Clinical Case Report

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Effectiveness and confounding factors of penetrating astigmatic keratotomy in clinical practice

Case report

Chu-Yu Yen, MD, Gow-Lieng Tseng, MD, PHD*

Abstract

Rationale: Penetrating astigmatic keratotomy (penetrating AK) is a well-known method to correct corneal astigmatism but rarely be performed nowadays. This article reevaluated the clinical effectiveness and confounding factors of penetrating AK.

Patient concerns: Penetrating AK has been introduced to serve as one alternative operation for astigmatism correction, and is thought to have the potential advantage of being more affordable and easy to perform. The purpose of our study is to evaluate the effectiveness and confounding factors of penetrating AK.

Diagnoses: The chart of 95 patients with corneal astigmatism (range: 0.75–3.25 diopters [D]) who received penetrating AK from January 2014 to December 2016 was collected. The corneal astigmatism were measured by an autokeratometer (Topcon KR8100PA topographer-autorefractor), and repeated with manual keratometer in low reproducibility cases.

Interventions: All patients received penetrating AK by an experienced ophthalmologist (Dr. Gow-Lieng Tseng, MD, PHD) in the operation room. Among which, 66 patients received penetrating AK with phacoemulsification simultaneously (group A), whereas 29 patients received penetrating AK at least 3 months after phacoemulsification (group B). After excluding the patients combined with other procedures or lost followed up, 79 patients are remaining for analysis. The outcome was evaluated by net correction, the difference between preoperative corneal astigmatism (PCA) and residual corneal astigmatism (RCA). Two sample t tests and Pearson test were used for effectiveness evaluation. For confounding factors, multivariate linear regression was used for statistical analysis.

Outcomes: The mean preoperative and postoperative refractive cylinders were 1.97 ± 0.77 and 1.08 ± 0.64 D, respectively, in group A and 2.62 ± 1.05 and 1.51 ± 0.89 D in group B. There were no statistically significant differences in net correction between these two groups (0.9 ± 0.66 vs. 1.1 ± 0.69, $P = .214$). Higher PCA were associated with higher net correction in both group A ($P = .002$) and group B ($P = .019$). Compound myopic astigmatism caused less net correction than others only in group A ($P = 0.031$).

Lessons: Penetrating AK is an accessible, affordable, and effective way to correct corneal astigmatism. The results of this procedure are comparable to modern methods in patients with low to moderate corneal astigmatism.

Abbreviations: AK = astigmatic keratotomy, IOL = intraocular lens, PCA = preoperative corneal astigmatism, RCA = residual corneal astigmatism.

Keywords: astigmatism, cataract, penetrating astigmatic keratotomy, phacoemulsification

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Department of Ophthalmology, Taipei City Hospital, Renai Branch, Taipei, Taiwan.

** Correspondence: Gow-Lieng Tseng, No.10, Sec. 4, Renai Rd., Daan Dist., Taipei City 10629, Taiwan (R.O.C.) (e-mail: daa26@tpech.gov.tw).*

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WHAT WAS KNOWN

- Modern methods, such as toric *intraocular lenses* or femtosecond-assisted refractive surgery, are useful in correcting corneal astigmatism in cataract surgery.
- However, these methods are expensive, complicated, and made it difficult to extend to the general population.

WHAT THIS PAPER ADDS

- Penetrating astigmatic keratotomy affords a much more easier and affordable way to correct corneal astigmatism whether it is combined with phacoemulsification or not.
- The effectiveness of penetrating astigmatic keratotomy is comparable to modern methods if we select the operation candidates with low to moderate degree corneal astigmatism (i.e., preoperative corneal astigmatism from +1–+3 Diopter).

1. Introduction

Astigmatic keratotomy is a widely used method to correct corneal astigmatism. It can be traced back to 1885, when a Norwegian ophthalmologist Hjalmar August Schiøtz (1850–1927), who used a von Graefe knife to reduce the residual astigmatism from 19.50 D to 7.00 D in a patient after cataract surgery.[1] However, when arcuate keratotomy, femtosecond laser-assisted refractive surgery and toric intraocular lens (IOL) came into the market in the late 20th century, astigmatic keratotomy was soon being overlooked.[2,3] However, there are many drawbacks of modern methods. First, they need more advanced skills. The effectiveness of astigmatism correction depended highly on physicians' experience.[4] Second, although many articles reported favorable outcomes of modern methods, they were more expensive and not readily available to the general population, and that made it difficult to extend to the general population.[5] These factors urged us to search for other methods which are easy to perform, not expensive, and had comparable outcomes. Penetrating AK, which was an old but relatively accessible and affordable method, was then taken into our consideration. In our research, we will reevaluate the effectiveness, timing of surgery, and confounding factors of penetrating AK.

2. Methods

This was a retrospective comparative study performed at Department of Ophthalmology, Taipei City Hospital Renai Branch in Taiwan. Penetrating astigmatic keratopathy and phacoemulsification were common surgeries to treat astigmatism and cataract, respectively, in clinical practice. Owing to this reason, the ethical approval was not included in this research. However, we informed the general and severe complications of ocular surgery to all the patients, including endothalmitis, and the surgical consents were signed. We collected the chart of 95 patients with corneal astigmatism (range: 0.75–3.25 diopters [D]) from January 2014 to December 2016. All patients received penetrating AK by an experienced ophthalmologist (Dr. Gow-Lieng Tseng, MD, PHD) in the operation room. We measured the preoperative corneal astigmatism by an autokeratometer (Topcon KR8100PA topographer-autorefractor), and repeated with manual keratometer in low reproducibility cases. After determining the steepest meridian, we made 2 marks at the axis when patients were in the sitting position by the slit lamp. Later, we remarked the patients on the operation table by an astigmatic keratotomy ruler. Under topical anesthesia, we made 2 incisions on the steepest meridian by a 2.75 mm keratome blade, and the distance of these 2 incision wounds was 9 mm apart (Fig. 1). In our research, 66 patients received penetrating AK with phacoemulsification simultaneously (defined as group A), and 29 patients received penetrating AK at least 3 months after phacoemulsification (group B). We used age, sex, axial length, anterior chamber depth before surgery, corneal astigmatism before and 3 months after surgery as our evaluating parameters. Among which, axial length and anterior chamber depth were measured by IOLMaster; Carl Zeiss Meditec Inc, Dublin, CA, and corneal astigmatism by autorefractometer mentioned above. We excluded the patients combined with other procedures or lost to follow-up (Table 1), and seventy-nine patients are remaining for analysis. Among which, fifty-six patients were in group A, and twenty–three patients were in group B. Preoperative corneal astigmatism (PCA) and residual corneal astigmatism (RCA) were collected, and the outcome was evaluated by net correction, the difference between PCA and RCA. All factors are adjusted by multivariate linear regression analysis. Two sample t test for continued variables, and Pearson Chi-square test for category variables were used for statistical analysis.

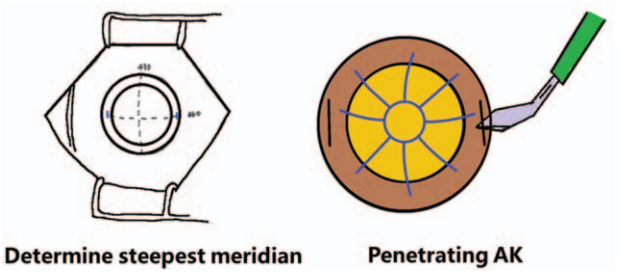

Figure 1. The procedures of penetrating astigmatic keratotomy. Left: determine the steepest meridian of cornea by autokeratometer. Right: 2 penetrating wounds 9 mm apart made by a 2.75 mm blade.

Table 1

The patients excluded in our research.

Exclusion cases	Numbers
Use of iris hook	1
Combine vitrectomy	2
Combine pterygium	2
Incision on manifest astigmatism	4
Lost follow-up at 3 mo	7
Dead	1
Follow-up elsewhere	2
Could not measure via autokeratometry	4

3. Results

Our baseline patient data was listed in Table 2. The average age in group A and B were 73.68 ± 10.24 and 77.30 ± 10.17, respectively. The mean PCA and RCA were 1.97 ± 0.77 and 1.08 ± 0.64 D, respectively, in group A and 2.62 ± 1.05 and 1.51 ± 0.89 D, respectively, in group B. There were no statistically significant differences in net correction between these 2 groups (0.9 ± 0.66 vs. 1.1 ± 0.69, $P = .214$) (Table 3). The confounding factors in group A and B were analyzed in Tables 4 and 5, respectively. In our research, higher PCA is associated with higher net correction in both groups. As PCA increased by 1 D, the net correction increased by 0.50 D in group A ($P = .002$) and 0.52 D in group B ($P = .019$). It indicated that higher PCA is associated with higher net correction. We also found that patients with compound myopic astigmatism got fewer net corrections than other groups only in group A ($P = .031$), but not in group B ($P = .939$). It implied that the correction effectiveness of patients with compound myopic astigmatism is poorer in group A.

4. Discussion

In modern times, there are many methods to correct corneal astigmatism in a patient receiving cataract surgery. One article compared the effectiveness of femtosecond laser-assisted arcuate keratotomy and toric IOL for correcting corneal astigmatism in patient with low to moderate degree corneal astigmatism (range: 1–3 D)), which was similar to our patients selection. The net correction was about 1 D in both groups.[6] In our research, penetrating AK can reduce 0.9 D corneal astigmatism in average if performed with phacoemulsification. It indicates that penetrat-

Table 2

Baseline data in patients receiving penetrating astigmatic keratotomy.

Variables	Group A (N = 56)	%	Group B (N = 23)	%
Sex				
Male	24	42.86	11	47.83
Female	32	57.14	12	52.17
Age (mean ± SD)	73.68 ± 10.24		77.30 ± 10.17	
Cyl (mean ± SD)	1.97 ± 0.77		2.62 ± 1.05	
Astigmatism category				
Compound hyperopic	9	16.07	0	0
Compound myopic	23	44.64	4	17.39
Simple hyperopic	3	5.36	2	8.70
Simple myopic	0	0.00	1	4.35
Mixed	16	28.57	16	69.57
Astigmatism distribution				
With the rule	5	8.93	0	0.00
Against the rule	36	64.29	14	60.87
Oblique	12	21.43	9	39.13
Corneal astigmatism				
With the rule	7	12.50	1	4.35
Against the rule	42	75.00	15	65.22
Oblique	7	12.50	7	30.73
Axial length	24.18 ± 1.70		–	
Anterior chamber depth	2.98 ± 0.44		–	
IOL diopter	19.29 ± 0.42		–	

Cyl = cylinder, i.e. = pre-operative corneal astigmatism, IOL = Intraocular lens, SD = Standard deviation.

ing AK is comparable to modern methods if we select the operation candidates with low to moderate degree corneal astigmatism.

Some surgeons may concern about the influence of phacoemulsification on corneal astigmatism correction. We found that there is no difference on astigmatism correction whether penetrating AK was combined with phacoemulsification or not. Thus, we may suggest the patients who are in need to correct astigmatism and senile cataract to perform these 2 procedures simultaneously.

Many researches searched for the confounding factors of the effectiveness of astigmatic surgery. Although corneal astigmatism decreased after performing penetrating AK, there were different outcomes among individuals. Similar findings were also reported by Mingo-Botín et al[7] In our study, higher PCA was associated with higher net correction. The possible cause behind it may be the basic characteristics of cornea asymmetry. Keech et al[8] reported that the thickest paracentral zone was the superior cornea and the thinnest was the temporal cornea, and simple measurement of central 3 mm corneal astigmatism by autokeratometer may not represented the actual condition. Previous literature also told that the corneal astigmatism of 1.0 D measured is 9 degree away from the actual steep meridian, and higher PCA were associated with more precise measurement.[9,10] To clarify these possible errors, we may collect corneal topography or even wavefront refraction for further analysis in the future.

Table 3

The effectiveness of penetrating AK performed with phacoemulsification and at least 3 months after phacoemulsification.

Variables	Group A penetrating AK + phacoemulsification (n = 56)	Group B delayed penetrating AK (N = 23)	P
PCA (D)	1.97 ± 0.77	2.62 ± 1.05	—
RCA (D)	1.08 ± 0.64	1.51 ± 0.89	—
Net Correction (D)	0.9 ± 0.66	1.1 ± 0.69	.214

AK = Astigmatic keratotomy, D = Diopters, PCA = Preoperative corneal astigmatism, RCA = Residual corneal astigmatism.

Table 4

Confounding factors of penetrating astigmatic keratotomy in group A to net correction.

Variables	Net correction (R^2 = 0.4926) β	SE	P
Sex			
Male	−0.10	0.19	.5908
Female (reference)	—	—	—
Age	−0.02	0.01	.1391
PCA (Cyl)	0.50	0.12	.0002
Astigmatism category			
Compound hyperopic	−0.14	0.26	.5637
Compound myopic	−0.59	0.24	.0309
Simple hyperopic	−0.13	0.39	.7338
Simple myopic	—	—	—
Mixed (reference)	—	—	—
Astigmatism distribution			
With the rule	−0.28	0.36	.5231
Oblique	−0.08	0.30	.7647
Against the rule (reference)	—	—	—
Corneal astigmatism			
With the rule	−0.34	0.36	.3520
Oblique	0.25	0.30	.4147
Against the rule (reference)	—	—	—
Axial length	0.23	0.12	.0510
Anterior chamber depth	0.09	0.26	.7251
IOL diopter	0.06	0.05	.2208

IOL = Intraocular lens, PCA = Preoperative corneal astigmatism, SE = standard error.

Table 5

Confounding factors of penetrating astigmatic keratotomy in group B to net correction.

Variables	Net Correction (R^2 = 0.4573) β	SE	P
Sex			
Male	0.52	0.40	.2172
Female (reference)	—	—	—
Age	0.00	0.02	.9731
PCA (Cyl)	0.52	0.19	.0185
Astigmatism category			
Compound hyperopic	—		
Compound myopic	−0.04	0.45	.9385
Simple hyperopic	−0.09	0.56	.8741
Simple myopic	0.83	0.85	.3448
Mixed (reference)	—	—	—
Astigmatism distribution			
With the rule	—	—	—
Oblique	0.98	0.76	.2214
Against the rule (reference)	—	—	—
Corneal astigmatism			
With the rule	−0.99	1.09	.3816
Oblique	1.08	0.81	.2054
Against the rule (reference)	—	—	—

PCA = preoperative corneal astigmatism, SE = standard error.

In our study, patients with compound myopic astigmatism yielded fewer net corrections than others in group A. We prefer the component of myopia was refractive rather than axial because there is no influence of axial length on astigmatism correction. This phenomenon only occurred in the group of penetrating AK performed with phacoemulsification, but not after phacoemulsification. Thus, the refractive astigmatic status maybe attributed to lens, not from cornea. As we know, senile cataract may induce lenticular myopic change, but how does lenticular myopic change affect corneal astigmatism is still in mystery. Previous article disclosed that anterior corneal astigmatism remained the same as people aging, but posterior corneal astigmatism decreased.[11] We hypothesized that there may be some effect of posterior corneal astigmatism on the effectiveness of penetrating AK, and further data collections are needed to clarify it. This finding reminded that the correction effectiveness of penetrating AK may be poorer in patients with compound myopic astigmatism, and we may treat these patients with more aggressive methods.

There were no correlations of age, sex, axial length and anterior chamber depth, and the effectiveness of penetrating AK. We hypothesized that penetrating AK is a method to correct refractive astigmatism; thus, axial component may not have direct influences on it. Nino Hirnschall et al[12] reported that the factors influencing efficacy of peripheral corneal relaxing incisions during cataract surgery included pre-op corneal astigmatism, eccentricity of the cornea and difference vector between the keratometry and the topography, and not associated with age and axial length. These findings were correlated with our study. In addition, the condition of with the rule or against the rule did not affect the correction effectiveness in our study, which may indicate the stability of our method. However, further studies can aim on the more long termed followed-up period, then the effectiveness of penetrating AK can be compared with the axial change individually, both physiologically and pathologically. This kind of analyses may eliminate the potential bias among different patients.

In our research, the complication rate was low. There was no wound leaks or infections in our patient selected after operation. Penetrating AK served as an adjunctive procedure to traditional phacoemulsification, and the complication rate was theoretically the same if these 2 procedures were performed together. However, if penetrating AK was performed alone, it reduced the possibility of posterior capsule rupture, vitreous prolapse and subsequent endothalmitis compared to toric IOL implantation. Also, there is no need to concern about the decentration or dislocation of IOL. It was a relatively easy and safe procedure in clinical practice.

There are some limitations of our research. First, we could only establish the conclusion based on the keratometry 3 months after penetrating AK, although most articles supports the stability of cornea was maintained at least 6 months after astigmatic keratotomy.[13] Second, the sample size was relative small, and the manual difference of penetrating AK between different operators is still in consideration. Finally, we did not measure the corneal astigmatism by more advanced methods, such as corneal topography and wavefront refraction, and the possibility of irregular astigmatism could be overlooked. In addition, posterior corneal astigmatism data were not collected in our research. Adequate collection of these data may yield a more precise evaluation in the future.

5. Conclusions

Penetrating AK is an accessible, affordable, reproducible, and effective way to correct corneal astigmatism. It can reduce 0.9 D corneal astigmatism in average when performed with phacoemulsification, and 1.1 D if performed at least 3 months after phacoemulsification. There is no difference on astigmatism correction whether penetrating AK was combined with phacoemulsification or not. Higher preoperative corneal astigmatism in penetrating AK is associated with higher net correction. Compound myopic astigmatism caused fewer net corrections than others when penetrating AK was performed with phacoemulsification.

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