

Rapid suture management of post-keratoplasty astigmatism

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Abstract

Aim Post-keratoplasty astigmatism is managed by topography-guided suture removal. This can take several weeks until satisfactory reduction in astigmatism is achieved. This study aimed to assess whether topography performed 30–40 min after the removal of the first pair of sutures would predict the next set of sutures requiring removal.

Methods A prospective study of 20 consecutive penetrating keratoplasty patients was carried out. Topography guided suture removal in the steep meridian was carried out. Topography was repeated after 30–40 min and 4–6 weeks later. The tight sutures requiring removal were identified for each occasion and compared. The difference was considered insignificant if the axes of sutures requiring removal was $<22.5^\circ$. Paired *t*-test and χ^2 were performed for statistical analysis.

Results In 85% of individuals, the 30–40 min topography gave an accurate indication of the next pair of sutures requiring removal. The difference in mean astigmatism at 30–40 min post suture removal (4.37 ± 2.08 D) and at 4–6 weeks (4.24 ± 1.97 D) was not significant ($P = 0.150$). However, the difference between vector-corrected change of topographic astigmatism at 30–40 min after suture removal and at 4–6 weeks (1.72 D) was significant ($P < 0.001$). Improved best-corrected visual acuity was seen in 50% of patients.

Conclusion This study showed that corneal topography performed 30–40 min after suture removal can identify the next set of sutures requiring removal. This can be used as a guide to remove more sutures at the same visit, thereby expediting post-keratoplasty visual rehabilitation and reducing the number of follow-up visits.

Eye (2010) 24, 540–546; doi:10.1038/eye.2009.146; published online 12 June 2009

Keywords: astigmatism; penetrating keratoplasty; corneal topography; suture removal

Introduction

Use of interrupted or combined running and interrupted sutures in penetrating and deep anterior lamellar keratoplasty allows for the selective removal of interrupted sutures, with the goal of reducing astigmatism in the post-operative period.^{1–7} Successful visual rehabilitation therefore depends in part on accurate identification of the interrupted suture or sutures, the removal of which would most effectively reduce astigmatism. In practice, this involves identifying the steep corneal semi-meridians and the tight suture that may be inducing this steepening. Refraction and keratometry are of limited help in this regard, as they identify one steep and one flat corneal meridian that may be misleading in patients undergoing keratoplasty in whom irregular astigmatism is common. Computer-assisted corneal topography has the advantage of mapping subtle corneal power changes accurately over the entire optical zone and beyond and allows identification of steep semi-meridians that can be attributed to specific sutures.^{8–10}

Yilmaz *et al*¹¹ found that unexpected high levels of astigmatic change could be encountered after suture removal following penetrating keratoplasty (PK) because of factors such as donor–recipient trephine diameter difference, high pre-existing astigmatism and underlying primary diagnosis such as keratoconus.

Selective suture removal usually starts at the fourth post-operative month. The usual practice adopted is the removal of one or two sutures in the steep meridian(s) and waiting for a few

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Received: 16 December 2008

Accepted in revised form: 18 April 2009

Published online: 12 June 2009

Presentation at any meeting: None
 Proprietary interests or research funding: None

weeks (4–6 weeks) before re-examining the patient for the effect of the suture removal and assessing further sutures to be removed. If further sutures require removal the process is repeated one or more times. This prolongs the duration before which the minimal achievable astigmatism is obtained and delays visual rehabilitation of the patients.

Materials and methods

This study included 20 consecutive PK patients subject to selective suture removal for management of high post-keratoplasty astigmatism (more than 3 dioptres of refractive astigmatism). Inclusion criteria were: Post-PK astigmatism requiring suture removal; regular astigmatism with readable corneal topographic map; post-operative period >4 months. Exclusion criteria were poor quality topographic maps, insufficient data due to irregular astigmatism with un-recordable simulated keratometry values, or when no sutures were present in the steep meridian.

Each patient followed a protocol of examination: medical history including indication for PK, suture technique, operation; whether PK or triple procedure (PK combined with cataract extraction and intraocular lens implantation) and slit lamp examination including intraocular pressure measurement. Uncorrected and best-corrected visual acuities (BCVAs) were recorded for all. Pre-suture removal topography was carried out using an EyeSys 2000 Corneal Analysis System (EyeSys, Houston, TX, USA). The sutures to be removed in the steep semi-meridians were identified (Figures 1a and b, Figure 2a) and removed at the slit lamp biomicroscope. Topography was repeated 30–40 min post suture removal (PSR), the new steep semi-meridians determined and the next set of sutures to be removed were identified and marked in a drawing in the case record (Figures 1c and d, Figure 2b). Topography was repeated 4–6 weeks later, the steep semi-meridians and tight sutures to be removed were identified again and compared with the 30–40 min PSR topography and the sutures identified at that time (Figures 1e and f, Figure 2c). The change in axis of astigmatism between 30 and 40 min topography and 4–6 weeks topography was calculated. If the axis in the 30–40 min topography differed from the axis at 4–6 weeks topography by $<22.5^\circ$ (the minimum angle difference between adjacent interrupted 16 sutures) the difference was considered to be not relevant. Changes in visual acuity and complications after suture removal were also noted. After suture removal, the changes in astigmatism were evaluated by calculation of the vector-corrected changes and the net reduction in astigmatism measured by topography. Jaffe and Clayman's¹² method of vector analysis was used to calculate the vector change in

astigmatism. Vector analysis was carried out using a computer programme on the spreadsheet of SPSS statistical package 8.0 (SPSS Inc., Chicago, IL, USA).

Assessment of visual acuity

A standard Snellen visual acuity chart was used for measurement of both uncorrected and BCVA.

Statistical analysis

Paired *t*-test and χ^2 were used for analysis of the results.

Selective suture removal technique

The tight sutures identified by corneal topography were selectively removed in pairs, one each for the steep semi-meridian. The superficial part of the suture furthest from the knot was nicked with a sharp hypodermic needle and the cut end prised out of the subepithelial space with the tip of the needle. The exposed end was grasped with a forceps and pulled out. This ensured that knot did not travel through the graft–host junction.

Results

Age of patients studied ranged from 42 to 77 years (mean 57 years), consisting of 11 males and 9 females. Time between PK and suture removal ranged from 5 to 19 months (mean 8.5 months). The relevant clinical characteristics of the patients are given in Table 1.

Two surgical techniques were used: In 10 patients, the button was sutured to the host cornea with 16 interrupted sutures (the angle between every two sutures measured at the corneal anatomical centre was 22.5°). In the other 10 patients, the corneal graft was sutured with 12 interrupted sutures combined with a single 12 bite continuous suture (the angle between every two interrupted sutures measured at the corneal anatomical centre was 30°).

Change in astigmatic axis between corneal topography 30–40 min after suture removal and 4–6 weeks later

After removal of the first pair of sutures, all patients showed a shift in the axis of the steep (semi) meridian. However, the shift in the steep meridian between 30 and 40 min topography after suture removal and 4–6 weeks topography was $<22.5^\circ$ in 17 out of 20 patients (85%). Thus corneal topography determined the same sutures for further removal both at the 30–40 min interval and at the 4–6 week interval in these patients.

In 3 out of 20 PK patients (15%), the shift in steep meridian between 30 and 40 min topography after suture

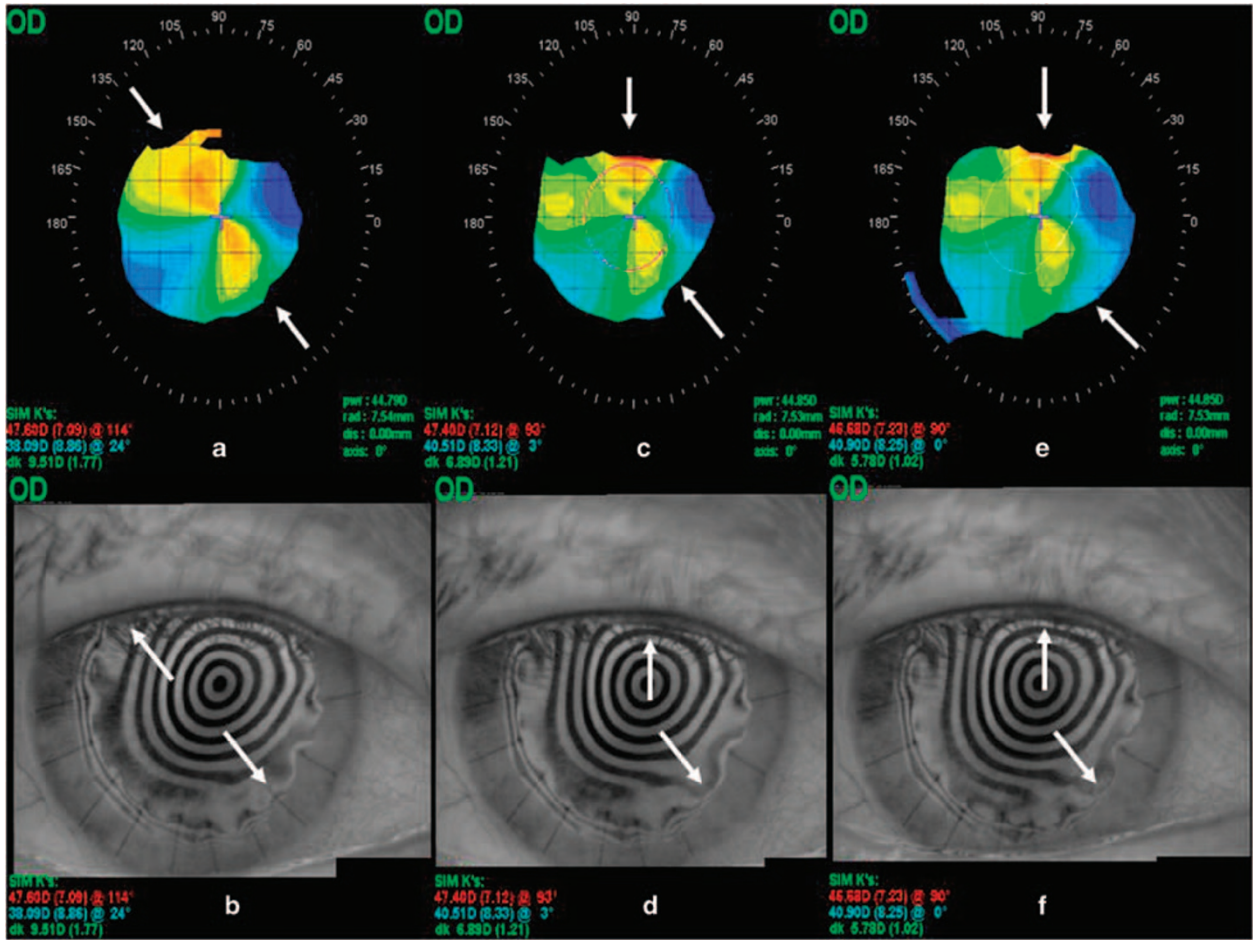


Figure 1 (a) EyeSys corneal topography of a patient with a corneal graft and 16 interrupted sutures. The arrows point to the steep semi-meridians (red), which are in the same axis and at right angles to the flat semi-meridians (blue). (b) Corresponding eye image showing the sutures to be removed (arrows) along the steep semi-meridians. (c) Topography repeated after 30 min illustrates that the steep semi-meridians have shifted to the 90° meridian above and to the 130 (310)° meridian below (arrows). (d) Corresponding eye image indicating the second set of sutures to be removed (arrows). (e) Topography repeated after 6 weeks showing in this case that the steep semi-meridians have remained the same as seen in the 30 min topography (arrows). (f) Corresponding eye image indicating the second set of sutures to be removed (arrows) has remained the same. The astigmatism was reduced by about 2.5 dioptres after first suture removal.

removal and 4–6 weeks topography was more than 30°. Corneal topography at 4–6 weeks did not indicate the same sutures previously estimated at 30–40 min PSR in these three patients. Suture removal was carried out between 6 and 9 months in all three, and two had combined running and interrupted sutures and one had only interrupted sutures.

The cases with marked axis shift showed a clockwise shift $\geq 40^\circ$ in two cases and an anticlockwise shift of 75° in one case. The mean axis shift was $57.33 \pm 17.50^\circ$ in these three cases. Owing to the small number of cases, we could not relate the presence of axis shift with suture technique, order of suture removal, or post-operative period. The mean axis shift in the 17 cases that did not show a change was $7.47 \pm 5.74^\circ$.

Changes in the amount of astigmatism at 30–40 min and 4–6 weeks after suture removal

There was a reduction of astigmatism after suture removal. The mean pre-suture removal topographic astigmatism was 6.36 ± 2.63 D, the mean 30–40 min PSR topographic astigmatism was 4.37 ± 2.08 D, and the mean 4–6 weeks PSR topographic astigmatism was 4.24 ± 1.97 D. The difference in remaining astigmatism between 30 and 40 min and 4–6 weeks after suture removal was not statistically significant ($P = 0.150$).

The mean of vector-corrected change in topographic astigmatism in the entire group was 3.56 D at 30–40 min after suture removal and 5.28 D at 4–6 weeks (difference = 1.72 D); this difference was statistically

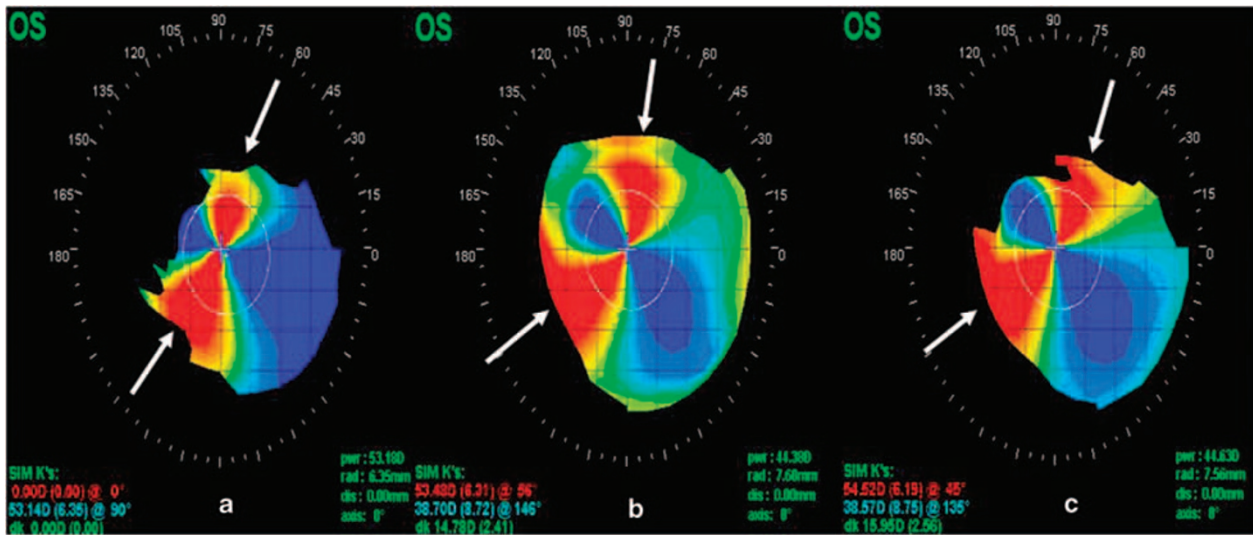


Figure 2 (a) EyeSys corneal topography showing steep semi-meridians (red) corresponding to the tight sutures (arrows). (b) Topography repeated 30 min later shows a shift in the axis of the steep semi-meridians and points to a new set of sutures requiring removal (arrows). (c) Topography repeated after 6 weeks showing that the steep semi-meridians have remained the same as seen in the 30 min topography (arrows). The astigmatism was reduced by 3.5 dioptres after first suture removal.

Table 1 Clinical characteristics of patients

Characteristics	Number
Age	
Range (years)	42–77
Mean ± SD	56.5 ± 11.65
Sex	
Male	11
Female	9
Diagnosis	
Fuch's dystrophy	4
Keratitis (HSV)	4
Graft failure	3
Bullous keratopathy	3
Keratoconus	2
Eccentric graft	2
Keratitis (HZV)	2
Suture technique	
Interrupted	10
Combined	10
Post-operative period	
Range (months)	5–19
Mean ± SD	8.50 ± 3.66

significant ($P < 0.001$). The mean of vector-corrected change in topographic astigmatism in the group with axis shift $> 30^\circ$ was 1.62 and 5.98 D at 30–40 min and at 4–6 weeks after suture removal, respectively

Table 2 Visual acuity changes after suture removal

	Improved number	No change number	Decreased number
Number of eyes	10	7	3
Astigmatic axis shifted $< 22.5^\circ$	08	6	3
Astigmatic axis shifted $> 22.5^\circ$	02	1	0

(difference = 4.36 D) ($P < 0.001$). The mean of vector-corrected change in topographic astigmatism in the group with axis shift $< 22.5^\circ$ was 3.90 and 5.16 D at 30–40 min and at 4–6 weeks after suture removal, respectively (difference = 1.26 D) ($P < 0.001$)

Visual acuity changes after suture removal

Best-corrected visual acuity improved in 10 cases (50%), did not change in seven cases (35%), and decreased in three cases (15%) in the entire group. Details of visual acuity for the patients with $< 22.5^\circ$ shift and those with $> 22.5^\circ$ after suture removal are given in Table 2. The recorded visual acuity after suture removal was however not the final visual acuity, as glasses or contact lenses were prescribed only after suture management was completed and the refraction was stable on at least two consecutive follow-up visits. One episode of graft rejection occurred in one case within a week after suture removal and was treated successfully with topical and systemic steroids. This case later developed posterior sub-capsular cataract and was treated with

phacoemulsification and posterior chamber intraocular lens implant. The graft survived the surgical procedure and BCVA improved to 6/9.

Discussion

This study is a non-randomized prospective study evaluating the possibility of use of corneal topography as a guide for removal of two sets of sutures at the same follow-up visit, which can help reduce the number of follow-up visits and shorten the visual rehabilitation period in patients undergoing PK. The conclusions would also be applicable to DALK, although no patients with DALK were included in the study.

This study showed that corneal topography performed between 30 and 40 min of suture removal can identify the next set of sutures requiring removal. As has been previously conclusively shown,^{7,13} selective suture removal in our study also reduced post-keratoplasty astigmatism and improved visual acuity. The reason for leaving the patient for 30–40 min after suture removal is to allow the cornea to take its new configuration after removal of the tight sutures.

Although refraction and keratometry are useful tools in the study of astigmatism, they have their limitations, as they assess astigmatism in two meridians only and assume that the two meridians are at right angles to each other. This is not usually the case in post-keratoplasty astigmatism, which is sometimes irregular and more complex. Topography enables determination of steep semi-meridians corresponding to tight sutures.^{13,14}

Burk *et al*² evaluated the removal of multiple sutures at the same visit to control post-keratoplasty astigmatism. They reported an average change of astigmatism of 2–3 D, but this average was associated with a large range (0–12 D). The outcome was so unpredictable that astigmatism increased in 18% of eyes and decreased in 54%. The vector-corrected changes were greater than the changes calculated by the absolute method. The identification of sutures in their study was based on keratometry in part of the study, and in two-thirds of the cases keratography was used.

Our study showed average post-PK astigmatism of 4.24 D at 4 weeks after suture removal; this was not the final stage of astigmatism control. In three patients, the corneal topography failed to detect the next set of sutures requiring removal, as the steep meridian shifted more than 30° between 30 and 40 min and 4–6 weeks after suture removal. The net remaining astigmatism decreased in these patients (net pre-suture removal astigmatism was 4.31 D, net PSR astigmatism was 3.64 and 3.13 D at 30–40 min and at 4–6 weeks, respectively).

The vector-corrected change in astigmatism in this group showed a marked difference between 30 and

40 min topography and 4–6 weeks topography. This difference is explained by the marked shift in axis that occurred with time.

Calculation of the vector-corrected change in astigmatism between 30 and 40 min and 4–6 weeks after suture removal showed that the astigmatism was not stable at that period of time and a mean change of 1.72 D was found. This change in astigmatism can be explained because vector analysis roughly doubles the amount of astigmatism calculated by the absolute method.¹² Three cases had a marked axis shift >30° between 30 and 40 min and 4–6 weeks after suture removal, skewing the change in astigmatism for the whole group. The change in astigmatism in either group was statistically significant when calculated by vector analysis and was not statistically significant when calculated by absolute changes.

In agreement with this study, Potamitis *et al*¹⁵ measured keratometric astigmatism at 5, 15, 30 min, and 2 weeks after suture removal and found that the rate of decay of post-operative astigmatism after suture removal decreased exponentially, with the maximum change occurred in the first 5 min. Keratometry 30 min after suture removal was only moderately different from that seen 2 weeks later, with a mean change in cylinder power of 1.20 D and in cylinder axis of 11.77°. Keratometry measured at 30–40 min after suture removal was a good indicator of the remaining cylinder found 2 weeks later and accurately predicted the necessity for further suture removal. The results of Potamitis *et al*¹⁵ study can be viewed as being in partial agreement with this study. They used keratometry in cataract patients, and in our study corneal topography was used for measurement of corneal astigmatism in PK patients.

Astigmatism after PK is usually irregular and causes reduction of BCVA. Selective suture removal helps to decrease the amount of astigmatism and render it more regular. In this study selective suture removal was associated with improvement of BCVA in 50% of cases. Visual acuity was unchanged in 35% and decreased in 15%. There was no apparent relationship between decrease in BCVA and marked axis shift after suture removal.

Strelow *et al*¹⁶ found that computer-assisted corneal topography was a useful guide in selective suture removal for reduction of astigmatism, and a powerful way of describing corneal power after PK.

The effect of suture removal on post-PK astigmatism has been documented in many studies.^{1,5,6,17,18} The theoretical advantage of selective suture removal is that the surgeon can modify astigmatism while sutures are in place, allowing the patient to receive spectacles or contact lenses between the fifth and seventh post-operative month. The disadvantage of this technique is that extra post-operative office visits are required to remove

interrupted sutures.^{17,18} Our study showed that the number of post-operative office visits can be reduced by removing additional sutures using the computer-assisted corneal topography as a guide for selective suture removal, with a minimum period of 30–40 min between the first and second suture set removal.

Several reports have documented encouraging results from use of a suture technique that allows for selective removal of sutures after PK. Cottingham¹⁹ presented information on a technique involving the use of 12 interrupted 10/0 nylon sutures combined with a single running 10/0 suture. During follow-up, he selectively removed the interrupted sutures according to the area where apparent tension was producing astigmatic change. His report of an average post-operative astigmatism of 1.5 D in 67 PK patients elicited attention, because this average was far lower than most surgeons were encountering.

Binder¹⁷ evaluated the astigmatism after 204 PKs in which he combined eight interrupted 10/0 monofilament nylon sutures with a continuous 11/0, 16-bite monofilament nylon suture technique. The mean astigmatism decreased from 7.5 D in the first post-operative month to 2.9 D 1 year after surgery by selective suture removal, and he concluded that selective removal of interrupted sutures in post-PK patients can improve the recovery of vision without subjecting the eyes to increased risk.

Removing more than one suture set in one visit, in addition to reducing the number of office visits, may decrease the risk of suture-induced irritation, rejection and infection due to the decrease in frequency of suture removal episodes.

Burk *et al*² compared the effect of removing a single suture with multiple sutures. They used keratometry and later keratography as a guide for suture removal in two-thirds of cases. They found that the number of cases with decrease and increase in astigmatism were similar when 1, 2, 3, or 4 sutures were removed at one visit, but the mean change in astigmatism was 2.2 D when one suture was removed and 3.7 D when three sutures were removed. They reported that, with many variables in play, the surgeon could not be certain of the effect of individual suture removal, indicating a need for improved techniques in identifying tight sutures. Binder suggested that it is best to limit interrupted suture removal to one or two per session and measure the effect a minimum of 4 weeks later.¹ In their work in 1991 Strelow *et al*¹⁶ commented that single suture removal was more efficacious and predictable at decreasing astigmatism than was the removal of multiple sutures at one time. However, they were unable to prove this conclusion because of their inability to separate the confounding variable of pre-existing irregular astigmatism.

Yamashita *et al*²⁰ compared selective removal of one or two sutures at a single visit in 12 eyes of 12 patients, and found that removal of a single suture was associated with predictable results and a greater reduction in astigmatism (an average of 4.2 D in single suture removal at a time and 2.9 D for the removal of two sutures at a time).

Our study showed that corneal topography can define the next set of sutures to be removed for the remaining astigmatism with considerable accuracy so that a second set of sutures can be removed at the same follow-up visit of PK patients. This reduces the number of follow-up visits and shortens the visual rehabilitation period (time to final spectacle or contact lens prescription) for those patients. However, because of the variable effects of suture removal and the possibility of wound slippage after removal of too many sutures at one sitting especially in the early months, a bigger study involving different subsets would be necessary to substantiate that corneal topography is efficacious and safe for defining the next set of sutures to be removed. How many sutures can be safely removed in one sitting without risk of graft dehiscence depends on a number of variables. By 6 months after surgery, most wounds are fairly secure to allow removal of one or more pairs of interrupted sutures. The longer the duration, the less likely are the chances of wound-related problems; but in elderly patients on long-term topical steroids, the healing may not be adequate. Removal of adjacent sutures is more likely to stress the wound than removal of alternate or non-adjacent sutures. If a combined running and interrupted suturing technique is used then many of the interrupted sutures can be safely removed with minimal risk of wound problems. Nylon sutures degrade with time and late removal (over a year) can be associated with suture breakage and incomplete removal. Every episode of suture removal has the added risk of infection and/or rejection and appropriate antibiotic and steroid cover is essential. Finally, if the knot is buried in the graft–host junction or if it is made to traverse the graft–host junction during removal, it would stress the wound and increase the risk of dehiscence. This should be avoided.

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