Original Article

The change of corneal curvatures after micro-trabeculectomy surgery among glaucoma patients

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Abstract

Background: *There has been few reports on analysing astigmatism after standard trabeculectomy and only one study about micro-trabeculectomy by Vernon et al. in 1991; there were none which compared 2 groups in one individual study.*

Objective: *To compare the postoperative changes of corneal curvature (surgically induced astigmatism –SIA) between two different glaucoma surgery techniques: microtrabeculectomy and standard trabeculectomy.*

Methods: *A randomized clinical trial was done including 81 eyes (81 patients) who were randomized selected to perform either standard trabeculectomy (4x4 mm scleral flap) or micro-trabeculectomy (2x2 mm scleral flap), both with antifibrotic 5- Fluorouracil. Patients' pre- and postoperative detailed ophthalmologic examinations were documented and topographic keratometric values (flattest K, steepest K) were noted. Vector analysis was performed on the data using a computerized method to calculate the SIA for each eye at 1st day, 4th, 12th, 24th week follow-up postoperatively.*

Results: *The mean SIA power reduced gradually from 1.89 Diopter to 1.30, 0.95, 0.73, 0.60 Diopter in the standard group and from 1.03 Diopter to 0.92, 0.83, 0.74, and 0.73 Diopter in the micro group at 1 day, 1st week, 4th week, 12th week and 24th week follow-up respectively. The SIA power values in standard group were significantly higher than the values in micro group at 1st day and 1st week postoperatively. There was no correlation between SIA and IOP in standard and micro-trabeculectomy group.*

Conclusion: *Micro-trabeculectomy is an invasive filtration procedure which caused minimally statistically significant induced astigmatism.*

Keywords: *micro-trabeculectomy, surgically induced astigmatism, keratometer*

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Introduction

Trabeculectomy was firstly introduced in 1968 by Cairns to reduce the levels of intra-ocular pressure (IOP) by allowing more controlled aqueous drainage from the anterior chamber into sub-tenon space; because of the presence of a partial thickness scleral flap. It has become the gold standard surgical procedure for many glaucomatous eyes worldwide.[3] Since then, it has undergone multiple modifications, including changing the size, shape, and position of the sclerostomy and trapdoor, limbal, or fornix-based conjunctival incisions, and altering the method of performing the sclerostomy by trephination, sclerectomy, and the use of a scleral punch.[13,15]

Surgically induced astigmatism (SIA) is defined as the difference between preoperative and postoperative astigmatism which has been studied widely in cataract surgery, vitrectomy, trabeculectomy, etc.[9] SIA is not consistent because different eyes will heal differently.[6] Many factors affects the degree of SIA such as the type and location of the surgical incision, the amount of scleral cauterization performed, the suture material and how to place the sutures.[1] SIA is necessary considered in surgery because it delays visual rehabilitation and may cause an unwanted negative effect to patient's visual outcome.[8] In 1999, small flap trabeculectomy (micro-trabeculectomy) was recommended by Stephen Vernon as it produces smaller changes in corneal curvature that resolved sooner than previous reports of larger flap technique. Trabeculectomy using a small scleral flap appears to provide medium to long-term IOP control comparable to large flap techniques and may offer potential advantages which includes reduced surgical tissue trauma, a larger area of undisturbed sclera and conjunctiva should repeat surgery be required, and reduced astigmatism induction.[12] In literature, a randomized clinical trial study haven't been done so far; therefore, evaluation on surgical induced astigmatism of micro-trabeculectomy compared with traditional trabeculectomy is necessary.

Methods

A prospective, surgical intervention study was registered and approved by Science and Technology Committee of Ho Chi Minh Eye Hospital, Vietnam. Eighty one patients were randomly selected; 40 patients were done standard trabeculectomy (standard TRAB) and others underwent micro–trabeculectomy (micro–TRAB) with one surgeon. The inclusion criteria was based on the following points: (1) patient's age were between 40 to 60 years old, both gender; (2) patients diagnosed with POAG, PACG had successful trabeculectomies; (3) none of the eyes had had corneal abnormality preoperatively, previous ocular surgery (cataract removal, previous glaucoma surgery) and other ocular pathology (pterygium, OSD). The exclusion criteria was included: (1) patients had secondary glaucoma; (2) visual acuity was no light perception; (3) patients were unwilling or unable to give consent or unwilling to accept randomization and (4) patients were out of area and potentially unavailable for follow-up visits. All patients participated in the study had signed the given consent form.

All subjects were admitted for trabeculectomy using a standard technique (40 eyes) and micro technique (41 eyes). This consisted of a fornix based conjunctival flap, a partial-thickness scleral flap centered at the 90 degree meridian. A 2x2 mm scleral trap door was done with a crescent blade in micro–trabeculectomy group; while a 4x4mm scleral flap was performed in standard trabeculectomy group. 5-fluorouracil (50-mg/mL) was applied intraoperatively on the flap for 5 minutes. An anteriorly sited 0.75 mm diameter internal sclerostomy with a Kelly punch (Storz). A small basal peripheral iridectomy was followed by two 10/0 nylon scleral trapdoor sutures placed at the corners of the scleral flap and three

8/0 vicryl sutures to the conjunctiva. Topical antibiotics (Moxifloxacin 0.5%, 6 times a day), steroid (Prednisolone acetate 1%, 6 times a day) and atropine 1% bid were given. At the 1 week review the atropine was stopped and the steroid/antibiotic reduced at the discretion of the clinician. All patients continued topical steroids for at least 1 month but for no longer than 3 months postoperatively.

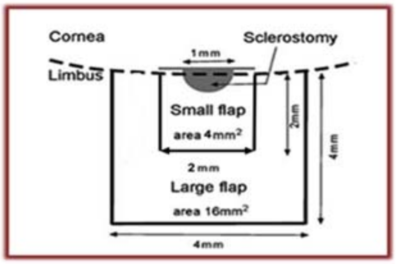

Figure 1. Diagram showing the relative proportions of the two flap sizes used and position relative to the internal sclerostomy by punch.

At the pre-operative assessment and at 1 day, 1 week, 4 weeks, 12 and 24 weeks post-operatively each patient was examined as follows: visual acuity (Snellen Acuity Chart converted to logMAR scale), intra-ocular pressure (Goldman Applanation Tonometry), and Carl Zeiss topography system Atlas 9000.

Vector analysis was performed on the data using a computerized method of calculating the surgically induced astigmatism (SIA) for each eye at every time postoperatively. All changes were compared with the preoperative data set and expressed in terms of negative cylinders. SIA was based on the theory that the combination of two crossed sphero-cylinders produces a third sphero-cylinder which provided a vector of induced cylinder for each eye at each time point.[11] Each astigmatism data was transferred into Cartesian coordinates based system which represented as vector (x, y) X, x = a cos2p, y= a sin 2p where "a" is magnitude of astigmatism and "p" is the axis of steep meridian. The angles of the astigmatisms were multiplied by 2 because the angles of the astigmatisms were expressed between 0° and 180° when in a trigonometric circle the angles change from 1° to 360°.

Sawhney *et al.* showed the vector analysis method uses trigonometric calculations to determine the SIA, "x" and "y" values generate for both pre- and post-operative data. Thus there were X pre, Y pre and X post, Y post.

To calculate Surgical Induced Astigmatism (SIA):
X SIA = X post - X pre; Y SIA = Y post- Y pre

Astigmatism vector: Magnitude

$$= \sqrt{XSIA^2 + YSIA^2}$$

Angle = 0.5 x arctan (YSIA/XSIA)

To get the final "Axis" which means 180^0 astigmatic scheme, the XSIA and YSIA decided:
If both XSIA and YSIA >0, then Axis = Angle
If XSIA <0, then Axis = Angle + 90
If XSIA >0, YSIA <0 then Axis= Angle + 180

The SIA data were calculated by using SIA calculator version 2.1.

At the end, there was the aggregate astigmatism data which had the magnitude and axis to analyze group changes. Those values gave a mathematical expression of the change in WTR or ATR or oblique astigmatism. WTR astigmatism is defined as corneal steepening in the vertical meridian corresponding to a positive induced cylinder at 90 degrees and ATR being the reverse.

Statistical analysis was performed using SPSS software version 20 (SPSS Inc, Chicago, Illinois, USA). Continuous variables were expressed as mean ± standard deviation (SD) and compared using *t* test or Mann-Whitney *U* test as appropriate. Categorical data were represented by number (n), percentage (%) and compared using the Pearson χ^2 test or Fisher exact test. Spearman test was performed to study correlation between SIA and IOP changes. Statistical significance was accepted if *p* value <0.05 for either test.

Results

A hundred patients were randomly chosen in 2 subgroups: 50 patients in standard trabeculectomy (standard TRAB) group and 50 patients in micro- trabeculectomy (micro-TRAB) group. 19 patients were excluded from the study (10 in standard group and 9 in micro group) due to inability to follow up. At 6 months, we have totally 40 eyes in standard group and 41 eyes in micro group for the final analysis. Demographic data of standard and micro-TRAB groups was summarized in table 1.

Table 1. Demographics of patients

	Micro-TRAB	Standard TRAB	*p* value
Number of patients (n)	41	40	-
Gender (n, %)			
• Male	21 (46.7)	24 (53.3)	0.51*
• Female	20 (55.6)	16 (44.4)	
Age (mean±SD, years)	52.17 ± 9.59	55.00 ± 12.89	0.06**
Kinds of glaucoma (n,%)			
• PACG	18 (43.9)	19 (47.5)	0.5**
• POAG	18 (43.9)	13 (32.5)	
• APAC	5 (12.5)	8 (20.0)	
Visual acuity (logMAR)	1.27 ±1.08	1.07±0.99	0.38**
Pre-op IOP (mean±SD, mmHg)	29.44±13.02	32.78±10.81	0.21**
Pre-op Kf (mean±SD, Diopter)	43.67±1.67	43.69±1.57	0.97**
Pre-op Ks (mean±SD, Diopter)	44.57±1.56	44.59±1.37	0.99**

(*) Chi square test (**) Mann-Withney test

There is no significant difference between 2 groups in gender, age, kinds of glaucoma, preoperative IOP, visual acuity and K readings with $p > 0.05$.

SIA Power Between Groups

The change of the SIA power median values for the six-month follow-ups in micro and standard trabeculectomy groups were shown in table 2.

Table 2. SIA power median value comparison in diopter between 2 groups through time.

Visits	Micro-TRAB (mean±SD, Diopter)	Standard TRAB (mean±SD, Diopter)	*p* value (*)
1 day post-op	1.03±0.68	1.89±1.13	0.00
1 week post-op	0.92±0.50	1.30±0.74	0.01
4 week post-op	0.83±0.48	0.95±0.76	0.77
12 week post-op	0.74±0.44	0.73±0.66	0.44
24 week post-op	0.73±0.48	0.60±0.49	0.07

(*) Mann –Whitney test

The mean SIA power reduced gradually from 1.89 Diopter to 1.30, 0.95, 0.73, 0.60 Diopter in the standard group and from 1.03 Diopter to 0.92, 0.83, 0.74, and 0.73 Diopter in the micro group at 1 day, 1 week, 4 weeks, 12 weeks and 24 weeks respectively. By using the Mann-Whitney test, the SIA power median values in standard group was significantly higher than the value in micro group with $p < 0.05$ at 1 day and 1 week. The SIA power median in remaining follow-ups showed no significant difference between 2 groups. The progression of the SIA power in 2 groups were displayed in figure 2 which especially showed the higher elevation of SIA in standard TRAB compared to micro-TRAB at 1 day and 1 week post-operation. Moreover, the SIA of both groups were under 1 Diopter at 4 week postoperatively.

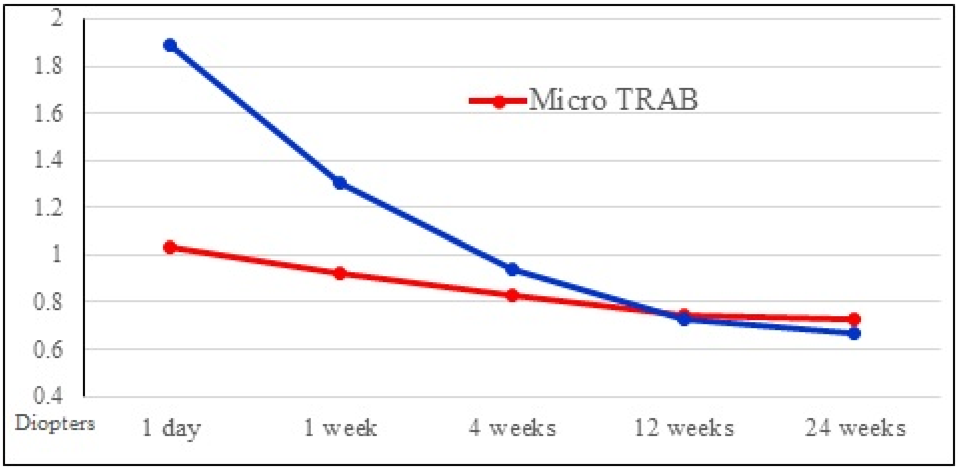

Figure 2. The progression of the SIA power in micro-TRAB and standard TRAB groups.

SIA Axis Between Groups

The SIA axis in 2 groups was compared and displayed in table 3. There was no significant difference in 1 day, 1 week, 4 week, 12 week, 24 week follow-up respectively.

Table 3. SIA Axis comparison between 2 groups through time.

Visits	Micro-TRAB	Standard TRAB	*p* value (*)
1 day post-op	85.97±38.97	98.65±51.17	0.18
1 week post-op	94.59±48.83	74.75±54.5	0.082
4 week post-op	76.41±52.58	84.15±52.43	0.461
12 week post-op	82.66±48.43	80.93±47.92	0.891
24 week post-op	81.34±47.19	90.55±48.16	0.362

*Mann-Whitney

Figure 3 showed the general polar map of both SIA power and axis. The micro group displayed a distribution of SIA power mainly located nearby circle 1 diopter and 2 diopter and few cases which were located at more than 2 diopter near 3 diopter circle. However, the SIA power in standard group was expanded nearby the 3 diopter and 4 diopter circle. The axis distribution looked similar between 2 groups.

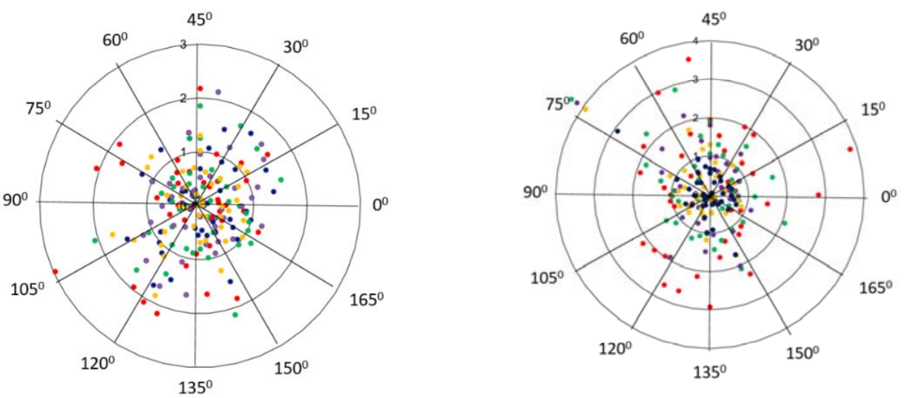

Figure 3. Demonstrating the surgically induced astigmatism distribution of every patient in microTRAB group (left) and standard TRAB group (right) on the vectorial map. Each circle represents 1D. Red, green, purple, yellow and blue dots symbolize 1^{st} day, 1^{st} week, 4^{th}, 12^{th} and 24^{th} week values, respectively.

IOP Comparison

The Mann-Withney test showed no significant difference of postoperative IOP between 2 groups in all follow-ups (p>0.05) in table 4. The IOP decreased from the preoperative day till 24 weeks postoperatively. The mean IOP of both groups were under 18mmHg at the end of the study (14.10±7.78mmHg in micro group, 12.50±3.37 in standard group).

Table 4. Pre – and post-operative IOP in 2 groups.

	Micro-TRAB	Standard TRAB	p value (*)
Pre-op	29.44±13.02	32.78±10.81	0.21
1 day post-op	10.29±4.19	9.29±4.27	0.25
1 week post-op	9.29±4.98	7.63±3.82	0.10
4 week post-op	14.12±8.30	11.80±6.43	0.16
12 week post-op	13.78±3.93	12.05±3.79	0.05
24 week post-op	14.10±7.78	12.50±3.37	0.24

(*) Mann-Withney test

SIA and IOP Correlation

There was no correlation between SIA and IOP in standard and micro-trabeculectomy group in all follow-ups (p>0.05) which was shown in table 5.

Table 5. Correlation analysis between SIA and IOP (Spearman test).

	Micro-TRAB		Standard TRAB	
	r value	*p* value	r value	*p* value
1 day post-op	-0.18	0.25	-0.04	0.80
1 week post-op	0.04	0.80	0.15	0.37
4 week post-op	-0.18	0.36	-0.09	0.60
12 week post-op	0.25	0.12	0.07	0.65
24 week post-op	0.14	0.39	-0.26	0.88

Discussion

There has been few reports on analysing astigmatism after trabeculectomy (both standard and micro type) and there were none which compared 2 groups in one individual study. Most of the existing reports had very few patients and the result sometimes conflicted. We analyzed the change of astigmatism after trabeculectomy by calculating and comparing the SIA vector which was believed the standard way to report the change of the postoperative astigmatism on patient's eye.

In the current study, even though the SIA power in both group decayed through time, but the SIA power in standard group had elevated significantly higher than the micro group at 1st day and 1st week follow-ups. At the 4th, 12th and 24th week, the SIA power in both group were about the same. New refraction and prescribed Rx could be considered to be given to the patient after 4 weeks since the residual SIA was not significant. After Kumari et al. stated that by using standard trabeculectomy procedure, the mean 1st post-operative SIA value was the highest value 2.73 D

(99 degree) which is larger than the current study value (standard group) which is 1.66 D. The mean SIA value in Kumari et al. research reduced to 0.41 D (3rd week) and 0.43 D (6th month) which is smaller than our study value 0.81 D (4th week) and 0.54 D (6th month).[7] The researchers concluded that the standard trabeculectomy showed significantly increased 1st post-operative day SIA which rapidly decreased to a minimum amount at just 3 weeks later. The standard trabeculectomy in Kumari study with larger conjunctival flap compared to the current study could be the reason for the opposed result. Moreover, all the surgery was done in Kumari study had not used the antifibrotic agent (5- Fluorouracil) but the current study did. The antifibrotic agent was considered as a factor that reduced the SIA also increased the healing rate of the bleb.[14] In comparison to standard trabeculectomy in Kumari's study, micro-TRABeculectomy in our study gave the median SIA at the first postoperative day 0.82 D which was remarkably smaller than the mean SIA in Kumari's study (2.73 D).

Previously, Vernon et al. had done the early research on corneal curvature changes after micro-trabeculectomy surgery with 4 follow ups in 1 year: 1 month, 3 months, 6 months and 12 months. The mean SIA value between the WTR and ATR SIA groups was compared to each other and found that there was significant induced WTR astigmatism at 1st month and 3rd month but not at 6 and 12 months postoperatively by measuring the topographic keratometry. Vernon found that by using the manual keratometry, the SIA power reduced from 0.68 D to 0.38, 0.52, 0.55 D and from 0.75D to 0.66, 0.59, 0.64 D by using topographic keratometry at 1 month, 3 months, 6 months and 12 month follow-up respectively.[14] Our micro-TRABeculectomy result were slightly higher than Vernon et al.'s result at most of the follow-ups even though our study had 40 eyes but Vernon et al.'s study only had 16 eyes. Hence, the current study supported Vernon et al.'s study with the similar surgical technique.

Ashai et al. also identified that there was a statistically significant change in vertical and horizontal k-reading after standard trabeculectomy in three follow-ups (2 weeks, 1 month and 3 months).[2] 100 subjects were involved in the study and the mean value of pre and postoperative K-readings were compared to each other which is not similar as the current study analysis but also showed the trend was toward the vertical steeping keratometry.

From 1999 until now, there was only one study done by Vernon that evaluated the change of corneal astigmatism after micro-trabeculectomy. The research had been done using topography, manual keratometry up to 1-year follow-up. The authors mentioned that the micro-trabeculectomy could controls IOP as well as previous reports of standard trabeculectomy (larger flap). Both two ways of analysis in the current study showed the same conclusion and gave a promising result compared to Vernon's study in which the induced astigmatism increased but not significantly in the 1st postoperative week, however it significantly decayed after that period.

By using TMS system, Claridge et al. identified that the largest group had an induced superior steepening of the cornea resulting in a mean WTR astigmatism of about 1 D which persisted to 1 year follow up.[4] The results were on eyes undergone trabeculectomy with 4x3 mm scleral trap door and two 10/0 nylon sutures. In comparison, the current study showed an unremarkably lowering induced astigmatism at week 4. The smaller scleral trap door produced in micro-TRABeculectomy (2x2 mm) was considered as the factor reduced the SIA.

By using manual keratometry, Cunliffe et al. conducted a study on 16 eyes undergone standard trabeculectomy with 5x3 mm scleral trap door.[5] They found a significant WTR astigmatism up to 2 months but not at 10 months. Besides, Rosen et al. showed that with a 3x2 mm scleral trap door and 10/0 nylon suture trabeculectomy[10], the mean vector power induced at 3 months was 1.24 D which is more than what the current study achieved, 0.72 D at week 4 only.

The induced astigmatism after micro-trabeculectomy had a trend to shift toward WTR axis similar to most of the previous studies. The cause for this alter was alternatively overtight the scleral flap sutures could lead to a WTR shift in astigmatism in the same way that a tight cataract section causes corneal steepening.[4]

Claridge et al. stated that the steepening of the cornea would be caused from the contraction of tissues around the trabeculectomy position as a result of extensive scleral cautery.[4] Rosen et al. considered that the cautery was mainly the factor that lead to the induced astigmatism and it was appeared to develop more when excessive cautery was used in one patient.[10] The authors also found that suture lysis did not prevent astigmatic change whereas scleral cautery was associated with corneal steepening in the post-operative period. Vernon et al. suggested that the size of internal sclerostomy and amount of cautery play a main role in induced astigmatism. In the current study, the cautery was not involved in the micro-trabeculectomy by the surgeons.[12] The rapid and very small amount of induced astigmatism was found instead of higher values like previous studies could be due to the absent of cautery step in the procedure. If the scleral flap is loose, superior corneal flattening may develop from wound gape around the trabeculectomy site. Other reasons lead to superior corneal flattening could be a large drainage bleb or a post-operative ptosis.[13]

Conclusion

Microtrabeculectomy showed significant lower surgical induced astigmatism (SIA) power compared to standard technique at early postoperative follow-ups (< 4 weeks). The SIA caused by both techniques rapidly decayed under 1 Diopter after 4 weeks, hence the necessary prescription would be given for patient at that period of time.

Conflicts of Interest

None

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