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Surgically Induced Corneal Astigmatism Following Cataract Surgery

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Abstract

Aim: To study the surgically induced astigmatism (SIA) caused by two different type main incisions in phacoemulsification. Methods: Sixty-eight eyes of 65 patients who underwent phacoemulsification were randomly divided into two groups according to main incision type: 2.8 mm superior limbal incision (in Group 1) and 2.8 mm upper clear corneal incision (in Group 2). Surgical techniques did not differ between the groups except for the main incisions. All patients received detailed ophthalmological examination in addition to keratometry at the pre- and post-operatively. The preoperative and postoperative astigmatisms were calculated by the vector analysis method and the SIA was compared between the groups. Results: The mean SIA values were 1.3 ± 0.67 D, 0.89 ± 0.47 D, 0.77 ± 37 D in Group 1 and 1.42 ± 0.62 D, 1.15 ± 0.54 D, 0.94 ± 0.47 D in Group 2 on the first day, first week and first month postoperatively, respectively. According to the vector analysis, SIA was less in Group 1 than Group 2; although the difference was not statistically significant ($p > 0.05$). Conclusion: Although less astigmatism was detected in the superior limbal incision group, this difference was not statistically significant.

Keywords

Cataract, Phacoemulsification, Surgically Induced Astigmatism

1. Introduction

Cataract is the leading treatable cause of blindness in the world and it is treated by surgery only. Due to fast visual improvement and lower complication rate, cataract extraction by phacoemulsification and the insertion of a foldable intraocular lens (IOL) through a small incision is the preferred surgical method [1].

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Currently, cataract surgery is considered as a type of refractive surgery and reduction of refractive defects to the lowest level is possible, leading to increased expectations of patients. Astigmatism due to surgery may affect vision quality and varies related to the type and size of the incision and suture utilization [2].

In this study, surgically induced astigmatism (SIA) following phacoemulsification by 2.8 mm superior limbal incision and superior clear corneal incision were compared.

2. Materials and Method

Patients with the diagnosis of cataracts over the age of 50 subjected to phacoemulsification and IOL implantation were enrolled in this study. Ethical approval was obtained from the local institutional ethics committees and informed consent was obtained from all patients. The study adhered to the tenets of the Declaration of Helsinki. Patients with previous ocular surgery, diabetes, systemic connective tissue disorder, severe dry eye, pytergium, corneal scar, degeneration and ectasia, pseudoexfoliation, uveitis, glaucoma, high myopia and retinal diseases were excluded. In addition, patients with complications such as non-completed capsulorhexis during the operation, zonule dialysis, posterior capsule opening, patients with sutured incisions and patients without regular post-op follow up were excluded.

Ophthalmologic evaluation included best corrected visual acuity (BCVA) by Snellen chart, refraction, keratometry, biomicroscopy, detailed fundus examination, and intraocular pressure (IOP) measurement and corneal topography (Orbscan 2z, B & L, USA). IOL diopter was calculated by Lensstar (Haag Streit Eyesuite™, USA) biometry instrument according to SRK-T formula. Pre- and post-operative astigmatism was calculated by vector analysis and the effect of the incision site on astigmatism due to surgery was compared.

All operations were performed by two surgeons (TK, HC) under topical anesthesia by proparacaine HCl 0.5% (Alcaine; Alcon, Puurs, Belgium). Patients were assigned randomly into two groups. Main incision was made with two sided 2.8-mm blade. One-step superior limbal incision was done in Group 1 and superior clear corneal incision in Group 2. There was no difference between the groups, except location of incision, in any aspects of surgery. Nucleus was broken by "horizontal chop" method and was emulsified using a Sovereign Compact (AMO Laboratories, USA) phacoemulsification instrument. Hydrophobic acrylic IOL (Acriva UD 613.VSY, Istanbul, Turkey) was placed by injector-cartridge system.

In this study, surgical SIA Calculator Version 2.1 vector analysis program developed by Sawhney and Aggarwal, was used. SPSS (Statistical Package for Social Sciences) 17.0 program was used for statistical analysis. Mann Whitney U, Friedman and t tests were used for data comparison. Any p value less than 0.05 ($p < 0.05$) was accepted as significant. Power analysis recommended a minimum of 33 eyes per group in order to obtain an efficacy size of 0.8, alpha value 0.05 and statistical power of 0.8.

3. Results

Sixty-eight eyes of 65 patients (31 females, 34 males) were included. Superior limbal incision was used in 35 patients (13 female, 22 male) (Group 1) and superior clear corneal incision in 33 patients (18 female, 15 male) (Group 2). Mean age was 64.00 ± 8.83 and 64.12 ± 10.30 years in Group 1 and 2, respectively. No statistical differences were present between the two groups in terms of mean age ($p = 0.959$) and gender distribution ($p = 0.150$).

Mean BCVAs in Group 1 were 0.19 ± 0.11, 0.36 ± 0.23, 0.70 ± 0.23 and 0.92 ± 0.08 pre-operatively, and postoperatively first day, first week and first month, respectively; same parameters were 0.17 ± 0.11, 0.38 ± 0.24, 0.72 ± 0.20 and 0.94 ± 0.08 in Group 2. No statistical difference was found between the groups in terms of these values ($p = 0.512$, $p = 0.808$, $p = 0.686$ and $p = 0.150$).

Mean IOP measured by non-contact tonometry in Group 1 were 12.71 ± 3.81 mmHg, 15.06 ± 3.39 mmHg, 12.85 ± 3.54 mmHg, and 12.66 ± 3.71 mmHg pre-operatively, postoperatively first day, first week and first month, respectively; same parameters were 13.09 ± 2.98 mmHg, 15.27 ± 4.93 mmHg, 13.00 ± 3.93 mmHg, 12.97 ± 2.70 mmHg in Group 2. No statistical difference was found between the two groups in terms of these values ($p = 0.643$, $p = 0.567$, $p = 0.875$ and $p = 0.715$).

Mean SIA calculated by vector analysis method was smaller in Group 1 than those in Group 2 however; the difference was not statistically significant between the groups (**Table 1** and **Figure 1**). In-group comparison, significant decrease was seen in astigmatism during postoperative wound healing period when analyzed by Friedman test (p values for Group 1 and 2 respectively, 0.045 and <0.001).

Mean SIA centroid values calculated by vector analysis method in Group 1 and 2 were seen in **Table 2** and **Figure 2**. Mean SIA centroid axial values revealed that patients in Group 1 had irregular astigmatism whereas oblique astigmatism were seen in Group 2 postoperatively.

Correlation between mean SIA calculated by vector analysis and mean IOP was evaluated and no significant correlation was detected by assessing the effect of mean IOP on SIA ($r < 0.50$) (**Table 3**).

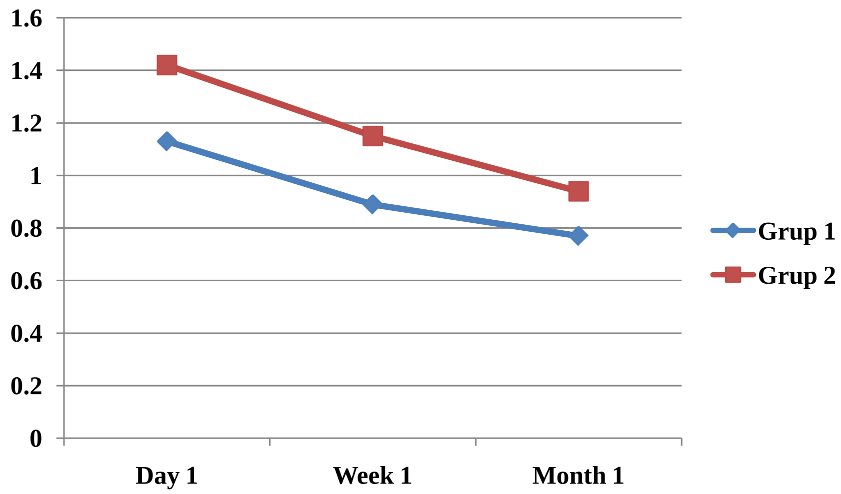

Figure 1. Mean SIA in both groups (diopter) calculated by vector analysis method in both groups on postoperative 1st day, 1st week and 1st month.

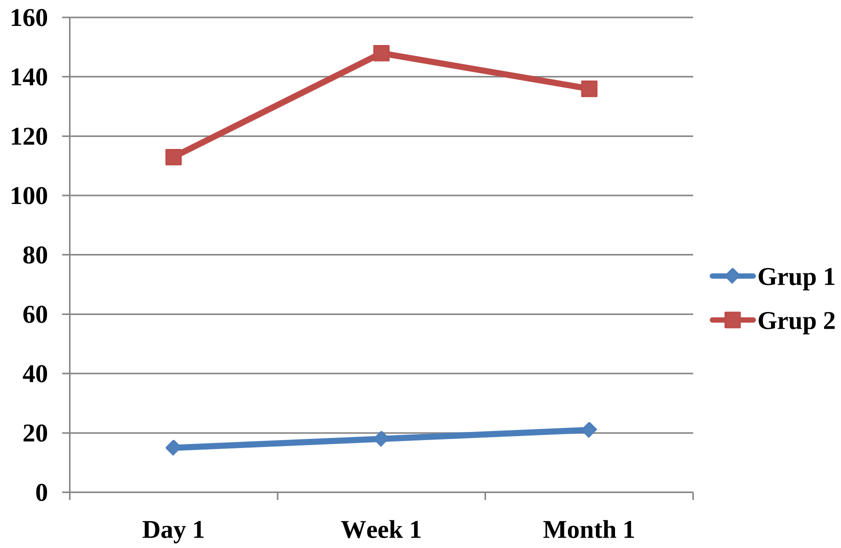

Figure 2. Mean SIA centroid axial values (degree) in both groups calculated by vector analysis method in both groups at postoperative 1st day, 1st week and 1st month.

Table 1. Surgery-related astigmatism ± SD (diopter) calculated by vector analysis method in both groups on postoperative 1st day, 1st week and 1st month.

Postoperative	Group 1	Group 2	t/u value	p value
1st day	1.13 ± 0.67	1.42 ± 0.62	−1.721 (t)	0.090
1st week	0.89 ± 0.47	1.15 ± 0.54	392 (u)	0.054
1st month	0.77 ± 0.37	0.94 ± 0.47	519 (u)	0.473

Table 2. Mean surgery-related astigmatism centroid (c) in both groups calculated by vector analysis method in both groups on postoperative 1st day, 1st week and 1st month.

	Group 1		Group 2	
Postoperative	Centroid	Axis	Centroid	Axis
1st day	0.81	15	0.31	113
1st week	0.60	18	0.26	148
1st month	0.43	21	0.46	136

Table 3. Correlation between mean surgery-related astigmatism calculated by vector analysis and mean IOP postoperative 1st day, 1st week, 1st month in both groups.

	Group 1		Group 2	
Postoperative	r value	p value	r value	p value
1st day	−0.21	0.219	−0.08	0.634
1st week	−0.27	0.116	−0.02	0.878
1st month	−0.14	0.421	0.18	0.300

4. Discussion

Phacoemulsification and IOL implantation technique is currently the most widely used ocular surgery. Corneal interventions affect corneal curve and refraction power. Post-surgical high astigmatism is one of the reasons behind unsatisfying visual outcomes of cataract procedure. Phacoemulsification provides faster visual improvement, smaller surgical incision and less irregular astigmatism than other techniques. Foldable IOL usage leads to small incision site and minimal SIA. Post operative astigmatism after cataract surgery is related to two factors: preoperative astigmatism of patient and SIA [3] [4].

Surgically induced astigmatism is a frequent complication of cataract surgery and plays an important role in postoperative visual acuity. Astigmatic variation is mostly due to corneal contour changes in SIA. Surgically induced astigmatism varies related to type, length and site of the incision, suture utilization, distance of incision to the optic center of cornea. Even lower astigmatism is important, since this would affect distance sight of patients [3] [5].

Incision site is an important factor affecting SIA. While superior corneal or limbal incision leads to irregular astigmatism, temporal corneal incision leads to regular astigmatism. One or two sided temporal incisions lead to minimal astigmatism; however three sided and deep groove incisions lead to increased astigmatism [6]. Kohnen *et al.* [7] showed more SIA in nasal incisions in their study. They suggested that this could be due to more stress and corneal stretch in the wound site related to more perpendicular entrance to cornea in nasal incision and also to the closer location of nasal incision to corneal center.

Wirbelauer *et al.* [8] compared superior, temporal and oblique vertical axial scleral tunnel incisions of 7.0 mm and detected flattening of vertical axis and steepening in horizontal axis. In addition, increased degrees of astigmatism were seen in superior incisions than all other incisions. Şimşek *et al.* [9] compared temporal clear corneal incision and superior clear corneal incision; they showed statistically significantly more and irregular astigmatism in superior corneal incisions.

In another study, Pakravan *et al.* [10] compared biplanar temporal and nasal clear corneal incisions of 3.2 mm and they determined statistically significantly less astigmatism for temporal incision (0.26 D) compared to nasal incision (0.92 D) at 6th month. Özkurt *et al.* [11] compared the effects of superior-nasal and superior-temporal clear corneal incisions on total astigmatism and they showed statistically significantly less total and SIA in temporal incision at 6th week. Long *et al.* [12] compared corneal tunnel incisions from vertical axis of 3.0 - 3.2 and 3.5 mm. Incisions on vertical meridian were reported to lead to more astigmatic change than ones at horizontal meridian. Kılıç *et al.* [13] compared superior temporal and superior nasal clear corneal incisions of 3.2 mm in their study. Surgically induced astigmatism was statistically significantly more frequent with nasal incision. Yaycıoğlu *et al.* [14] compared nasal, temporal, superior temporal or superior clear corneal incisions to vertical axis and they showed less SIA with temporal and superior temporal incisions**.** Rainer *et al*. [15] compared temporal and superior-lateral clear corneal incisions of 3.0 mm and they observed corneal flattening at incision site of all types, being more frequent with superior-lateral incisions. In these studies comparing temporal, nasal and superior corneal incisions, astigmatism was less frequent with temporal incisions. This was related to the existence of more distance of temporal incision to central cornea than superior incision due to ellipsoid figure of cornea. The other cause was reported to be fluctuation of wound site due to pressure of superior lid. This was related with both scleral tunnel incisions and clear corneal incisions [8]-[15]. Ermiş *et al*. [16] compared superior temporal and superior nasal clear corneal incisions of 3.3 - 3.5 mm in their study and they found no statistically significant difference in terms of SIA. Tejedor *et al*. [17] found out less corneal alterations by temporal incision in patients without preoperative corneal astigmatism. Furthermore, when surgery was performed by temporal clear corneal incisions in eyes with preoperative irregular astigmatism, it was observed that astigmatism decreased in the postoperative period [18] [19]. Temporal incision was recommended in patients with preoperative regular lower astigmatism and preoperative neutral patients [10] [11] [13].

In our study, superior limbal incision of 2.8 mm was used in Group 1 and superior clear corneal incision of 2.8 mm in Group 2. Post-operative surgery related centroid axis values were detected as irregular astigmatism in Group 1 on first day, first week and first month. In Group 2, post-operative surgery related axis were oblique at all measurements on first day, first week and first month.

Type of incision site is an important factor affecting astigmatism. He *et al*. [20] compared astigmatism parameters measured by keratometry for clear temporal corneal incision and superior scleral tunnel incision in terms of astigmatic effect following phacoemulsification.

Postoperatively, more astigmatism was present with corneal incision at first month. However, no statistically significant difference was present between two groups on postoperative third month.

Barequet *et al*. [21] reported that no conjunctival scar developed with clear corneal incisions, thus conjunctiva were preserved for possible future glaucoma surgery. They also reported that conjunctival hemorrhage, hyphema risk and post-operative blood-aqueous changes were low, and also that shorter tunnel incision provided better vision and more comfortable surgery. Therefore, clear corneal incisions were found to be more advantageous than cornea-scleral incisions. Stabilization of corneal tunnel incision lasts postoperative two to six weeks [21]. Astigmatism increased as incision approached the corneal center. Ernest *et al*. [22] compared phacoemulsification with 2.2 mm posterior limbal incision by one surgeon and surgery of 2.2 mm clear corneal incision by five different surgeons and they reported that SIA with posterior limbal incision was statistically significantly less (0.25 D) than all other lowest SIA (0.38). Limbus and cornea are structurally different. Thus, their patterns of wound healing would be different. Cornea is an avascular and starched tissue with dense fibroblasts. Limbus has vascular structures constituting the source of fibroblasts, resulting in a faster wound healing. Wound healing occurs within seven days at limbus however this period may be extended to 60 days for cornea [23]. Since limbus is more resistant than cornea against the pressure, clear corneal incision has 5.8 times more risk of endophthalmitis than limbal and scleral tunnel incisions [24]. In our study, superior limbal incision was used in Group 1 and superior clear corneal incision was used in Group 2. Mean SIA was less in the group with limbal incision than in the group with corneal incision on postoperative first day, first week and first month. However, this difference was not statistically significant. In-group comparison, during wound healing process, decrease in astigmatism is more prominent in Group 2 in the first month postoperatively.

Suture is also an important factor for astigmatism. Suture and tissue adhesive reduce tissue elasticity. Suture at appropriate stretch and localization may reduce SIA. However, stretched and misplaced sutures may flatten the incision site and increase astigmatism in that meridian by steepening in the central optic zone [25]. In our study, we have no patients with suture.

Corneal burn due to phacoemulsification also leads to serious SIA especially in clear corneal incision. Same amount of corneal burn results in more SIA in clear corneal incision than in limbal incision.

Reducing SIA is an important issue in modern cataract surgery. Currently, cataract surgery is considered as a kind of refractive surgery. Development of modified techniques may reduce post-operative astigmatism. Examples of these methods are incision at vertical axis of cornea, corneal-limbal relaxing incisions, toric IOL implantation and excimer laser. Preoperative astigmatism of 1.5 D may be corrected by incision at vertical corneal axis. Astigmatism of >1.5 D may require additional relaxing incisions or other methods. In patients with preoperative irregular astigmatism, temporal incision may reduce astigmatism [3] [4]. Tejedor *et al*. [17] reported that clear corneal incisions reduce preoperative astigmatism by performing incision at vertical axis. In patients without preoperative astigmatism, superior corneal incision may lead to more astigmatism than temporal incision, especially incision at vertical axis should be recommended in preoperative astigmatism of 1.50 D and more at vertical axis of 90˚ and preoperative astigmatism of 0.75 D and more at vertical axis of 180˚. He *et al*. [20] reported that refractive stabilization of cornea may take three months. Therefore, in cases of additional corneal limbal relaxing suture or incision on wound site, they would be done within postoperative three months. SIA may be reduced by toric-multifocal IOL [26]. In patients with preoperative astigmatism of >1 D multifocal IOL may be used [27].

5. Conclusion

In conclusion, no differences were present in our study in terms of incision site and size between groups. Mean SIA was lower in limbal incision group than clear corneal incision group on postoperative first day, first week and first month. However, no statistically significant difference was present.

Declaration of Interest

None.

Conflicts

The authors report no conflicts of interest.

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