Topographic data that were obtained before surgery were subtracted from data obtained 1 day after surgery. Corneal astigmatism was induced in direction of buckle (as indicated by white star). (**b**) Topographic data that were obtained before surgery were subtracted from data obtained 90 days after surgery. Corneal astigmatism was induced in direction of buckle (as indicated by white star).

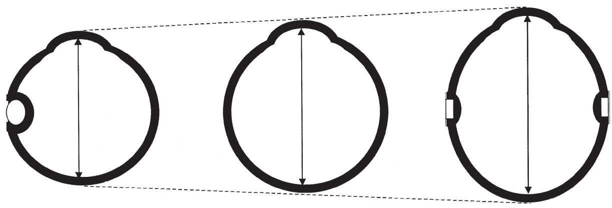

Figure 7. Schematic drawings of changes in axis of the eye. (**a**) Local buckling. Shortening of axial length caused by change in eye that is similar to change brought about by scleral shortening surgery. (**b**) Eye before surgery. (**c**) Encircling with additional segmental buckling. Elongation of axial length as result of eye being reshaped in form of ellipse due to encircling of equator.

ter encircling with additional segmental buckling. However, the degree of elongation was greater in our study than in that of Hayashi et al or Tanihara et al.[2,3] Although this difference may have been caused by the severity of RD, we believe that it is mainly attributable to the difference in the tightness of the encircling material, ie, how tightly a tire was fastened. On the other hand, using eyes obtained from the eye bank,[8] Harris et al found that the axial length shortens following encircling with additional segmental buckling. In another study,[9] when eyes obtained from the eye bank were tightly encircled, the axial length shortened and when the ocular pressure was reduced from 20 to 10 mm Hg, the axial length shortened further. However, because these two studies were conducted under nonphysiological conditions, the results differed from ours. Furthermore, although Hayashi et al reported that local buckling had almost no effect on axial length,[2] our results showed that the axial length most frequently (70.8%) shortened following local buckling, and the refractive status showed a hyperopic shift. This difference is attributable mainly to the difference in the size of the silicone sponges used. We used 3 × 5 mm elliptical silicone sponges, whereas Hayashi et al used 3 or 4 mm spherical silicone sponges. Our wider sponges caused changes in the eye similar to the changes caused by scleral shortening surgery, ie, a shortening of the axial length. Tanihara et al. reported that local buckling caused an average decrease in axial length of 0.2 mm,[3] while the average decrease in axial length in the present study was 0.48 mm. It is difficult to determine why the postoperative changes in the axial length in the present study showed greater shortening than in the data reported by Tanihara et al because of the lack of a description of the materials and methods used by Tanihara's group. This difference may also be attributable mainly to the difference in the degree of local buckling (ie, how tightly a silicone sponge is fastened).

Figure 7 shows schematic drawings of the changes in the axis of the eye brought about by local buckling or encircling with additional segmental buckling. We theorize that local buckling of the eye changes not only the sclera but the corneal shape, thus inducing postoperative astigmatism. The differential map of astigmatism shows that astigmatism was induced in the direction of the center of the buckle. Therefore, we propose that when the sclera is locally buckled, the radius of curvature of the sclera decreases in the vicinity of the buckle. Subsequently, the adjacent cornea is affected, and the radius of curvature in this direction decreases.

A myopic shift resulting from a change in corneal curvature can be nullified by a hyperopic shift due to shortening of axial length by local buckling, while changes in both corneal curvature and axial length induced by encircling with additional segmental buckling causes a myopic shift. This indicates that local buckling is a better procedure for maintaining the preoperative refractive status.

Furthermore, to investigate the relationship between changes in corneal shape and the distance between the limbus and the buckle, we analyzed the absolute value of induced corneal astigmatic vectors. No previous study has examined the relationship between changes in corneal shape and the distance between the limbus and the buckle. In the present study, the tendency was that the shorter the buckle distance (distance between the limbus and the buckle), the greater the absolute value of induced corneal astigmatic vectors. This local change in the sclera caused by buckling (reduced radius of curvature) also affected the cornea, and this effect was greater when a buckle was placed closer to the cornea.

The relationship between the absolute value of the induced refractive astigmatic vectors and the buckle distance closely resembled the relationship between the absolute value of induced corneal astigmatic vectors and the buckle distance. This suggests that the cause of refractive astigmatism after scleral buckling surgery was attributable mainly to corneal astigmatism.

The chronological shifts in the absolute value of induced corneal astigmatic vectors were also analyzed, and revealed that the degree of astigmatism at

Jpn J Ophthalmol
Vol 44: 132–138, 2000

any time after surgery was greater following local buckling than following encircling with additional segmental buckling. This suggests that local buckling is more likely to cause postoperative astigmatism. Hayashi et al reported that irregular changes in the corneal shape persist for 6 months after surgery,[6] and the results of our study agree with their finding in terms of the absolute value of induced corneal astigmatic vectors. In addition, we were able to confirm that the absolute value of the induced corneal astigmatic vectors gradually decreases with time, and is almost stable 3 months after surgery. Thus, the state of astigmatism at about 3 months after surgery predicts the state of astigmatism of that patient in the future. In other words, the astigmatism does not disappear but continues indefinitely.

In recent years, the success rate of scleral buckling surgery has improved markedly. Surgeons should select a surgical procedure that will not simply reposition the retina, but also ensure favorable visual acuity recovery. With this goal, surgeons should not fasten a tire or a silicone sponge so tightly as to cause changes to the shape of the cornea, resulting in refractive errors.

References

1. Michels RG, Wilkinson CP, Rice TA. Results of retinal reattachment surgery. In: Wilkinson CP, Rice TA, eds. Michels retinal detachment. 2nd ed. St. Louis: Mosby, 1996:935–77.
2. Hayashi H, Hayashi K, Nakao F, Hayashi F. Changes in axial length after scleral buckling surgery. Nippon Ganka Gakkai Zasshi (J Jpn Ophthalmol Soc) 1996;100:302–6.
3. Tanihara H, Negi A, Kawano S, et al. Axial length of eyes with rhegmatogenous retinal detachment. Ophthalmologica 1993;206:76–82.
4. Givner I, Karlin D. Alternations in refraction and their clinical significance. Eye Ear Nose Throat Monthly 1958;37:676–8.
5. Wolter JR. Regular astigmatism resulting from retinal detachment surgery in a young man with a disinsertion. J Pediatr Ophthalmol Strabismus 1967;4:27–9.
6. Hayashi H, Hayashi K, Nakao F, Hayashi F. Corneal shape changes after scleral buckling surgery. Ophthalmology 1997;104:831–7.
7. Jaffe NS, Clayman HM. The pathophysiology of corneal astigmatism after cataract extraction. Trans Am Acad Ophthalmol Otolaryngol 1975;79:615–30.
8. Harris MJ, Blumenkranz MS, Wittpenn J, Levada A, Brown R, Frazier-Byrne S. Geometric alterations produced by encircling scleral buckles: biometric and clinical consideration. Retina 1987;7:14–9.
9. Rubin ML. The induction of refractive errors by retinal detachment surgery. Trans Am Ophthalmol Soc 1975;73:452–90.