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Factors affecting changes in astigmatism before and after suture removal following penetrating keratoplasty

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PURPOSE. *To analyze the factors related to changes in astigmatism before and after suture removal in patients who underwent penetrating keratoplasty (PK).*
METHODS. *The study group consisted of 171 consecutive PKs in 171 patients. Keratometric astigmatism was measured before and after suture removal in all patients. The vectorial difference for each eye was calculated between the examination before suture removal and the first year after suture removal. The vectorial difference values were compared with the possible factors affecting astigmatic change such as age of the patient, donor-recipient trephine diameter difference, preoperative diagnosis, and time of suture removal. All sutures were removed completely in one session. The vectorial difference values of all groups were compared with each other statistically.*
RESULTS. *Before suture removal, the mean cylinder was 4.40±3.24 D; it was 3.96±2.19 D at 1 year after suture removal. The net difference of astigmatism was –0.27±3.50. The mean value of vectorial difference for all patients was 4.93±4.02 D. There was a statistically significant negative correlation between the trephine diameter difference and the vectorial difference ($r=-0.582$, $p<0.01$). There was a significant change in vectorial difference values in patients with high pre–suture removal astigmatism. Patients with keratoconus had a positive correlation between the pre–suture removal astigmatism and the vectorial difference ($r=0.615$, $p=0.038$).*
CONCLUSIONS. *After suture removal following PK, unexpected high levels of astigmatic change could be encountered due to donor–recipient trephine diameter difference and underlying primary diagnosis such as keratoconus. In particular, high level astigmatism before suture removal has a greater risk of increased astigmatic change after suture removal. (Eur J Ophthalmol 2007; 17: 301-6)*

KEY WORDS. *Astigmatism, Penetrating keratoplasty, Suture removal*

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INTRODUCTION

Penetrating keratoplasty (PK) is considered to be a successful operation if graft clarity is provided. Corneal astigmatism after PK is the main factor influencing visual acuity, and this remains a significant barrier to rapid visual recovery. Corneal astigmatism after PK arises from a variety of causes such as tight sutures, unequal wound healing, trephination of the donor material, trephination of the recipient bed, and suturing of the donor cornea to the recipient bed. Since none of these factors can be controlled in patients after surgery, early visual recovery is managed by adjustment of the sutures, suture removal, or through refractive procedures such as relaxing incision, compres-

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sion sutures, and wedge resection (1-8).

In this study, we evaluated the influence of various factors on vectorial difference. The factors we studied were the age of the patient, donor-recipient trephine diameter difference, the diagnosis requiring PK, and time of suture removal. We also examined the relationship between the pre–suture removal astigmatism and astigmatic change after suture removal.

METHODS

Between 1999 and 2004, the records of 306 consecutive patients who underwent PK were reviewed. A total of 135 patients were excluded from the study because of the following reasons: no keratometric reading before or after the suture removal (45 eyes); insufficient data about operation (27 eyes); suture reactions or replacement required (18 eyes); operations that could affect astigmatism and cause refractive alteration such as cataract, trabeculectomy, scleral buckling, or cyclocryotherapy (24 eyes); anterior segment diseases such as glaucoma or uveitis (12 eyes); and graft failure (9 eyes).

This study was approved by the Institutional Review Board of Izmir Ataturk Training and Research Hospital.

A total of 171 eyes of 171 patients were included in the study and a standard PK procedure was performed in all eyes. Donor tissue was stored at 4 °C for up to 2 weeks. All operations were performed under local anesthesia. A suction Barron trephine was used to make a circular incision up to about two thirds of the corneal thickness. All donor corneal tissue was trephined larger in diameter ranging from 0.25 to 0.50 mm than the recipient trephination, except for patients with primary keratoconus, in which case same size donor–host trephination was performed. The average donor trephination size was 7.50±0.37 mm (range, 7.0–8.5 mm). After trephination, the donor tissue was fixated to the recipient bed by four cardinal sutures which were placed 90 degrees apart. Subsequently the graft was attached into the recipient cornea by either interrupted sutures for high risk groups like vascularized leukoma, or continuous suturing method by using 10/0 monofilament or by continuous-interrupted suturing combination methods. Cardinal sutures were removed at the end of the operation.

Corneal astigmatism was measured with either an optical keratometer (Javal-Schiotz) or auto-keratorefractometer or both. The astigmatic measurements we examined were those just prior to suture removal and 12 months after suture removal. At the time of suture removal, all existing sutures whether continuous or interrupted were removed completely, since all patients with interrupted sutures in this study were admitted for follow-up to our institution too late, ranging from 15 to 36 months after PK.

The patients whose sutures were removed sequentially were not included in this study.

Results of the quantitative data were expressed as means ± SD. Astigmatic changes after suture removal were represented in two ways: net difference and vectorial difference.

Net difference was calculated by subtraction of the amount of astigmatism before and the first year after suture removal regardless of changes in axis. Negative values indicate decrease in absolute value of astigmatism and positive values indicate increase in astigmatism.

Vectorial difference was found by measurement of the change in keratometric astigmatism after suture removal regarding both the axis shift and amount of astigmatism, as proposed by Jaffe and Clayman (9).

Linear regression analysis was used to examine the relationship between the vector analysis results as the dependent variables and age of the patient, donor–recipient trephine diameter difference, as well as time of suture removal as independent variables.

The patients were divided into three groups according to primary diagnosis requiring PK and three groups according to the astigmatism before the suture removal. The vectorial difference values of all groups were compared with each other by using Kruskal-Wallis test. In addition, Pearson correlation test was used to assess the correlations. Statistical differences among astigmatic changes of the primary diagnosis were determined using StatView (Abacus Concepts, Berkeley, CA) software. Statistical significance was accepted for $p \leq 0.05$. The β value represents regression coefficient for linear regression analysis.

RESULTS

The average age of the 171 patients was 39.5±17.4 years, with a range of 15 to 73 years. A total of 102 of 171 (59.6%) patients were male. The mean follow-up time was 28.40±21.20 months (range, 20–136) and the sutures were removed 5–60 months (mean, 15.24±10.57) after PK. Before suture removal, the mean keratometric cylinder was 4.40±3.24 D; it was 3.96±2.19 D at the comple-

tion of suture removal at 1 year. The mean net difference of the patients was –0.27±3.50, indicating a decrease in astigmatism after suture removal. The keratometric changes were also evaluated by vector analysis. The mean absolute value of the cylinder vectorial difference for all patients was 4.93±4.02 D (range, 0.16–19.51).

On first year examination after suture removal, we found a change of less than 20 degrees in the axis in 93 patients (65%) and more than 20 degrees in 78 (35%) patients.

All suture-removed patients were classified according to their astigmatic values before the suture removal as patients with less than 3 diopters (D) of astigmatism, patients with 3–6 D of astigmatism, and patients with over 6 D of astigmatism. Then, comparisons were performed among all the groups using their vector analysis (Tab. I). The greater than 6 D of astigmatism group had the highest mean vectorial difference among all the groups after the suture removal. We also studied the correlation between the astigmatism before the suture removal and vectorial difference and found a significant positive correlation (r=0.615, p=0.038). With the astigmatism axis, there was no correlation of the measurements between the pre–suture removal axis and vectorial difference astigmatism axis. The evaluation of the results revealed that the vectorial difference values were higher in patients with high astigmatism before the suture removal.

The trephine diameter differences used in the operation were 0.50 and 0.25 mm in 93 (54.4%) and 33 (19.3%) patients, respectively. All of the 42 (24.5%) patients with keratoconus had the same recipient and donor diameter. There was a statistically significant negative correlation between the trephine diameter difference and the vectorial difference astigmatism (r=–0.582, p<0.01). When the vectorial difference values were compared with the possible factors by linear regression analysis, we found that the trephine diameter difference significantly affected the astigmatism (p=0.007, ß: –0.489, 95% confidence intervals for ß; lower bound: –0.764 and upper_bound: –0.283) and axis (p=0.028, ß: 0.291, 95% confidence intervals for ß; lower bound:.05 and upper bound: –0.632). On the other hand, there was no correlation between the age of the patient and time of suture removal and vectorial difference. The relationships of the vectorial difference values among the factors affecting changes in astigmatism are shown in Table II.

In the study, the primary diagnosis was keratoconus in 42 (42.5%), leukoma in 81, dystrophy in 39 (22.8%), and bullous keratopathy in 9 eyes. We divided the patients into the three groups to make a comparison according to the primary diagnosis. Since the number of patients with bullous keratopathy was too small, they were added into the leukoma group. The least astigmatic change was found in the dystrophy group. The vectorial difference values among the groups were significantly different in the pa-

TABLE I - VECTORIAL DIFFERENCE OF ASTIGMATISM ACCORDING TO ASTIGMATISM BEFORE SUTURE REMOVAL

Astigmatism before suture removal, D	Patient no.	Vectorial difference (VD) mean ± SD
<3	60	3.2±1.7
3–6	75	4.4±3.0
>6	36	8.8±5.8

Overall p<0.05 (Kruskal-Wallis test).
VD between <3D and >6D; p<0.01 by Mann-Whitney U test.
VD between 3-6 D and >6D; p<0.05 by Mann-Whitney U test

TABLE II - THE CORRELATION (R) BETWEEN THE VECTORIAL DIFFERENCE VALUES AND THE FACTORS AFFECTING CHANGES IN ASTIGMATISM

Vectorial difference TSR	Age	Factors TDD
Cylindric 0.147	–0.018	–0.582*
Axis –0.249	–0.027	–0.431†

* p<0.01, †p<0.05 by linear regression analysis.
TDD = trephine diameter difference; TSR = Time of suture removal.

TABLE III - THE MEAN MEASURES OF VECTORIAL DIFFERENCE ACCORDING TO THE PRIMARY DIAGNOSIS

Primary diagnosis	Difference vector values (DVVs) Cylindric mean ± SD	Axis mean ± SD
Keratoconus (n=42)	6.6±6.0	132.8±56.2
Leukoma (n=90)	3.21±2.1	97.4±33.6
Dystrophy (n=39)	4.9±3.2	103.5±41.9
p value (Kruskal-Wallis test)	<0.05	NS

DVV (cylindric) between keratoconus and leukoma; p<0.01 by Mann-Whitney test. DVV (cylindric) between keratoconus and dystrophy; p<0.05 by Mann-Whitney U test.

tients with keratoconus. The comparisons and data according to the primary diagnosis are shown in Table III.

DISCUSSION

PK has improved significantly during past decades due to advances in surgical techniques. However, post-keratoplasty astigmatism over 6 D has been shown to occur in about 20% to 30% of patients (10). Much effort has been directed toward the prevention of astigmatism after PK recently (11). Williams et al evaluated 60 patients who underwent PK with different preoperative diagnoses and noted that 38% of patients had 5 or more D of astigmatism (12). In our study the mean astigmatic level (4.40±3.24 D) before suture removal was found to be similar to other studies.

In patients with high astigmatism, the expectation for early visual recovery could be achieved by suture intervention (13-16). However, early suture removal carries risk of wound dehiscence and subsequent infection (15). Early selective suture removal in patients with multiple interrupted sutures and early postoperative suture adjustment in patients with continuous running sutures have been recommended (14, 15, 17, 18). At the time of suture removal, all existing sutures whether continuous or interrupted were removed completely, since all patients with interrupted sutures in this study were admitted for follow-up to our institution too late, ranging from 15 to 36 months after PK. Therefore, the comparison was not made in terms of suture removal technique in the present study.

Although the influence of various factors on post–suture removal astigmatism after penetrating keratoplasty has been previously studied (12, 19), to our knowledge, the factors affecting changes in astigmatism before and after suture removal have been analyzed in a limited study by Mader et al (19). In our study, we assessed the influence of age of the patient, donor–recipient trephine diameter difference, time of suture removal, and the primary diagnosis requiring PK on vectorial difference. We also examined the relationship between pre–suture removal astigmatism and the astigmatic shift after suture removal.

We found a significant negative correlation between trephine diameter difference and astigmatic shift following suture removal. But we also found a significant positive correlation between pre-PK diagnosis of keratoconus and astigmatic shift following suture removal. Since we used 0 mm trephine diameter difference in all keratoconus patients we are not sure if the pre-PK diagnosis of keratoconus independently correlates with astigmatic shift following suture removal.

Few studies reported that the astigmatism significantly decreased by suture removal following PK in patients with high astigmatic levels before the suture removal (19, 20). We found the astigmatic change over 2 D in 12 of 16 patients (81%) with 6 D or more astigmatism before the suture removal. On the basis of our findings, the astigmatic level of patients with higher astigmatism before suture removal predicted greater decrease after suture removal, when compared to the patients with lower astigmatism.

Mader et al reported that unpredictable high changes could occur in a period of 1 year after the suture removal (19). Some published series have shown that irregular astigmatism occurs frequently when interrupted sutures are still in place (21-25). Suture removal usually performed 1 year or later postoperatively may induce substantial changes in refraction (15-26). Approximately 25% of these patients had a final postoperative refractive cylinder higher than 4.5 D (24, 26). We also classified the patients in our study group according to their suture removal times. Then, we compared the vectorial difference values of patients and found no statistically significant difference between vectorial difference and suture removal time ($p=0.147$). However, the change over 2 D has been recognized in 54% of the patients with the suture removal before 1 year and 62% of patients with the suture removal after 1 year. Our finding that significant astigmatic shifts may occur when sutures are removed after 1 year postoperatively is in agreement with the study by Mader et al demonstrating the compressive effect of the sutures even after 1 year (19).

Mader et al reported that the sutures of the patients with astigmatism less than 3 D and no suture-related complication need not be removed because unexpected astigmatic shifts may occur after suture removal (19). However, astigmatic change, vascularization, inflammation, subepithelial fibrosis, infectious keratitis, and even endophthalmitis could occur because of the degeneration of nylon material as late suture complication (20, 22).

The change in axis is as important as the change in astigmatism for visual rehabilitation. Of 171 patients in our study, 99 (57.8%) had less than 20º change in the axis of astigmatism, while 63 (36.8%) had a change between 30º and 90º. Thus, it is possible that suture removal may cause significant levels of rotation in the visual axis.

Musch et al reported that the axis change was seen in 84 patients with double continuous sutures 1 year after the suture removal (23). They also found that 84% of these patients had an axis change below 20º. The axis change was present below 20º in 45% of 130 patients with single continuous sutures in Mader et al's study (19).

Seitz et al evaluated the mean astigmatic change before and after suture removal following PK by measuring refraction, keratometry, and topography in two groups of patients, one assigned to trephination with the 193-nm Meditec excimer laser and the other assigned to trephination with hand-held motorized trephine (27). They reported that although mean astigmatism did not differ between the excimer and motorized trephine group before suture removal, astigmatism after suture removal was significantly lower in the excimer group than in the control group (27).

We used Barron vacuum trephination system and all of our donors were punched from the endothelial side and compared the vectorial difference value to donor–recipient trephine diameter difference. We found statistically significant difference in vectorial difference astigmatism in terms of trephine-punch diameter difference. This result was contrary to that of Mader et al's study (19). In addition, Jensen and Maumenee reported in a study including 99 patients with keratoplasty that the donor graft diameter did not affect the residual astigmatism (1).

The studies investigating the relationship between the preoperative diagnoses and astigmatic changes showed no statistically significant difference between the keratoconus patients and patients with another diagnosis (1, 19, 23). In our study there was a statistically significant vectorial difference in astigmatism in patients with preoperative diagnosis of keratoconus. The group with keratoconus has a significant change in astigmatism after the suture removal compared to the other groups (p=0.0062).

In conclusion, significant high levels of astigmatic change due to donor–recipient trephine diameter difference and underlying primary diagnosis of keratoconus could be encountered after suture removal following PK. On the other hand, after suture removal, there is a greater risk of increased astigmatic change in a patient with high pre–suture removal astigmatism as compared to a patient with low pre–suture removal astigmatism.

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