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Long-term results of corneal wedge resections for the correction of high astigmatism

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Abstract. We retrospectively evaluated 41 corneal wedge resections, performed for the correction of high astigmatism in 40 patients who were spectacle and contact lens intolerant. Keratometric astigmatism decreased from an average of 11.7 diopters (range 5 to 22.5 D) preoperatively to 3.5 diopters (range 0 to 10 D) postoperatively, representing a mean reduction of 8.2 D (range 0 to 16.5), or 70%. The length of follow-up averaged 11 months. Twenty-five, 15 and 9 cases had a follow-up of at least 3, 5 and 10 years, respectively. In 16 cases the keratometry readings remained stable over the years. However, in 1 case of Fuchs' endothelial dystrophy (follow-up 13 years) and 5 cases of keratoconus (follow-up 3, 4, 12, 13 and 14 years) the astigmatism gradually increased during the various follow-up periods. In 3 other cases the astigmatism gradually decreased over the years. Corneal wedge resection is an effective technique for managing high corneal astigmatism. The results remain stable over the years except in some patients with keratoconus.

Introduction

Thanks to improvements in microsurgical and eye banking technology, the chance of a successful longtime clear graft after penetrating keratoplasty has improved markedly. However, the final goal for both surgeon and patient is good visual acuity. Good vision is not always achieved when high residual astigmatism accompanies an otherwise clear and physiologically successful graft. Even when various techniques designed to reduce postoperative astigmatism, such as donor punches, intraoperative keratometry, and selective postoperative suture removal, are used, a significant number of these cases still arise. A clear graft with high astigmatism is often interpreted by the patient as a bad result. If high residual corneal astigmatism cannot be managed successfully with glasses or contact lenses, a surgical approach may be indicated. A number of approaches for the surgical reduction of

astigmatism after keratoplasty have emerged, all with variable success [1–15].

Relaxing incisions [1–8] and wedge resections [6–12] are probably the most common procedures currently performed. The use of relaxing incisions, performed in the axis of the steeper meridian under the slit lamp on routine outpatient visits, is a simple technique with fast recovery, but corrects the astigmatism to a lesser degree than wedge resections. The addition of compression sutures in the flat axis has been used to augment the effect obtained by relaxing incisions [13, 14]. Recently, Limberg et al. described the use of compression sutures alone for the reduction of astigmatism after penetrating keratoplasty [15]. A wedge resection comprises the resection of a wedge of tissue inside, encompassing, or outside the graft-recipient scar in the flat axis, followed by the placement of multiple sutures. It can correct larger degrees of astigmatism but the recovery period is long. The aim of this study was to determine the effectiveness of corneal wedge resections during a long period of time. As far as we know, a follow-up of ten years or more has not been described before.

Materials and methods

We retrospectively reviewed 42 consecutive patients, who underwent corneal wedge resection at the Eye Hospital in Rotterdam between November 1974 and June 1989. Wedge resections were performed on all patients with high astigmatism who were unable to wear glasses or contact lenses. The results of astigmatism correction in the first 17 patients with a short follow-up period have been described before [10]. Two patients were lost to follow-up and were excluded. The study reports on the remaining 40 patients. Wedge resections were performed after: penetrating keratoplasty (32 patients), lamellar keratoplasty (4 patients), corneal perforation (2 patients), radial keratotomy (1 patient) and lipoid cornea dystrophy in 1 patient. The initial corneal diseases are listed in Table 1.

Patients' ages at the time of wedge resection ranged from 7 to 83 years (mean age 53 years). There were 26 females and 14 males in our group. The refractive state of the patients was followed by refraction and keratometry. All patients had stable keratometry readings. During the operation we identified the steep and flat corneal meridians with a contact keratoscope, an 18 mm diameter cylindrical device that is placed on the globe and projects concentric rings over the graft and host cornea, including the limbal area [16]. The wedge resection was performed at the flatter end of the flat corneal meridian.

Table 1. Initial diagnosis.

Diagnosis	Number of eyes	Diagnosis	Number of eyes
Keratoconus	13 (32.5%)	Bullous keratopathy	1 (2.5%)
Interstitial keratitis	8 (20.0%)	Terrien's marginal degeneration	1 (2.5%)
Herpetic keratitis	5 (12.5%)	Reis-Bücklers' dystrophy	1 (2.5%)
Corneal scar (trauma)	5 (12.5%)	Cornea dystrophy (lipoid)	1 (2.5%)
Fuchs' endothelial dystrophy	4 (10.0%)	Radial keratotomy	1 (2.5%)
	Total		40(100%)

From 1974 to 1979, we used the technique described by Troutman [1]; the wedge resection was performed with a 30° razor-blade knife (12 wedge resections). From 1979 to 1984 we used a V-shaped knife (8 wedge resections) [10]. After 1984 sharp V-shaped knives were no longer available and a 30° razor-blade knife was used again (21 wedge resections). The wedge resection was taken outside the graft-recipient scar or encompassed it. Where there was wound slippage or elevation, the resection was made in the sector of the wound disturbance. The length of the incision, centered on the axis of the flatter meridian, was approximately 60–90° of the graft circumference. The depth was approximately 90% of the corneal thickness. The width at the center of the wedge varied from 0.1 to 0.8 mm, depending on the amount of preoperative astigmatism to be corrected and on the presence or absence of wound override (graft elevation). If graft elevation existed less tissue was removed. Sometimes slight graft elevation could only be observed after removing the epithelium covering the graft-recipient interface. Over the years the size of the wedge resections made became smaller. The anterior chamber was entered in the central part of the wedge with the razor-blade knife, then the anterior chamber was refilled with a balanced salt solution and air. The wound was closed with 6 to 8 interrupted 10-0 nylon sutures. The immediate surgical goal was to overcorrect the preoperative astigmatism to a degree approximately equal to the original cylinder, with a 90° shift in axis.

Postoperatively, the patients received a regimen of topically applied antibiotics and corticosteriods. Numerous postoperative visits were required, beginning one week postoperatively. During the follow-up visits, corneal curvature readings were obtained and the wound was examined under the slit lamp. By judicious suture removal, we attempted to titrate the amount of residual astigmatism toward the ideal endpoint of a spherical cornea. Sutures were first removed between 4 weeks and several months postoperatively. In some cases a few sutures were left in place for more than one year. Spectacles or contact lenses were used for final optical correction.

In 2 patients a complementary relaxing incision in the steep axis was required, after 3 and 7 months respectively, to reduce the residual corneal astigmatism. One patient underwent a second wedge resection after 6.5 years.

The short-term results of 41 wedge resections, performed in 40 patients, are given after an average follow-up of 11 months. Twenty-four patients (with 25 wedge resections) reached a follow-up of 3 years or more. The follow-up was 5 years or more in 14 patients (15 wedge resections) and 10 years or more in 9 patients.

Results

Short-term results

The interval between the primary operation and the corneal wedge resection averaged 43.1 months (range, 7 months to 18 years). The mean corneal astigmatism before wedge resection was 11.7 diopters (range, 5 to 22.5 D). Following wedge resection, the residual corneal astigmatism averaged 3.5 diopters (range, 0 to 10 D) after a mean follow-up of 11 months (range, 5 to 24 months). The average reduction of astigmatism amounted to 8.2 diopters (range, 0 to 16.5 D), which represents a decrease of 70% of the preoperative value (Table 2).

The net change in spheroequivalence was measured by keratometry by subtracting the average preoperative keratometric reading from the average postoperative keratometric reading. The mean spheroequivalent change was a hyperopic postoperative shift of 1.02 diopters with a range of -6.45 to $+5.39$ diopters. Six corneas were steeper after wedge resection, 25 were flatter, and 9 were essentially unchanged (-0.5 to $+0.5$ D) (Unkown 1x).

Table 2. Short-term results of 41 corneal wedge resections (40 patients).

Mean astigmatism		
preoperative	11.7 D	(5–22.5 D)
postoperative	3.5 D	(0–10.0 D)
change	8.2 D	(0–16.5 D)
Mean follow-up 11 mos (5–24 mos)		
Mean keratometry [(steep + flat axis)/2]		
preoperative	45.74 D	(34.60–59.98 D)
postoperative	44.72 D	(34.48–53.53 D)
change	−1.02 D	(−6.45–+5.39 D)

After wedge resection, 19 corneas showed a more than 45° shift in their axis of astigmatism; these were considered overcorrected. After the procedure, the best corrected visual acuity with spectacles or contact lenses improved in 25 eyes, deteriorated in 2 eyes, showed no change in 12 eyes, and was unknown in 2 eyes.

No major complications were encountered during surgery or during follow-up in any of the 40 patients. Two patients were regrafted 1.5 and 2.5 years after a prior lamellar and penetrating keratoplasty respectively, in one patient due to interface opacities after a lamellar graft and in the other due to recurrent herpetic keratitis. Three patients required a subsequent surgical procedure to reduce residual corneal astigmatism. One patient with a thin corneal recipient underwent a successful second wedge resection after 6.5 years. A complementary relaxing incision in the steepest axis was successfully performed in 2 patients with interstitial keratitis after 3 and 7 months. In these 2 patients the residual astigmatism before this second procedure amounted to 10 and 9 diopters, respectively.

Long-term results

Sixteen patients had a follow-up of less than 3 years because they had not reached this postexamination period, were lost to follow-up or had died. Twenty-four patients (with 25 wedge resections) were observed for 3 years or more. The follow-up period of 14 patients (15 wedge resections) was 5 years or more. Nine patients were followed for 10 years or more. The preoperative astigmatism and the course of the postoperative astigmatism of these patients are presented in Table 3. The results show that during the various follow-up periods the corneal astigmatism hardly changed in 15 out of 24 patients, corresponding with 16 out of 25 cases of wedge resections. However, in 6 patients, 5 with keratoconus and 1 with Fuchs' dystrophy, the astigmatism gradually increased over the years (Table 3: case 4, 10, 18, 21, 22 and 23). The inexplicable development of astigmatism in patient 4 with keratoconus is shown from the time of the penetrating keratoplasty up to the present (Table 4). In the remaining 3 patients, 2 with herpetic keratitis and 1 with radial keratotomy, the astigmatism gradually decreased over the years (Table 3: case 2, 9 and 19).

The axis of the keratometry readings hardly changed in 21 out of 25 cases of wedge resections during the follow-up period (range of axis shift was 0 to 25°). In 4 patients, all of whom suffered from keratoconus, the axis of astigmatism changed 45° or more over the years (case 3: 80°; case 4: 50°; case 11: 55°; case 24: 45°). In 3 of these patients, however, the astigmatism remained stable at a low level.

Table 3. Long-term results of 25 corneal wedge resections (24 patients).

Case	Diagnosis	Astigmatism preoperative	Astigmatism postoperatively								
			1 yr	2 yr	3 yr	4 yr	5 yr	7 yr	9 yr	> 9 yr	Follow-up
1	Bullous keratopathy	18.1	6	6	5						36 mos
2	Radial keratotomy	14	5	4	2.5						36 mos
3	Keratoconus	8	0	1.5	2						36 mos
4	Keratoconus (Table 4)	11.2	2.5	3.5	4.5						39 mos
5	Corneal scar (trauma)	15	3.5	3.5	3.5						39 mos
6	Interstitial keratitis	8	4	3	4	4					46 mos
7	Cornea dystrophy (lipoid)	12	3	3	3	3					46 mos
8	Herpetic keratitis	5	2	2.5	2.5	2.5					45 mos
9	Herpetic keratitis	9	5	3	1.5	0					52 mos
10	Keratoconus	16.2	2	1	3	4.5					51 mos
11	Keratoconus	14.5	2.5	3	1	0	0.5				60 mos
12	Interstitial keratitis	13	6.5	6	7	6.5	6				62 mos
13	Reis–Bücklers' dystrophy	8	2.5	2	2	1	2				63 mos
14a	Corneal scar (trauma)	7	7	7.5	7.5	7	7	8			75 mos
14b	Repeat wedge resection	8	3	–	3	–	3				68 mos
15	Herpetic keratitis	6	1	1	1	1	1.5				60 mos
16	Interstitial keratitis	14.5	2.5	3	3	2.5	3	2.5	2.5	1.5	10 yr
17	Terrien's marginal degen.	20	6	–	–	6	–	5	–	4.5	12 yr
18	Fuchs' dystrophy	7.5	2	–	1	–	1	4.5	–	5	13 yr
19	Herpetic keratitis	11	4	–	3	–	1.5	1.5	–	1	14 yr
20	Keratoconus	13	2	2	2	2	–	2	2	2	10 yr
21	Keratoconus	14	3	1	2	2.5	4	3	3.5	3.5	12 yr
22	Keratoconus	11	4	4	5	6	6	–	–	9	13 yr
23	Keratoconus	12	5	–	9	–	–	11.5	–	18	14 yr
24	Keratoconus	17	2	3	–	2	–	1	1	0	14 yr

Comment

After penetrating keratoplasties, corneal astigmatism is a common problem that perplexes both clinician and patient. Surgical corrections of severe astigmatism by various microsurgical techniques have been described [1–15]. The most important are relaxing incisions, with or without compression sutures, and corneal wedge resections.

The corneal wedge resection technique for management of post-keratoplasty astigmatism has been described by Troutman [1] and others (Table 5). The effect of a wedge resection on the cornea is that it steepens the flatter curvature, but also flattens the steeper opposite one [17]. Wedge resections provide a graded control of astigmatic correction through selective keratometric-controlled suture removal, which is an important advantage. Occasionally, irregular astigmatism develops after a wedge resection, especially when irregular or wide wedges are cut.

In our study the keratometric astigmatism decreased from an average of 11.7 diopters preoperatively to 3.5 diopters postoperatively, a reduction of 8.2 diopters or 70%. These findings are comparable to the previously reported data on wedge resections (Table 5). An average final cylinder of 3.5 D after wedge resection compares favorably with published averages of 2.5 to 5.0 diopters after uncomplicated penetrating keratoplasty [18–20]. After wedge resection, the mean change in spherical equivalent measured by keratometry was a hyperopic shift of 1.02 D. Other studies reported either an almost unchanged spherical equivalent [8, 11] or a trend toward a more

Table 4. Postoperative follow-up of Astigmatism after Penetrating Keratoplasty (PKP) and Wedge Resection in patient 4 with a keratoconus.

Follow-up (postoperative)	Astigmatism in diopters	Steepest meridian
PKP		
1 year	3	120°
2 years	4	110°
5 years	6	120°
10 years	6	115°
14 years	11	120°
16 years	11.2	120°
Wedge resection		
6 months	1.5	110°
1 year	2.5	110°
2 years	3.5	120°
3 years	4.5	115°

myopic spherical equivalent [3, 9]. The small change suggests that the corneal wedge resection does not alter the ametropia consistently, i.e., it creates a reasonably predictable myopic or hyperopic postoperative shift. The amount of steepening of the flat meridian or flattening of the steeper meridian, as well as the direction of the ametropic change, appear to be less predictable for individual cases (range of postoperative shift: −6.45 to +5.39 D).

In many publications the results of wedge resections have been described with a short follow-up [8–11]. These suggest that the keratometric readings are stable in the period between 6 months and 3 years after surgical correction. The purpose of our study was to examine the stability of the keratometric readings after wedge resection in the long run. In 19 out of 25 corneas the keratometric astigmatism remained practically stable or decreased over the years. However, in 6 patients with varying follow-up periods the astigmatism gradually increased over the years (Table 3). In 2 keratoconic patients with a follow-up of 39 and 51 months the astigmatism increased from 1.5 to 4.5 and from 1 to 4.5 diopters, respectively. It will be interesting to watch these patients in the years to come. In a patient with Fuchs' dystrophy the astigmatism remained stable for 5 years, then showed an increase of 4 diopters during the next 8 years. In a keratoconic eye the astigmatism increased from 1 to 4 diopters in 3 years, then remaining stable. In 2 other patients, who underwent penetrating keratoplasty for keratoconus, the astigmatism gradually increased by 5 and 14 diopters in the course of 13 and 14 years respectively (Table 3).

Table 5. Previously published results of corneal wedge resections.

Authors	Number of wedge resections	Average keratometric astigmatism (diopters)			Follow-up period (+ range)
		preoperative (+ range)	postoperative (+ range)	change (+ range)	
Troutman [9]	10	11.50 D (9.00–16.00)	3.83 D (2.00–6.00)	7.67 D (3.00–11.5)	?
Krachmer and Frenzl [8]	10	11.50 D (5.75–18.00)	4.75 D (1.75–7.00)	6.75 D (2.75–16.25)	16 mos (4–43)
Dutescu et al. [12]	8	10.4 D (8.0–12.0)	4.13 D (3.00–5.75)	6.3 D (4.3–8.5)	? (5–60)
Lugo et al. [11]	14	9.29 D (3.00–17.00)	5.54 D (0.50–14.00)	3.75 D (0.50–11.00)	17 mos (5–35)
Present study	41	11.7 D (5.0–22.5)	3.5 D (0–10.0)	8.2 D (0–16.5)	11 mos (5–24)

In these 6 patients, who had undergone penetrating keratoplasty, the progress of the astigmatism is difficult to explain. It has been shown that in 64% of keratoconic cases the astigmatism after penetrating keratoplasty correlates well with the preoperative Placido axis [21]. In keratoconus not only the centre but also the periphery of the cornea may be involved. Moreover, some authors suggest that the distortion may involve the sclera, peripheral to the cornea as well [21, 22]. Therefore, a built-in astigmatism seems to be present in the recipient cornea and sclera, which largely determines the axis and degree of astigmatism after penetrating keratoplasty and astigmatism correction. The cornea may therefore resume its original, preoperative shape. It may well be that built-in astigmatism or the progression of the disease in the recipient cornea and sclera explains the gradual increase of astigmatism over the years in our keratoconic eyes.

In recent years corneal relaxing incisions have gained popularity in the management of high postsurgical astigmatism [1–8]. The use of relaxing incisions in the steep axis is a simple technique with fairly rapid visual rehabilitation. It corrects small amounts of astigmatism and can be repeated if necessary [4, 5, 8]. The amount of correction, however, is unpredictable [3–6], and the risk of wound dehiscence, graft instability and corneal perforation must be considered [3–6, 8]. Recently, Limberg et al. described the use of compression sutures alone for the reduction of astigmatism after penetrating keratoplasty [15]. The astigmatism was reduced by only 4.8 D on average 9 to 12 months after surgery.

For the correction of high astigmatism, we still prefer wedge resection, because wedge resection is capable of correcting greater amounts of astigmatism and because the results are reasonably predictable. In most of our patients, who had had penetrating keratoplasty, the corneas showed graft elevation or wound dehiscence before or after removal of the running suture. If this is discovered early, resuturing with or without opening of the wound is the better technique. In our opinion however, if many months have passed, a small wedge resection should be performed where the transplant has loosened or become slightly elevated. It is important to instruct the patients to return to the office if their vision changes substantially after suture removal, because resuturing is much easier to perform shortly after the graft elevation or wound dehiscence has occurred.

In this study we found stable keratometry readings after wedge resections in the majority of our patients. The astigmatism gradually increased in 6 patients, 5 with keratoconus and 1 with Fuchs' dystrophy.

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