Corneal astigmatism following cataract extraction

M S WISHART, P K WISHART, AND Z J GREGOR

From Moorfields Eye Hospital, City Road, London EC1V 2PD

SUMMARY The changes in corneal curvature in the first six months after cataract extraction were studied by performing sequential keratometry on a group of 57 patients. 8/0 Virgin silk interrupted sutures were used for the closure of corneoscleral incisions, and 10/0 monofilament tied in double running (bootlace) or single running (continuous) fashion was used for corneal wound closure. A high degree of with-the-rule astigmatism was evident in all patients two weeks postoperatively, but thereafter the character of the astigmatism produced by 8/0 virgin silk and 10/0 monofilament closure was quite different: in the 8/0 virgin silk group there was an early and pronounced shift in the axis of astigmatism to against-the-rule, whereas in the 10/0 monofilament group there was little further change in the astigmatism unless the sutures were removed. Wound compression and wound gape as factors responsible for these changes are discussed.

Astigmatism resulting from cataract extraction has been the subject of many studies. Wound gape occurring with absorbable sutures and wound compression occurring with non-absorbable sutures have been proposed by Jaffe and Clayman¹ as the prime factors responsible for changes in the corneal curvature following cataract extraction, whereas in other studies attention has been directed to factors such as length and shape of section and material and method of suturing.²⁻⁶

A further source of confusion is that many authors use only postoperative keratometry readings to discuss the effects of surgery, not taking into consideration that corneal curvature after cataract extraction is dependent on the preoperative corneal curvature as well as the change induced by surgery. Jaffe and Clayman¹ were the first to report exact quantitative differences between pre- and postoperative corneal curvature. They showed how the difference between these two values can be calculated mathematically and therefore provide a measure of change induced by surgery—the surgically induced astigmatism (SIA).

The aim of our study was to document the changes in corneal curvature occurring after cataract extraction over a six-month period. We planned to compare the SIA produced by closure of cataract sections with 10/0 monofilament and 8/0 virgin silk, and relate the

changes in corneal curvature to wound healing, removal of monofilament, and signs of biodegradation of virgin silk. By choosing these materials we felt that the differing effects attributable to wound gape and wound compression might be more readily evident.

Materials and methods

All patients undergoing cataract extraction for senile cataract in a four-month period were included. Patients were allocated in turn and consecutively to one of the following three groups:

(1) *Limbal (L)*. In this group cataract extraction was performed via a mid-limbal section of approximately 160° under a short limbus based conjunctival flap. The section was closed with six interrupted 8/0 virgin silk sutures, two preplaced and four post-placed.

(2) *Bootlace (B)*. In this group a corneal section of 160° immediately anterior to the limbal vessels was made. The section was closed with a continuous double row of 10/0 monofilament sutures tied at one end of the section (bootlace fashion) (Fig. 1(B)).

(3) *Continuous (C)*. In this group a corneal incision was made as in group B, but closure was with a single row of 10/0 monofilament suture tied in the wound at both ends of the section (Fig. 1(C)).

The section was thus of a standard length and shape in all three groups, the only difference being the mid-limbal position of the incision in group L and

Fig. 1(B) Diagram of continuous double row of 10/0 monofilament suture used to close a corneal cataract section (bootlace fashion).

Fig. 1(C) Diagram of continuous single row of 10/0 monofilament suture used to close a corneal cataract section.

the corneal position in groups B and C. In all cases the section was cut vertically downwards with a razor fragment and completed with corneal scissors.

The surgery was performed by one of two surgeons—the consultant and the resident of the firm. The operating microscope was used in every case. Extracapsular cataract extraction was performed in all but three cases in which intracapsular cataract extraction was performed. A modified J loop Sinsky-type posterior chamber intraocular lens was implanted when clinically indicated. Both surgeons used all three types of incision and closure, and no patient

was selectively allocated to any particular group. Any patient with previous anterior segment surgery or with any pre-existing eye disease other than cataract was excluded.

Corneal astigmatism was measured with a Topcon keratometer by an observer not involved in the surgery and without prior knowledge of the type of surgery or the surgeon involved. Keratometry was performed immediately preoperatively (K1) and postoperatively (K3) at 2, 6, 13, and 26 weeks. The law of sines and cosines¹ was used to calculate K3 minus K1 to give K2, the SIA, for each patient at each

Fig. 2(L) Changes in power of surgically induced astigmatism during the first six months following surgery in group L with limbal section and virgin silk sutures. Solid circles represent individual patients.

Fig. 2(B) Changes in power of surgically induced astigmatism during the first six months following surgery in group B with corneal section and bootlace suture. Solid circles represent individual patients.

Corneal astigmatism following cataract extraction

Fig. 2(C) Changes in power of surgically induced astigmatism during the first six months following surgery in group C with corneal section and continuous suture. Solid circles represent individual patients.

visit. Monofilament sutures were removed after four months if an unacceptably high degree of post-operative astigmatism was present.

Results

Fifty-seven patients were entered in the study, but two had to be withdrawn, because owing to ill health they could not attend at the required times for follow up. Seventeen patients were included in group L, 19 in group B, and 19 in group C.

POWER OF ASTIGMATISM

The change in power of SIA for each of the three groups in the first six months following surgery is shown in Fig. 2. The power of SIA is given in dioptres.

These three graphs show that, although at two weeks the power of SIA was very similar in all three groups, at six and 13 weeks a steep fall in power of SIA had occurred in group L but only a slight reduction in power of SIA in groups B and C. The reduction in power of SIA in group L between 13 and 26 weeks was only very slight, whereas groups B and

Fig. 3(B) Changes in power of surgically induced astigmatism in group B, with those who retained their sutures represented by solid circles and those who underwent ROS represented by squares. CUT indicates the time of ROS.

C both showed a much larger drop in power of SIA over this period. However, when the patients in groups B and C are divided into those who retained their sutures and those who had their sutures removed (ROS) (Figs. 3B and 3C), we see retention of sutures was associated with near constancy of SIA, and ROS was associated with a dramatic reduction of power of SIA.

AXIS OF ASTIGMATISM

The axis of SIA is given as the plus cylinder necessary to correct the induced corneal change. With-the-rule astigmatism is defined as that which is corrected by a plus cylinder at $90^\circ \pm 30^\circ$,⁷ against-the-rule astigmatism as that which is corrected by a plus cylinder at $180^\circ \pm 30^\circ$, the remaining 60° representing oblique astigmatism.

The changes in axis of SIA occurring in each group over the six-month period are shown in Figs. 4 L, B, and C. In the limbal group there was a marked change from predominantly with-the-rule to predominantly against-the-rule between weeks two and 13. In groups B and C the axis of astigmatism was predominantly with-the-rule and showed little

Fig. 3(C) Changes in power of surgically induced astigmatism in group C, with those who retained their sutures represented by solid circles and those who underwent ROS represented by squares. CUT indicates the time of ROS.

change over the first 15 weeks. ROS was carried out after four months, and Fig. 4 shows that ROS was associated in group B with a marked change in the axis of astigmatism. This change was not so marked following ROS in group C, possibly because there was a greater number of patients with oblique astigmatism in this group.

Fig. 4(L) Changes in the axis of surgically induced astigmatism during the first six months following cataract extraction in patients who underwent a limbal section: group L.

Fig. 4(B) Changes in the axis of surgically induced astigmatism during the first six months following cataract extraction in patients who underwent a corneal section closed with a double row of 10/0 monofilament suture tied at one end of the section (bootlace fashion): group B.

SUTURES

It was evident that those patients who had had a corneal section had much quieter eyes post-operatively than the limbal section group sutured with 8/0 virgin silk. During the early stages of healing in the limbal group an increased amount of inflammation at the wound is to be expected because of the additional surgical trauma to the conjunctiva caused by this method. In seven of the limbal group this marked inflammation settled in the course of time, but in 10 patients a persistent redness and infiltration around the sutures associated with a marked papillary conjunctivitis was noted. This reaction did not respond to treatment with topical prednisolone 1% but did settle quickly when the virgin silk sutures were removed. ROS of virgin silk was not associated

Fig. 4(C) Changes in the axis of surgically induced astigmatism during the first six months following cataract extraction in patients who underwent corneal section closed with a single continuous row of 10/0 monofilament suture: group C.

with any appreciable change in power or axis of SIA. Two patients in group L, both of whom had a severe inflammatory reaction to virgin silk sutures, developed peripheral anterior synechiae (PAS) noted at the six weeks visit which were not present at the two weeks follow-up visit. No other patient in this study developed PAS.

In group B monofilament sutures were associated with an unacceptably high degree of SIA in 10 patients (52.6%), and ROS was necessary to reduce this astigmatism. In group C 11 patients (57%) required ROS to reduce astigmatism. In addition in group C five patients (26%) required ROS to relieve irritation associated with broken or loose sutures. None of these patients with broken or loose sutures developed a wound leak.

Removal of the bootlace suture, when necessary, was more easily accomplished than removal of the single running continuous suture, as the single buried knot of the bootlace could be more easily pulled out of the section than the two closed loops of the tied ends of the single running suture.

Discussion

To the surgeon interested in reducing postcataract astigmatism a bewildering amount of advice on achieving this goal appears in the ophthalmic literature. Among the subjects of attention in this respect have been: the length of the section,² the number of sutures,^{8,9} prevention of sideways shift of the wound,⁴ variation in the suturing technique,^{3,6,10} the use and value of the operative keratometer,¹¹⁻¹³ and the distance of the section from the limbus.¹⁴ These studies show that different factors affect the change in corneal curvature following cataract extraction, but controversy surrounds their relative importance. We consider that the changes and similarities of SIA which occurred in our three groups of patients can be explained by the occurrence of wound gape and wound compression in the healing of cataract wounds.

At two weeks the results for all three groups were very similar. All three groups at this stage showed a high degree of SIA, axis with the rule, or less commonly, oblique. Despite the similarity at two weeks, at the six weeks and 13 weeks visits group L had become very different from groups B and C. Group L showed a marked reduction in power of SIA and a marked change of axis from with to against the rule. Groups B and C showed only a small reduction in power over this time and retained their axis orientation. It is apparent, therefore, that a factor common to all three groups at two weeks is no longer evident at six and 13 weeks. It would appear that the 10/0 monofilament suture holds the wound stable,

whereas the 8/0 virgin silk allows a marked change in the corneal curvature to develop over the weeks in which healing is taking place. Wound compression in the first two weeks postoperatively would be similar for all three groups. Tight sutures and wound oedema would result in reduction in the radius of the curvature of the vertical meridian and astigmatism with the rule. The occurrence of oblique astigmatism at this stage can also be explained by wound compression—the meridian in which the sutures are tightest being that of the shortest radius of curvature.

Jaffe and Clayman's explanation for the occurrence of astigmatism against the rule is that, when absorbable sutures and large diameter sutures that are intended to be removed are used, wound gape occurs, and this increases the circumference of the globe in the meridian perpendicular to the line of the incision and therefore flattens the vertical meridian.¹ Virgin silk is classed as a non-absorbable suture,¹⁵ and the 8/0 diameter sutures used in this study were not intended to be removed. However, biodegradation of virgin silk does occur,¹⁶ and in our study this was evident from the large number of patients who required ROS for relief of suture related inflammation. It is also possible that the development of PAS in two patients was due to inflammatory reaction and wound gape related to the virgin silk sutures. Change to against-the-rule astigmatism associated with extrusion of 8/0 virgin silk has also been reported by Luntz and Livingstone.¹⁷ Adverse reactions to virgin silk have been reported by Soong and Kenyon, who suggest that an immunological reaction mounted against the sericin gum of the virgin silk may occur.¹⁸

Further evidence in support of wound compression by monofilament sutures is shown by their removal. A dramatic fall in the power of SIA occurred in groups B and C in those patients who underwent ROS. A large change in the axis of astigmatism was also seen in many patients following ROS. The reduction of astigmatism following removal of monofilament sutures in corneal sections has been reported by others.^{1,18,19}

In reviewing our results we were surprised at the large variation in power of astigmatism produced in our bootlace group (Fig. 3(B)). In producing a watertight closure of the section we believed we were tightening our sutures to a similar degree, yet 52.6% of group B showed a considerably higher degree of SIA. Hyde and Maumenee have pointed out that with bootlace closure, if longer bites than necessary are taken, considerably more tissue is subjected to compression by the suture.²⁰ The occurrence of a small percentage of patients in groups B and C who showed against-the-rule astigmatism might be explained by a mechanism proposed by Hyde.²¹ He suggests that, if monofilament is used and wound gape is allowed to

occur during suturing, scar formation will develop and increase the circumference of the globe, thus flattening the cornea in the meridian perpendicular to the section.

The variation in power and axis of astigmatism associated with the clinical picture of wound inflammation and suture extrusion in the 8/0 virgin silk group was in marked contrast to the constancy of power and axis of astigmatism in those patients with 10/0 monofilament closure. Furthermore, the marked reduction in SIA following removal of 10/0 monofilament showed the importance of tension in the monofilament as a cause of SIA. We consider, therefore, that wound compression and wound gape, as proposed by Jaffe and Clayman in 1975,¹ are the most important determinants of corneal astigmatism after cataract surgery, and these factors should be taken into account in any discussion of the parameters thought to influence postcataract astigmatism. We also agree with the findings of Stainer *et al.*¹⁹ that the appropriate choice of suture material helps the surgeon to control postoperative corneal astigmatism.

References

- 1 Jaffe NS, Clayman HM. The pathophysiology of corneal astigmatism after cataract extraction. *Ophthalmology (Rochester)* 1975; **79**: 615–30.
- 2 Reading VM. Astigmatism following cataract surgery. *Br J Ophthalmol* 1984; **68**: 97–104.
- 3 Thygesen J, Reersted P, Fledelius H, Corydon L. Corneal astigmatism after cataract extraction. A comparison of corneal and corneoscleral incisions. *Acta Ophthalmol (Kbh)* 1979; **57**: 243–50.
- 4 Torchia RT, McCarthy RW. The cornered incision—a precision cataract wound. *Ophthalmic Surg* 1983; **14**: 72–4.
- 5 Meredith TA, Maumenee AE. A review of one thousand cases of intracapsular cataract extraction: II Visual results and astigmatic analysis. *Ophthalmic Surg* 1979; **10**: 42–5.
- 6 Gibson Moore J. Incidence of astigmatism after cataract surgery: comparison of continuous and interrupted sutures. *Trans Ophthalmol Soc UK* 1977; **97**: 104–5.
- 7 Waring G. Corneal structure and pathophysiology. In: Leibowitz HM, ed. *Corneal disorders*. Philadelphia: Saunders, 1984; **1**: 6.
- 8 Singh D, Kumar K. Keratometric changes after cataract extraction. *Br J Ophthalmol* 1976; **60**: 638–41.
- 9 Rowan PJ. Corneal astigmatism following cataract extraction. *Ann Ophthalmol* 1978; **10**: 231–4.
- 10 Pearce JL. Discussion on suture material. *Adv Ophthalmol* 1970; **22**: 58–9.
- 11 Terry CM. Introduction to a surgical keratometer. In: Emery JM, Jacobson AC, eds. *Current concepts in cataract surgery; selected proceedings of the Sixth Biennial Cataract Surgical Congress*. St Louis: Mosby, 1980: 27–9.
- 12 Samples JR, Binder PS, Earl K. The value of the Terry keratometer in predicting postoperative astigmatism. *Ophthalmology (Rochester)* 1984; **91**: 280–4.
- 13 Perl T, Binder PS, Earl K. Post-cataract astigmatism with and without the use of the Terry keratometer. *Ophthalmology (Rochester)* 1984; **91**: 489–93.
- 14 Iliff CE, Khodadoust, A. The control of astigmatism in cataract surgery. *Trans Am Ophthalmol Soc* 1967; **65**: 160–7.
- 15 Henkind P, Walsh JB, Berger AW. eds. *Physicians' desk reference for ophthalmology*. 10th ed. Oradell, NJ: Medical Economics, 1982: 19.
- 16 Salthouse TN, Matlaga BF, Wykoff MH. Comparative tissue response to six suture materials in rabbit cornea, sclera and ocular muscle. *Am J Ophthalmol* 1977; **84**: 224–33.
- 17 Luntz MH, Livingstone DG. Astigmatism in cataract surgery. *Br J Ophthalmol* 1977; **61**: 360–5.
- 18 Soong HK, Kenyon KR. Adverse reactions to virgin silk sutures in cataract surgery. *Ophthalmology (Rochester)* 1984; **91**: 479–83.
- 19 Stainer GA, Binder PS, Packer WT, Perl T. The natural and modified course of post-cataract astigmatism. *Ophthalmic Surg* 1982; **13**: 822–7.
- 20 Hyde LL, Maumenee AE. The double shoelace cross-tied suture. In: Emery JA, Paton D, eds. *Current concepts in cataract surgery; selected proceedings of the Fourth Biennial Cataract Surgical Congress*. Philadelphia: Mosby, 1976: 62.
- 21 Hyde LL. Corneal astigmatism after cataract extraction. In: Emery JA, Paton D, eds. *Current concepts in cataract surgery; selected proceedings of the Fourth Biennial Cataract Surgical Congress*. Philadelphia: Mosby, 1976: 182.