·Clinical Research·

Surgical induced astigmatism correlated with corneal pachymetry and intraocular pressure: transconjunctival sutureless 23-gauge versus 20-gauge sutured vitrectomy in diabetes mellitus

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Abstract

• **AIM: To determine the difference of surgical induced astigmatism between conventional 20-gauge sutured vitrectomy and 23-gauge transconjunctival sutureless vitrectomy, and the influence of corneal pachymetry and intraocular pressure (IOP) on surgical induced astigmatism in diabetic patients.**

• **METHODS: This retrospective, consecutive case series consisted of 40 eyes of 38 diabetic subjects who underwent either 20-gauge or 23-gauge vitrectomy. The corneal curvature and thickness were measured with Scheimpflug imaging before surgery and 1wk; 1, 3mo after surgery. We compared the surgical induced astigmatism (SIA) on the true net power in 23-gauge group with that in 20-gauge group. We determined the correlation between corneal thickness change ratio, IOP and SIA measured by Pentacam.**

• **RESULTS: The mean SIAs were 1.082±0.085 D (mean±SEM), 0.689±0.070 D and 0.459±0.063 D at postoperative 1wk; 1, 3mo respectively in diabetic subjects. The vitrectomy induced astigmatisms were declined significantly with time ($F_{2,36}$=33.629, P=0.000) postoperatively. The 23-gauge surgery group induced significantly less astigmatism than 20-gauge surgery group ($F_{1,37}$=11.046, P=0.020). Corneal thickness in diabetes elevated after surgery ($F_{3,78}$=10.532, P=0.000). The linear regression analysis at postoperatively 1wk went as: SIA=-4.519+4.931 change ratio (Port$_3$) +0.026 IOP (R^2=0.46, P=0.000), whereas the rate of corneal thickness change and IOP showed no correlation with the change of astigmatism at postoperatively 1 and 3mo.**

• **CONCLUSION: There are significant serial changes in both 20-gauge and 23-gauge group in diabetic subjects. 23-gauge induce less astigmatism than 20-gauge and become stable more rapidly than 20-gauge. The elevation of corneal thickness and IOP was associated with increased astigmatim at the early postoperative stage both in 23-gauge and 20-gauge surgery group.**

• **KEYWORDS:** astigmatism; corneal pachymetry; vitrectomy; intraocular pressure; diabetes mellitus

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INTRODUCTION

The presence of astigmatism can lead to substantial reductions in visual performance. Both short and longer term adaptations to astigmatism occur in the visual system[1]. The significant visual and functional impacts of astigmatism emphasize the importance of control of surgical induced astigmatism (SIA). Quality assurance of SIA has therefore becaome a public health issue, and analysis of SIA is as important as the technical part of the procedure. The aim of surgery is to achieve a good visual function with the refraction tailored to each patient's needs. Recently, transconjunctival sutureless vitrectomy (TSV) has gained in popularity, as a lot of clinical studies have shown its clinical efficacy. By eliminating the need for scleral cautery or suture, shortening surgical time and lessening postoperative inflammation, TSV can reduce SIA. There have been some studies focusing on corneal topography changes following TSV. Using Fourier harmonic analysis, Okamoto *et al*[2] found that 20-gauge vitrectomy group had significant changes in corneal topography, whereas the 25-gauge TSV group did

Table 1 Clinical characteristics of the subjects

Parameters	23-gauge vitrectomy	20-gauge vitrectomy	*P*
No. of eyes	20	20	
M/F	9/10	11/8	[1]0.515
Age (a)	53.0±9.3	50.2±13.3	[2]0.114
Duration of diabetes (a)	9.8±7.8	12.7±5.7	[2]0.083
Tamponade (fluid/gas/silicon oil)	12/5/3	11/6/3	[3]0.101
Surgical time (min)	56.5±19.1	67.5±25.4	[2]0.159

[1]Wilcoxon test, Pearson Chi-square; [2]Independent-samples *t* test; [3]Wilcoxon test, Fisher's Exact Test.

not. Beacause the sclerotomy size in 23-gauge TSV is larger than 25-gauge, dose the 23-gauge vitrectomy have a greater potential for causing SIA? However, Kim *et al* [3] evaluated the SIA following 23-gauge TSV or TSV combined with cataract surgery, with Naeser's polar method using the simulated keratometric values. No significant serial changes were found in patients receiving the 23-gauge TSV, whereas in the patients subjected to the TSV combined with cataract surgery, the postoperative △KP showed a significant decrease. Diabetic subjects may differ from the non-diabetic with regards to many properties of the cornea [4,5]. However, there is no report about the effect of pachymetry and intraocular pressure (IOP) on SIA changes in diabetic patients. We hypothesis that 23-gauge TSV reduced the topography change than 20-gauge vitrectomy in diabetic subjects, and corneal thickness and IOP may have influence on SIA. Thus, we performed this study to compare SIA after 20-gauge with 23-gauge TSV, and the influence of corneal thickness and IOP on SIA. By controlling these influence factors, doctors could make patients get best vision as soon as possible.

SUBJECTS AND METHODS

Subjects The study is a retrospective, non-randomised consecutive case series of vitrectomies performed by a single surgeon (Li XR). A total of 38 diabetic subjects (40 eyes) were recruited at the Tianjin Medical University Eye Hospital (Table 1). Experimental procedures were approved by an Institutional Review Board and complied with the tenets of the Declaration of Helsinki. The surgery was performed to treat proliferative diabetic retinopathy. Exclusion criteria included: 1) astigmatism before surgery ＞1 D; 2) ocular surgery, trauma history or pathology altering corneal topography (*e.g.* dystrophies, degeneration, and ulcers); 3) absence of a complete record including pre- and post-vitrectomy keratography, pachymetry and IOP data.

Methods

Surgical procedures The surgical procedures were performed by a single surgeon from November 2012 to August 2013. Each patient under local anesthesia underwent vitrectomy. Briefly, pars plana sclerotomies were performed in both groups at 4.0 mm posterior to the corneal limbus at the 2-, 8-, 10-o'clock positions in the right eyes and at the 2-, 4-, 10-o'clock positions in the left eyes. All 20-gauge patients underwent standard 3-port pars plana vitectomy (Accurus surgical system; Alcon Laboratories, Inc., Fort Worth, TX, USA). After conjunctival peritomy, the sclera was exposed and cautery was applied for hemostasis. Sclerotomies were generated with a 20-gauge myringo-vitreal-retinal blade at 4 mm from the limbus. At the end of the operation, sclerotomies and conjunctival peritomies were sutured by absorbable 8-0 polyglacin sutures (Vicryl; Ethicon, Norderstedt, Germany), respectively. The 23-gauge surgery (Constellation surgical system; Alcon Laboratories, Inc, Fort Worth, TX, USA) was performed by single-step technique (Beveled incision). The conjunctiva is displaced laterally. The trocar is then inserted intrasclerally at 45° to the surface, changing the direction tangential to the ocular surface once the sclera has penetrated fully. This causes a valve-like effect to occur and helps in wound apposition. The inferotemporal sclerotomy was the site of infusion, and both superior quadrant sclerotomies were used for intraocular instrumentation. For most of surgery time, the 10-o'clock site was for vitrectomy, and the 2-o'clock site was for illumination, hence we defined 10-o'clock as vitrectomy site and 2-o'clock as illumination site for both eyes, and the 8-o'clock in right eye, 4-o'clock in left eye as infusion site respectively. All eyes underwent core vitrectomy followed by elevation and removal of the posterior hyaloids membrane. In eyes with diabetic macular edema, the internal limiting membrane was dissected and removed with microforceps after brilliant blue G staining at the discretion of the surgeon. Fluid gas exchange was performed in 9 cases in 20-gauge group and 8 cases in 23-gauge group; in these, either perfluoropropane-air mixture or sterile air was used.

At presentation, all patients were phakic in the affected eye. Measurements were made using a scheimpflug imaging examination. Vector analysis of pre- and post-vitrectomy readings was performed using Jaffe and Clayman's method.

Scheimpflug imaging examination Previously, only the topography of the anterior corneal surface has been described, and the accurate data on the shape of the posterior surface of the cornea have been rather deficient, despite the considerable contribution of the posterior surface to total corneal power. A Scheimpflug imaging-based commercial

Table 2 Comparison of SIA at each follow-up time in 23-gauge and 20-gauge group $\bar{x}\pm s$

Groups	23-gauge vitrectomy		20-gauge vitrectomy	
	Difference	*P*	Difference	*P*
SIA_{1wk} *vs* SIA_{1mo}	0.383±0.071	0.000[a]	0.404±0.089	0.010[a]
SIA_{1wk} *vs* SIA_{3mo}	0.432±0.062	0.000[a]	0.814±0.135	0.000[a]
SIA_{1mo} *vs* SIA_{3mo}	0.049±0.019	0.051	0.411±0.088	0.000[a]

SIA: Surgical induced astigmatism. Post hoc analysis was worked out by the Mann-Whitney test. [a]$P<0.05$.

device, the Pentacam (Oculus GmbH, Wetzler, Germany) has recently become available to assess the corneal topography[6]. This system allows for calculation of posterior corneal elevation without mathematical reconstruction [7]. In this study, we presented measurements of the topography and pachmetry by using Pentacam. A detailed reference database was generated to determine the shape of both anterior and posterior corneal surface in postoperative astigmatism.

Data Collection and Analysis SIA and axis of SIA were calculated on true net power using vector analysis of Jaffe and Clayman [8], which were characterized by both astigmatic magnitude and direction. Thickness values from four corneal zone were obtained, including central corneal thickness, 3 peripheral cornea ports that were the intersection of 3 mm away from vertex of cornea on vertical and 240°, 120°, 60° meridian (right eye) or 300°, 120°, 60° meridian (left eye). Central corneal thickness ($Port_1$) was given by Pentacam automatically and other 3 sites representing cornea near irrigation ($Port_2$), cutting ($Port_3$) and illumination ($Port_4$) were manually measured (Figure 1).

Statistical Analysis All the data were expressed as mean±SD. SPSS 13.0 software was used for all the data analysis. Normality of all data distributions were confirmed using the Kolmogorov-Smirnov test. Preoperative and postoperative values in 23-gauge and 20-gauge groups were compared using repeated measures analysis of variance, followed by post hoc analysis of Mann-Whitney test. Pearson correlation analysis was used to assess the correlation between SIA and 4 ports of corneal thickness change ratio, as well as the correlation between SIA and IOP. In addition, linear regression analysis was performed to determine the relationship between astigmatism and change ratio, also between astigmatism and IOP. A *P*-value less than 0.05 was considered statistically significant.

RESULTS

General Information The study enrolled 40 eyes of 38 patients with a mean age of 51.6±11.4y (ranging from 30 to 73y). In all 40 eyes, no intraoperative complications occurred. In addition, none of the 20 eyes in the 23-gauge group required conversion to conventional 20-gauge vitrectomy or sutures to close leaking sclerotomies. Although IOP remained stable throughout the postoperative course in most of eyes, IOP of 3 eyes in 20-gauge group were elevated (>20 mm Hg) but well controlled (<30 mm Hg) by antiglaucoma drugs during postoperatively 1mo period. One eye in the 23-gauge group exhibited shallow choroidal detachments that resolved by day 7.

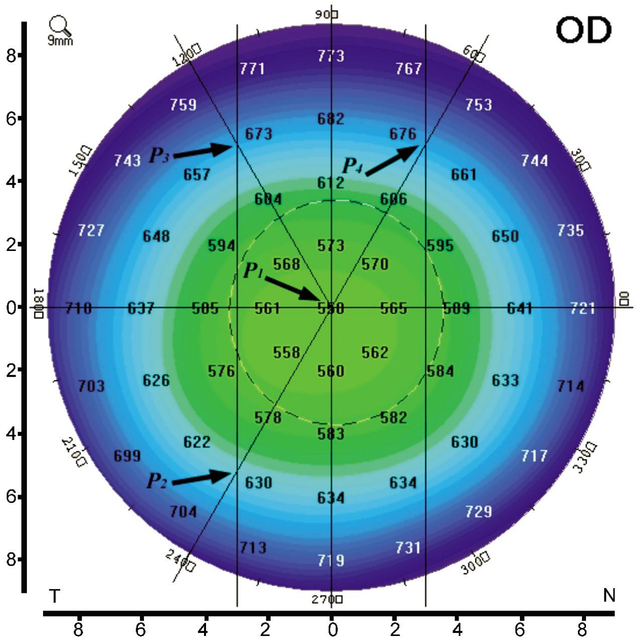


Figure 1 Corneal thickness map showing the criteria for 4 cornea sites selection (arrow) In order to offset the individual and port variance, the rate of corneal thickness change (designated as change ratio) was calculated. Change ratio=corneal thickness at each follow-up postoperatively/corneal thickness preoperatively 1d.

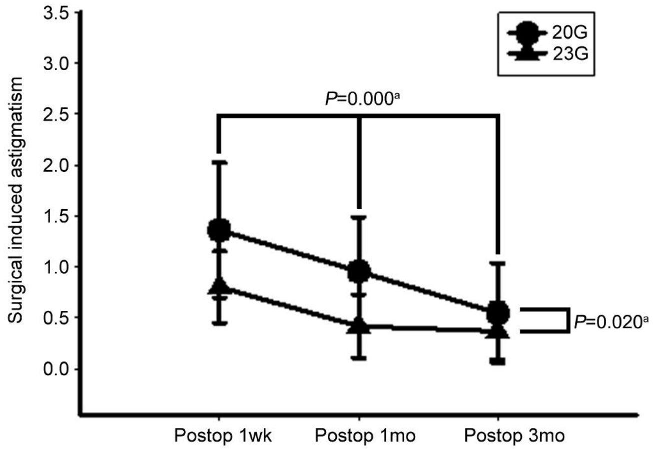
Change of Surgical Induced Astigmatism After 20-gauge Vitrectomy Compare with that of 23-gauge The SIA (D) were 1.082±0.085 D, 0.689±0.070 D, 0.459±0.063 D separately at postoperative 1wk; 1, 3mo ($F_{1,37}$=135.238, P=0.000), respectively. SIA were declined significantly as time went by ($F_{2,36}$=33.629, P=0.000). The SIA in 20-gauge and 23-gauge group were significantly different ($F_{1,37}$=11.046, P=0.020; Figure 2). In 20-gauge group SIAs were different during the follow-up time: in contrast, SIAs in 23-gauge group did not show statistically significant difference between 1 and 3mo (Table 2).

Change of Corneal Thickness After 20-gauge Vitrectomy Compare with that of 23-gauge Corneal thickness increased at early stage postoperatively (Figure 3). At $Port_1$, $Port_2$ and $Port_4$, the corneal thickness had only insignificant increase ($F_{3,19}$=1.793, 2.511, 0.873; P=0.158, 0.067, 0.46; respectively). However, corneal thickness at $Port_3$ was significantly increased postoperatively, as

Table 3 Correlation coefficients for corneal thickness change ratio with SIA and IOP with SIA postoperatively

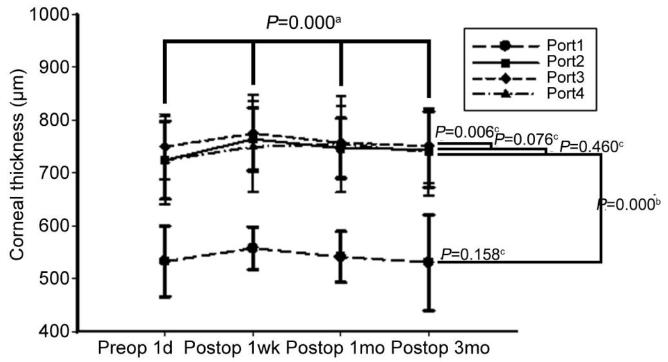
Parameters	Change ratio ($Port_1$)		Change ratio ($Port_2$)		Change ratio ($Port_3$)		Change ratio ($Port_4$)		IOP	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*	*r*	*P*
SIA_{1wk}	-0.214	0.186	-0.072	0.66	0.616	0.000	-0.033	0.841	0.327	0.039
SIA_{1mo}	0.121	0.475	0.167	0.3324	0.168	0.320	0.268	0.109	-0.283	0.428
SIA_{3mo}	0.084	0.690	0.158	0.388	0.297	0.159	0.238	0.274	-1.59	0.640

SIA: Surgical induced astigmatism; IOP: Intraocular pressure. $Port_1$: Centeral cornea; $Port_2$: Cornea near infusion entry site; $Port_3$: Cornea near cutting entry site; $Port_4$: Cornea near illumination entry site.



aRepeated measures ANOVA

Figure 2 SIA changes in diabetic patients postoperatively Results represent mean ±standard deviation. aDifference among 3 follow-up times and between 2 surgery mode.



aRepeated measures ANOVA

Figure 3 Corneal thickness in 4 ports preoperatively and postoperatively Results represent mean ±standard deviation. aDifference among 4 follow-up times; bDifference among 4 corneal ports; cDifference among 4 follow-up times in 4 corneal ports.

compared to that before operation ($F_{3,19}$=6.091, P=0.006). The corneal thickness in 23-gauge increased more than that in 20-gauge group after operation ($F_{1,80}$=80.887, P=0.000)

Correlation Analysis of Surgical Induced Astigmatism and Influence Factors The amount of SIA correlated with the influence factors (the corneal thickness change ratio and IOP) at 1wk; 1, 3mo were listed in Table 3. At postoperatively 1wk, the amount of SIA was significantly positively correlated with cornea thickness change ratio at $Port_3$ and IOP. The linear regression analysis went as: $SIA_{(postop\ 1wk)}$=-4.519+4.931 corneal thickness change ratio ($Port_3$) +0.026 IOP (R^2=0.46, P=0.000).

DISCUSSION

In recent years, vitrectomy enters into a minimally invasive era. Indications of 23-gauge vitrectomy become increasingly wider[9-12]. Especially when vitrectomy combined with cataract and refractive surgery, it is important to control SIA [8,13-15]. In the past few years, several studies had shown that the corneal contour was significantly changed by 20-gauge standard vitrectomy, inducing postoperative astigmatism [16,17]. The induced astigmatism was usually transient and returned to the baseline level during 1 to 4mo after surgery[18,19]. The increase in the postoperative astigmatism might be attributed to the scleral cautery [20] and suturing at the entry port in 20-gauge surgery [19]. On the other hand, there had been a few studies focused on the astigmatic changes after TSV, which is no need of cautery and suture. Galway *et al* [21] compared the SIA in 20- *vs* 25-gauge vitrectomy procedures and found that 25-gauge vitrectomy significantly reduced the amount of SIA. And Yanyali *et al* [22] concluded that regular and irregular astigmatism of the cornea did not change when 25-gauge TSV was used. Although both the 25-gauge and 23-gauge TSV systems have some same advantages, there are differences in terms of instrumentation. Corneal surface and astigmatic changes may therefore be different in these vitrectomy systems due to different sclerotomy port sizes: 0.6 mm in 23-gauge and 0.5 mm in 25-gauge. Hence, unlike 25-gauge vitrectomy, Yanyali *et al* [23] reported that the mean surgically induced astigmatism for 23-gauge vitretomy was 0.67 D (first day), 0.36 D (first week) and 0.33 D (first month) postoperatively, surface regularity index change significantly at first day after surgery and then returned to preoperative level at first week.

23 -gauge Vitrectomy Induce Less Surgical Induced Astigmatism and Faster Recovery In our study, we demonstrated the following results: SIAs were decreased as time went by and 23-gauge induced smaller SIA than 20-gauge in diabetic patients. Moreover, SIA was stabilized more rapidly in 23-gauge group than in 20-gauge group. We present findings consistent with the previous reports: 23-gauge definitely decrease SIA in diabetic subjects. About the recovery time of 23-gauge and 20-gauge, we compared the SIA postoperatively. In both groups, SIA_{1wk} was statistically significant larger than SIA_{1mo} and SIA_{3mo}. But in 23-gauge group, there was no significant difference between SIA_{1mo} and SIA_{3mo}, whereas SIA_{1mo} was still significant larger than SIA_{3mo} in 20-gauge group. Hence SIA in 23-gauge was stable in postoperative 1mo, but still changeable in 20-gauge group. That is to say, for diabetes, 23-gauge has more rapid recovery time than 20-gauge in the aspect of SIA. The time course of the corneal astigmatism alterations should be considered in the postoperative management to detect refractive causes of inadequate visual acuity.

Relationship Between Surgical Induced Astigmatism and Corneal Thickness In our study, the corneal edema and astigmatism caused by vitrectomy were measured with the Pentacam. This device was appropriate for investigating postoperative corneal thickness and corneal curvature changes in patients preoperatively and immediately postoperative in a clinical setting. Because the data was collected in a single detection, the systemic error caused by measurement was lower than that in which the data was collected by two separate devices. Hence, the relationtionship between SIA and corneal thickness seems more credible. Corneal thickness also can be changed by TSV transiently[24]. The change in corneal thickness following vitreous surgery was attributed to the functional decline of the corneal endothelial cell caused by surgery induced inflammation. Evidence suggest that diabetic patients have greater CCT, though there is still a controversy that diabetic subjects differ from the non-diabetic control subjects with regards to endothelial cell morphology weather or not [4,5]. In our study, the change was more obvious in cornea near the cutting port than other sites in diabetic subjects. Maybe mechanical energy released by cutting equipment while working is another factor causing the corneal swollen and thickened. Corneal thickness has influence on SIA at early stage postoperatively in our study. There is no relative study on correlation between corneal thickness and SIA after vitrectomy. But Woo and Lee [25] studied the effect of central corneal thickness on SIA in cataract surgery using temporal clear corneal incision, and observed that central corneal thickness could negertively influence the amount of SIA immediately postoperatively. The correlation was not present 2mo after surgery. In our study, the corneal thickness change ratio near the cutting incision in the peripheral cornea was the biggest among all four ports. As we know, the change of corneal thickness can induce the change of corneal shape and diopter power on both the back and front surface of cornea. Increase of the peripheral corneal thickness can flatten the front surface of the cornea, but sharpen the back surface. Therefore the greater the corneal thickness change, the greater keratometric value get (Figure 4).

Relationship Between Surgical Induced Astigmatism and Introcular Pressure IOP is another factor cause SIA in our study. IOP serves as a centrifugal force to push eyeball wall out. In an eye with unsutural incision, the distribution of centrifugal tension vectors at the center of cornea is not

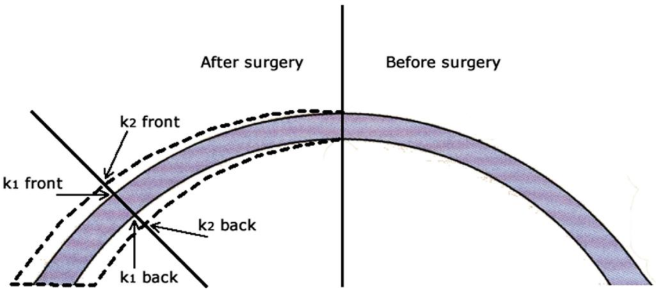


Figure 4 Illustrations of effect of corneal thickness on corneal curvature Cross-sectional views of the cornea along the cutting site meridian $k=k_{front}-k_{back}$, Preop: $k_1=k_{1front}-k_{1back}$, Postop: $k_2=k_{2front}-k_{2back}$. Because $k_{1front}>k_{2front}$, $k_{1back}<k_{2back}$, hence $k_1>k_2$. The more corneal thickness change, the smaller k_2 become, the more astigmatism be induced.

uniform in all directions[25]. Mechanism of action as a corneal limbus lysis procedure, the sclerotomy decreased the curvature along the incision meridian. Hence, the SIA generate as a result of astigmatism change. Because the IOP is more fluctuated during the early stage of postoperation, the relationship between SIA and IOP has statistically significance.

In conclusion, 23-gauge has the advantage over 20-gauge as far as SIA is considered. And Pentacam can be a good device to detect the anterior segment changes after vitrectomy. Thought the influence factors of SIA, such as IOP and corneal thickness change are transient [26], doctors should pay more attention to decrease the influence of these factors for faster rehabilitation for diabetic patients. Future study will add confocal microscope and biomechanic research to explore the mechanism of the influence induced by vitrectomy on corneal thickness and SIA.

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