Int J Clin Exp Med 2015;8(2):2607-2613
www.ijcem.com /ISSN:1940-5901/IJCEM0003385

Original Article

Clinical outcomes of non-torque pattern double running suture technique for optical penetrating keratoplasty

Xu Wang[1*], Chong-Hui Fan[2*], Yang Gao[1], Lian Duan[1], Guang-Fu Dang[1]

[1]Department of Ophthalmology, Shandong Provincial Qianfoshan Hospital, Medical School of Shandong University, Jinan, China; [2]Department of Ophthalmology, Longkou Longkuang Central Hospital, Yantai, China. [*]Equal contributors.

Received October 25, 2014; Accepted January 21, 2015; Epub February 15, 2015; Published February 28, 2015

Abstract: Objective: To validate non-torque pattern double running suture technique for optical penetrating keratoplasty compared with traditional suture method. Methods: 56 patients (56 eyes) undergoing optical penetrating keratoplasty were divided into two groups. The experimental group (28 cases) underwent non-torque pattern double running suture technique, and the control group (28 cases) underwent interrupted suture. All participants were followed up at 2 weeks, 2 months, 6 months, and 1 year postoperatively. The best corrected visual acuity (BCVA), corneal curvature change and astigmatism change were observed and compared between the two groups, and corneal topographer was used to measure refractive change. Results: BCVA in experimental group was significantly improved ($P<0.05$); the corneal topographer showed that astigmatism in experimental group was significantly lower than that in control group at the early postoperative phase ($P<0.001$). Six months later postoperatively, astigmatism gap between the two groups was narrowed, but the differences were still statistically significant ($P<0.001$). Twelve months later, astigmatism in the experimental group was similar to six months ago, but astigmatism in control group reduced significantly. No significant difference in astigmatism was observed between two groups ($P>0.05$). Conclusion: Non-torque pattern double running suture technique for optical penetrating keratoplasty can achieve the BCVA at the very early phase, with stable postoperative refractive status. This novel suture method is accurate and safe with elegant appearance.

Keywords: Keratoplasty, optical penetrating, non-torque, double running suture

Introduction

For optical penetrating keratoplasty, the surgically induced astigmatism will affect the postoperative vision recovery. The tissue alignment between the grafts and the recipient bed, the matching degree, graft diameter, underlying diagnosis of the recipient, wound configuration abnormality, suture skills and suture methods are the main causes of astigmatism currently [1]. There are plentiful suturing techniques used in corneal graft retention, which are dependent upon surgeon preference [2]. Two of the most commonly used suture methods are radially placed interrupted (individual) sutures and continuous sutures [3]. With the development of microscope instruments, the increased application of matched grafts, and the improvement of surgical skills, the suture method has been the main cause of astigmatism currently [3, 4]. Many researchers tried to develop novel suture methods to reduce astigmatism [5, 6]. The presented study aimed to design and improve a non-torque pattern double running suture technique for optical penetrating keratoplasty and observe the optical outcomes postoperatively.

Methods and materials

General information

From January 2011 to June 2013 in Ophthalmology Department, Shandong Qianfoshan Hospital, 56 patients undergoing optical penetrating keratoplasty were included in the study. According to different suture methods, all participants were divided into two groups randomly. The experimental group (28 cases) receiving non-torque pattern double running suture tech-

Table 1. Basic information for both groups

Group	Age (yrs)	Gender	Number (eyes)	Diagnosis before surgery			
				Keratoconus	Keratoleukoma	Bullous keratopathy	Patchy corneal degeneration
Experimental group	38.07±17.51	M	18	11	4	2	1
		F	10	2	3	3	2
Control group	39.75±17.82	M	15	8	6	1	0
		F	13	2	4	3	4

nique included 18 men (18 eyes) and 10 women (10 eyes), whose age ranged from 17 to 68 years (mean age 38.07±17.51 years) and were followed up 1-3 years (mean follow-ups 2.01±0.59 years). The control group (28 cases) undergoing interrupted suture included 15 men (15 eyes) and 13 women (13 eyes), whose age ranged from 15 to 71 years (mean age 39.75±17.82 years) and were followed up for 1-3 years (mean follow-ups 1.98±0.63 years) (**Table 1**).

Preoperative examinations

The medical histories of the patients were reviewed, and their visual acuities were examined. Slit-lamp examination was conducted to identify the corneal condition. Ophthalmological ultrasound was used to exclude vitreous body and retina diseases.

Operating procedure

All surgeries were conducted under general anesthesia by one experienced surgeon.

Firstly, corneal graft was fixed by 4 sutures (cardinal sutures) at 12 o'clock, 6 o'clock, 3 o'clock and 9 o'clock respectively keeping sutures on the vertical and horizontal directions from surgeon's perspective. These sutures were required to remain the same length (about 1 mm) in both corneal graft and corneal recipient bed. Withdrawal pinhole and insert pinhole formed the two virtual circles, virtual circle 1 and 2, respectively (**Figure 1**).

The midpoint "B" of the arc between 3 o'clock and 6 o'clock on virtual circle 1 and its parallel line with sutures at 6 o'clock were marked. The crossover point of the parallel line and the edge of corneal recipient bed was the first insert pinhole of double running sutures. Paralleling with suture at 6 o'clock, suture needle was inserted and withdrawn from the crossover point "C" on the virtual circle 2. After withdrawal from crossover point "C", suture needle was inserted into corneal graft at 6 o'clock on virtual circle 1 (**Figure 1**). The insert direction of suture needle had a 45° angle with sutures at 6 o'clock and was perpendicular to the first suture to ensure that the angle between adjacent two sutures on virtual circle 1 was 90°. The final suture (the eighth suture) was inserted into crossover point "B" on virtual circle 1 and withdrawn at crossover point "A" on real circle of the corneal graft overlapped with the first insert pinhole. With a triple reef knot, the knot was buried in the incision to avoid being exposed.

The first insert pinhole's position of second round continuous suture inserting on the corneal recipient bed depended on surgeon's habit. Each insert pinhole on the corneal graft was at the midpoint of adjacent two insert pinholes of the first round sutures (**Figure 1**). All sutures depth was more than 80% corneal thickness.

The follow-up time was up to one year (**Figure 2**). The intraocular pressure change, postoperative complications and visual acuity including change of the BCVA, corneal topography curvature change and objective optometry astigmatism change were recorded at 2 weeks, 2 months, 6 months and 1 year after surgery. All these data were analyzed by SPSS 170.0 software. Different analyzing methods were adopted to analyze to statistics according to their different characteristics and objectives. t test was used to compare BCVA, corneal curvature and astigmatism between two groups. $P>0.05$ was considered to be significantly different.

Results

Changes of the best corrected visual acuity (BCAV)

At 2 weeks postoperatively (pre-discharge), the BCAV in the experiment group was 4.53±0.18, which was averagely improved. The BCAV in the

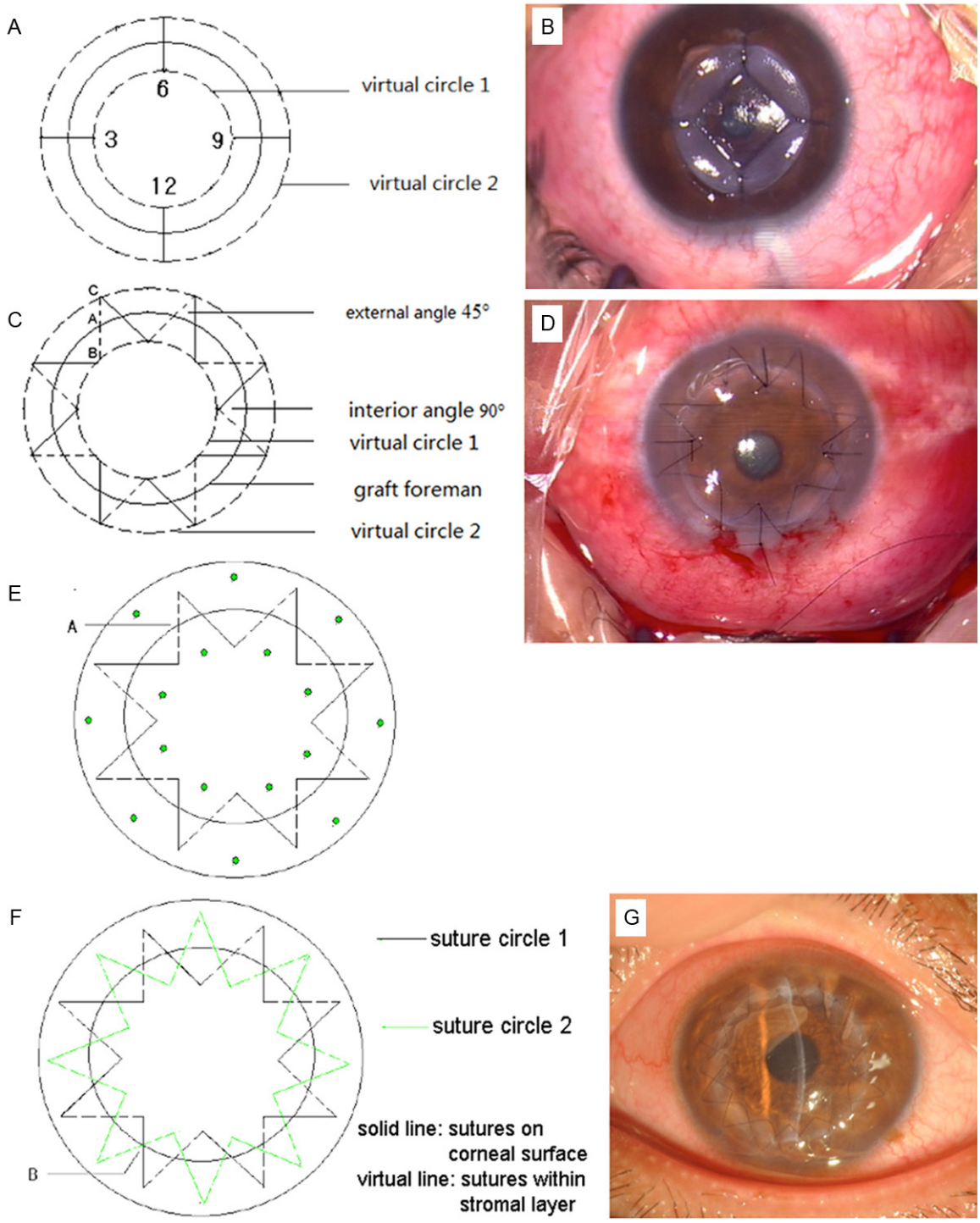

Figure 1. A, B: The initial 4 sutures fixing the corneal graft and the two virtual circles that have the same distance from the circular boundary of implantation hole respectively. C, D: Schematic diagram after first round of continuous suture. A: crossover point of the parallel line of B with sutures at 6 o'clock on real circle of the corneal graft; B: on of the arc between 3 o'clock and 6 o'clock on virtual circle 1; C: crossover point of the parallel line of B with sutures at 6 o'clock on the virtual circle 2. E: The distribution of the second round sutures on insert pinholes and withdrawal pinholes. Point A was on real circle of the corneal graft overlapped with the first insert pinhole. F, G: Postoperative sketch of non-torque pattern double running suture technique: Point B was the knot of the second round suture.

control group was 4.31±0.23, which was averagely improved. The differences between the two groups were statistically significant (paired t=3.217, P<0.05). Comparisons of visual acuity

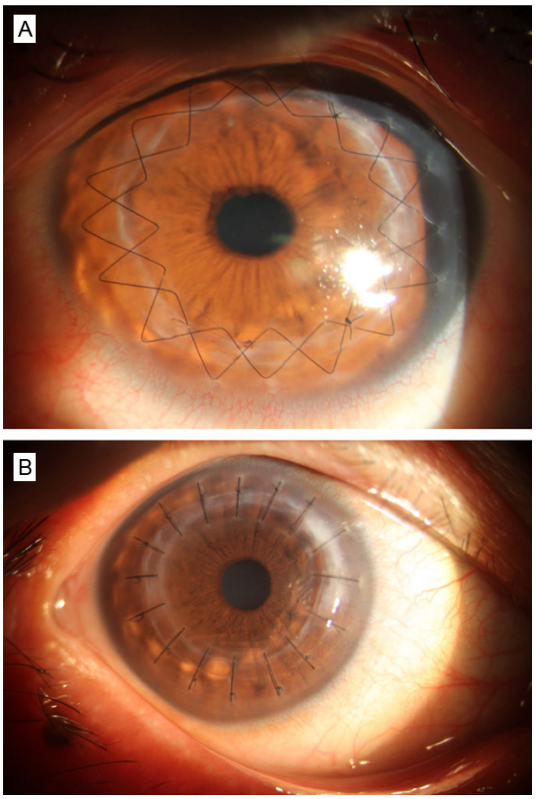

Figure 2. Postoperative effect at the one-year follow-up (A) experimental group; (B) control group.

at 2 months, 6 months and 1 year postoperatively are shown in **Table 2**.

Postoperative changes of corneal curvature and astigmatism

1) Corneal topographer astigmatism examination: Corneal topographer in early postoperative phase postoperatively showed that astigmatism in experiment group was lower than that in control group. Two weeks later postoperatively, there had statistically significant differences in the astigmatism between the two groups (t test, t=-11.765, P<0.001). Two months later postoperatively, there had statistically significant differences in the astigmatism between the two groups (t test, t=-10.331, P<0.001). Six months later postoperatively, the astigmatism in experimental group increased slightly while astigmatism in control group decreased slightly (t test, t=-7.458, P<0.001). Twelve months later postoperatively, the astigmatism in experimental group had no significant change, but astigmatism in control group decreased significantly. There had no statistically significant differences in the astigmatism between the two groups (t=-0.929, P>0.05) (**Table 2**).

2) Objective optometry examination astigmatism: objective optometry examination of astigmatism in early postoperative phase showed that astigmatism in experiment group was significantly lower than that in control group (t test, t=-14.468, P<0.001). Six months later postoperatively, astigmatism in experimental group increased slightly, while astigmatism in control group decreased slightly. There had statistically significant differences in the astigmatism between the two groups (t test, t=-3.777, P<0.001). Twelve months later postoperatively, astigmatism in experimental group had no significant change, but astigmatism in control group decreased significantly. The astigmatism differences between the two groups were not statistically significant (t test, t=0.455, P>0.05) (**Table 2**).

Discussion

With the development of microsurgery and the gradual advance of microscope instruments and sutures, corneal suture technology gains a huge progression. Plenty of in-depth researches compared the double running suture and single suture technology, most of which deemed that double running suture technology achieved the least postoperative astigmatism [7].

Non-torque sutures achieve less surgically induced astigmatism

According to different ways of sutures, continuous suture were divided into torque suture (Torque pattern), twisting torque suture (Antitorque pattern) and non-torque suture (Non-torque pattern) [8]. Torque suture and twisting torque suture achieved more surgically induced astigmatism than non-torque suture.

The tensile force produced by torque suture was radial extrusion force pointing to center of circle acting an anticlockwise warping force on corneal graft. Twisting torque suture produced a resultant force combined by clockwise tensile force paralleling with implantation hole tangent and radial extrusion force pointing to center of circle. Therefore, twisting torque suture acted as a clockwise warping force on corneal graft. Non-torque suture produced inclined tensile forces, which were resultant force combined by two tensile forces (one was clockwise, and the

Table 2. The clinical outcomes between experimental and control group

		Experimental group	Control group	t	*p* value
BCVA change	Two weeks	4.53±0.18	4.31±0.23	3.217	0.003
	2 months	4.61±0.09	4.37±0.22	5.256	0.000
	6 months	4.73±0.16	4.59±0.23	3.193	0.004
	1 year	4.78±0.14	4.71±0.17	1.585	0.125
Corneal topographer astigmatism	Two weeks	3.18±1.01	6.69±1.25	-11.765	0.000
	2 months	3.59±0.96	6.71±1.26	-10.331	0.000
	6 months	3.51±1.02	4.59±1.03	-7.458	0.000
	1 year	2.54±0.67	2.70±0.71	-0.929	0.361
Objective optometry examining astigmatism	Two weeks	2.83±0.74	5.78±1.06	-14.468	0.000
	2 months	3.11±0.76	5.89±0.99	-12.846	0.000
	6 months	3.10±0.92	3.88±0.69	-3.777	0.001
	1 year	2.64±0.76	2.87±0.80	-1.151	0.260

other was anticlockwise) paralleling with implantation hole tangent and extrusion force pointing to center of circle.

If the angles of adjacent two sutures were equal, the tensile force paralleling with tangent might counteract to remain the radial extrusion force. Obviously, the extrusion force was less than extrusion force produced by torque suture. Similarly, unidirectional warping force produced by twisting torque suture was not produced in the non-torque suture. As a result, astigmatism in the no torque suture was less.

The modified double running suture in current study was a typical non-torque suture pattern with the same suture angles. Our study showed that the incidence of postoperative astigmatism in the experimental group reduced, and patients gained better naked vision in the early postoperative phase.

The initial 4 sutures are the key to successful sutures

Seitz B1 [9] pointed out that the unfavorable position of the initial 4 sutures in the optical penetrating keratoplasty would lead to torsion of corneal graft on the horizontal direction or on the vertical direction. The corneal graft deviated from implantation hole was one of the main reasons accounting for postoperative astigmatism. The initial 4 sutures were more essential to the non-torque pattern double running suture technique designed by our study. The opposite 2 sutures must be in a straight line and the adjacent 2 sutures direction must be perpendicular to ensure the four pinholes on the corneal graft forming a standard square and the equal span of each suture. The modified suture in the study did need to meet the requirement.

(1) Equal span of the following sutures.

The double running suture described in the article included two circle of continuous suture lines each consisting of eight sutures. Suture direction was clockwise with suture needle inserting into corneal graft and was withdrawn out of the recipient (the first needle was inserted into blade edge of recipient bed and withdrawn out of the blade edge of corneal graft and then knotted, so that the line knot was buried in the corneal stroma layer of blade edge). The virtual circle 1 on the corneal graft consisting of 8 insert pinholes and the virtual circle 2 on the recipient bed consisting of eight withdrawal pinholes held the equal distance to the actual circle consisting of the boundary of implantation hole. The distance determined by the initial 4 sutures ensured the equal suture distance of each suture on the corneal graft and corneal recipient bed and set a reference for the followed sutures.

(2) Suture angle of inside and outside the corneal are kept at 90° and 45° respectively.

For the linkage of the first and second sutures, we could conclude that directions of the two sutures were symmetrical with 6 o'clock suture line (preset reference suture line) as axis. The directions of these two suture lines were on the link of 9 o'clock and 6 o'clock and the extension of link of the 3 o'clock and 6 o'clock respec-

tively. The angel of the two sutures was 90°, because we should set four sutures to fix a square. The first sutures were parallel with suture at 6 o'clock, so the suture angle outside corneal graft was 45°. That kept the distance between the two sutures equal.

Modified suture method is safer

According to modified double running suture method, the second round sutures would not cut off the first round sutures. This was due to that the crossover point would be never on the same plane on the actual circle formed by corneal recipient bed and corneal graft. That was to way, the final portion of the sutures were in the corneal stroma, while the sutures of the other round were on the surface of cornea.

It has been reported that if the tensile force suture line applied on the corneal graft and recipient bed were not well distributed, or the suture span was not symmetric, suture cutting through the cornea phenomenon would be produced [10]. That might result into tissue tearing on one side or two sides, suture line loss, even the whole suture line falling off. Besides, it would also lead to microbe entering corneal deep stroma, even anterior chamber from the loosen suture line, which would result in severe intraocular infection.

The angle formed by the adjacent suture line of suture method in this study was completely (or basically) equal and so were the force on the vertical direction and the horizontal direction. As a result, well-distributed tensile force applied on the corneal graft and recipient bed would avoid suture cutting through the cornea phenomenon's occurrence.

The sutures with elegant appearance and low operative astigmatism should accord with the followings: 1). The distance of each suture was equal. The distance between each insert pinhole and each withdrawal pinhole was equal. 2). Span of each suture was equal, in other words, the span of sutures on the corneal graft and corneal recipient bed were equal. 3). The tensile force of each sutures were well distributed to ensure less crease on the inner cuticle [11]. The study modified the traditional double running suture method of corneal graft and adopted non-torque suture method designed by a prospective way. Our modified suture method permitted surgeons to set references to conduct next procedure constantly with a fixed process and standard operation. The presented study was consistent with the above three conditions, and the postoperative astigmatism were reduced to gain a satisfied optical transplantation effect.

Disclosure of conflict of interest

None.

Address correspondence to: Guang-Fu Dang, Department of Ophthalmology, Shandong Provincial Qianfoshan Hospital, Medical School of Shandong University, No. 16766 Jingshi Road, Jinan 250014, Shandong Province, China. E-mail: dangguangfu_00@163.com

References

[1] Serdarevic ON, Renard GJ and Pouliquen Y. Randomized clinical trial comparing astigmatism and visual rehabilitation after penetrating keratoplasty with and without intraoperative suture adjustment. Ophthalmology 1994; 101: 990-999.

[2] Ljunggren MK, Elizondo RA, Edin J, Olsen D, Merrett K, Lee CJ, Salerud G, Polarek J, Fagerholm P and Griffith M. Effect of surgical technique on corneal implant performance. Transl Vis Sci Technol 2014; 3: 6.

[3] Lee RM, Lam FC, Georgiou T, Paul B, Then KY, Mavrikakis I, Avadhanam VS and Liu CS. Suturing techniques and postoperative management in penetrating keratoplasty in the United Kingdom. Clin Ophthalmol 2012; 6: 1335-1340.

[4] Kim SJ, Wee WR, Lee JH and Kim MK. The effect of different suturing techniques on astigmatism after penetrating keratoplasty. J Korean Med Sci 2008; 23: 1015-1019.

[5] Fares U, Mokashi AA, Al-Aqaba MA, Otri AM, Miri A and Dua HS. Management of postkeratoplasty astigmatism by paired arcuate incisions with compression sutures. Br J Ophthalmol 2013; 97: 438-443.

[6] Khokhar S, Agarwal T, Gupta S, Sehra S and Panda A. Shifting bubble-guided sutureless technique for performing descemetorhexis for retained Descemet's membrane after penetrating keratoplasty. Int Ophthalmol 2014; 34: 125-128.

[7] Naydis I, Klemm M, Hassenstein A, Richard G, Katz T and Linke SJ. [Postkeratoplasty astigmatism: comparison of three suturing techniques]. Ophthalmologe 2011; 108: 252-259.

[8] Vajpayee RB, Sharma V, Sharma N, Panda A and Taylor HR. Evaluation of techniques of

single continuous suturing in penetrating keratoplasty. Br J Ophthalmol 2001; 85: 134-138.
[9] Ramirez M, Hodge DO and Bourne WM. Keratometric results during the first year after keratoplasty: adjustable single running suture technique versus double running suture technique. Ophthalmic Surg Lasers 2001; 32: 370-374.
[10] Huang T, Chen JQ, Chen LS and Liu ZG. [Clinical observation of wound dehiscence after penetrating keratoplasty]. Zhonghua Yan Ke Za Zhi 2006; 42: 12-16.
[11] Fares U, Sarhan AR and Dua HS. Management of post-keratoplasty astigmatism. J Cataract Refract Surg 2012; 38: 2029-2039.