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Clear corneal incision of 2.75 mm for cataract surgery induces little change of astigmatism in eyes with low preoperative corneal cylinder

F. GIANSANTI, E. RAPIZZI, G. VIRGILI, R. MENCUCCI, A. BINI, L. VANNOZZI, U. MENCHINI

Eye Clinic, Department of Oto-Neuro-Ophthalmological Surgical Sciences, Univ. of Firenze, Firenze - Italy

PURPOSE. *To assess the early astigmatic effect induced by 2.75 mm clear cornea incisions with different locations for cataract surgery.*

METHODS. *A total of 146 eyes of different patients were studied prospectively. Cataract surgery was performed by three surgeons, two using a temporal approach and one using a superior approach. For both approaches, the site of the 2.75 mm incision was allowed to vary slightly according to the characteristics of the eye and orbit. Computerized videokeratography was used to measure corneal astigmatism before surgery and after 1, 4, and 12 weeks. Corneal astigmatism was recorded as cylinder and axis and it was then converted to 2 power vector. Model based prediction and comparisons were made for the most commonly used corneal incision sites: 12 (both eyes), 2 (left eye), and 8 (right eye) o'clock meridian.*

RESULTS. *After 3 months the differences in corneal astigmatism (JCC_0) between the incisions performed at 12 and 2 o'clock were not statistically significant (-0.08, 95% CI: -0.19, -0.02); the differences in JCC_0 between incisions at 12 and 8 o'clock were -0.17 (95% CI: -0.30, -0.05; $p<0.01$). After 3 months the change in JCC_0 for the patients with 0.5 D with-the-rule preoperatively were -0.32 (95% CI: -0.44, 0.21; $p<0.01$) for incisions at 12; -0.24 (95% CI: -0.36, 0.13; $p<0.01$) for incisions at 2; and -0.15 (95% CI: -0.27, -0.03; $p<0.05$) for incisions at 8. After 3 months the changes of JCC_0 for the patients with -0.5 D against-the-rule preoperatively were 0.10 (95% CI: 0.04, 0.23) for incision at 12; 0.18 (95% CI: 0.04, 0.32; $p<0.05$) for incisions at 2; and 0.27 (95% CI: 0.14, 0.40; $p<0.01$) for incisions at 8 o'clock. The oblique astigmatic vector (JCC_{45}) was very modest in this sample before surgery and underwent minimal and nonsignificant change after it.*

CONCLUSIONS. *This study has shown that a 2.75 mm clear corneal incision causes a small change of corneal cylinder regardless of incision site. (Eur J Ophthalmol 2006; 16: 385-93)*

KEY WORDS. *Astigmatism, Cataract surgery, Clear corneal incision*

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INTRODUCTION

One of the aims of modern cataract surgery is to minimize surgically induced astigmatism (SIA). Recently, improvement in surgical instruments for cataract phacoemulsification has allowed reduction of the size of corneal incisions. Many factors such as wound size, position, and architecture are known to influence postoperative astigmatism. Several studies have shown that a 3.2 mm or little more sutureless clear corneal incision (CCI) followed by implantation of a foldable intraocular lens (IOL) result in a low and stable astigmatism (1-9). Some authors showed that postoperative astigmatism after a small temporal CCI is less than after superior and superolateral CCI (6, 10-12).

In this study we evaluated the early astigmatic effect induced by 2.75 mm sutureless corneal incisions with different locations for phacoemulsification cataract surgery.

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METHODS

A total of 146 eyes of different patients were studied prospectively. A complete ophthalmologic examination was performed preoperatively and 1, 4, and 12 weeks after surgery.

Exclusion criteria included a preoperative diagnosis of an inflammatory ocular condition, ocular surface irregularity, a history of ocular surgery, or intraoperative or postoperative complications. Patients with systemic connective tissue disease were also excluded. Informed consent was obtained from all participants. No ethics committee approval was required.

Computerized videokeratography (EyeSys Corneal Analysis System, EyeSys Laboratories, Inc.) was recorded preoperatively and at each follow-up visit (1, 4, and 12 weeks after surgery) to measure corneal astigmatism (Figs. 1 and 2).

Surgery was performed by three right-handed surgeons (A, B, and C) who were experienced in phacoemulsification cataract surgery. All operations were performed at the Department of Ophthalmology of Florence using the same technique except for the position of the surgeons (superior or lateral) and the incision locations. Surgeon A used a superior position, whereas surgeons B and C used a lateral access.

The site of 2.75 mm incisions could be varied slightly by the surgeon according to preference and the characteristics of the patient's eye and orbit. Patients were assigned to surgeons based on the same waiting list, so that no association was expected between corneal cylinder and incision site, as demonstrated in statistical analyses. Topical anesthesia was used in all cases. A 2.75 mm precalibrated steel blade (Slit Knife 2.75 mm, Alcon Surgical) was used to create a biplanar corneal incision at the anterior edge of the limbal vessels.

The tunnels were 2.75 mm wide and 1.7 to 2.00 mm long. Two 1-mm-wide paracentesis were also made at 90 degrees from the tunnel. Phacoemulsification was performed using Series 20000 Legacy® with Turbosonics® MicroTip (Alcon Surgical, Irvine, CA).

Without enlarging the tunnel, an acrylic IOL (AcrySof SA60AT) was then placed in the capsular bag using injector and cartridge Monarch II (model 8065977759, Alcon Surgical); the viscoelastic material was removed and the wound was hydrated and not sutured.

The corneal incision locations were recorded as the clock hour corresponding to the middle of the corneal tunnel.

Statistical analyses

Corneal astigmatism was recorded as cylinder and axis and then converted in 2 power vectors (14, 15).

A Jackson crossed-cylinder at 0°/90° (JCC_0) and one at 45°/135° (JCC_{45}) are obtained through the formulas (-Cylinder/2)*cos(2α) and (-Cylinder/2)*sin(2α), respectively.

A Markov transition regression model was used to evaluate the temporal pattern of the two cylinder components and the influence exerted on this pattern by the site of corneal incision. Transition models are suitable to analyze factors associated to change with time (15). In these time-series regression models the disturbance term was first-order autoregressive, meaning that every measure is regressed on the preceding one.

To model the effect of incision size, the clock hours were converted to degrees with the null value placed at 12 o'clock. Both a sine and a cosine function of this transformation were used in regressions to allow for a continuous and recursive effect of incision site location. Because of this setting, the JCC_0 is expected to be particularly associated with the cosine function, which changes more rapidly near to the null angle. Time was used as a nominal variable to avoid fitting specific temporal patterns to only four points.

The baseline value of the JCC_0 and ICC45 were entered both as a linear and as a quadratic term in the regressions. An interaction with time was used to evaluate the effect of longitudinal trend of change of the covariates on the cylinder components.

Because the regression model allowed analysis of incision site as a continuous variable, predictions were made for the most commonly used incision sites: 12 (right and left eye), 2 (left eye), and 8 (right eye).

RESULTS

The number of eyes at each follow-up visit were as follows: week 0 = 146; week 1 = 135; week 4 = 139; week 12 = 119. Mean age was 72 years (range 41 to 92 years).

The incision site and the eye operated on are shown in Table I. The surgeon who used the superior approach performed the incisions at 11 and 12 o'clock meridians in the right eyes and at 12 in the left eye. The surgeon who used the temporal approach performed the incisions at 9, 8, and 7 o'clock meridians in the right eye and at 2 and 3 in the left eye.

Mean JCC_0 was 0.05 D (standard deviation: 0.47 D;

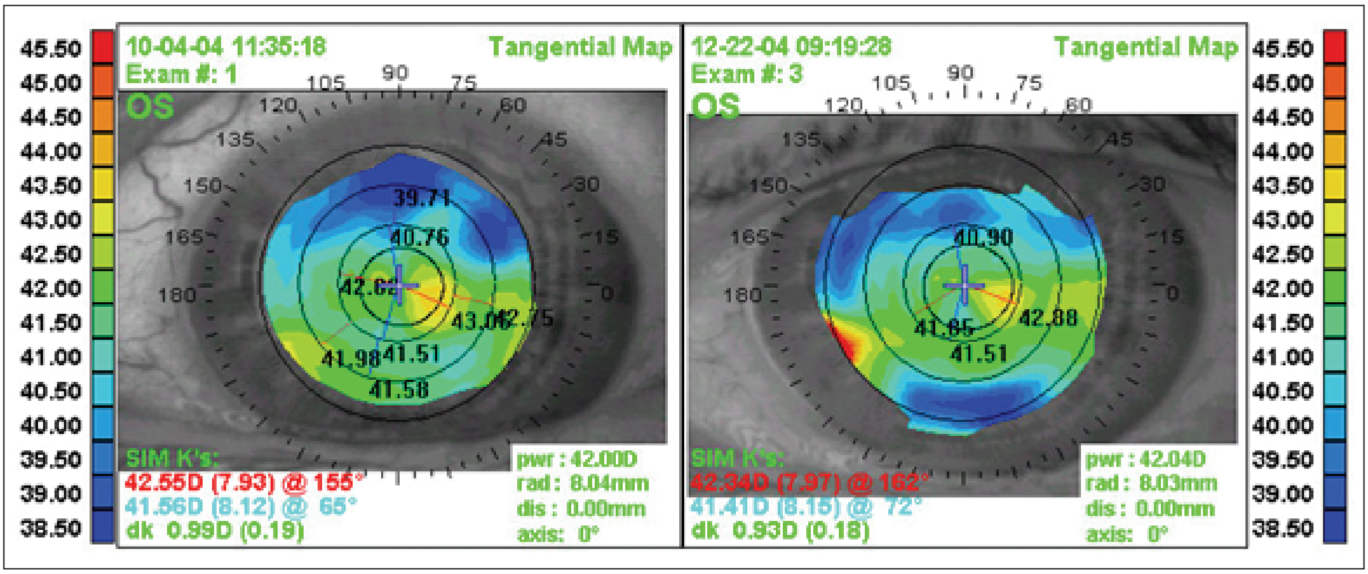

Fig. 1 - *Preoperative (left side) and postoperative (right side) videokeratography of a 77-year-old man (left eye) with the steep axis of presurgical corneal astigmatism at 155 degrees (0.99 diopters). He underwent phacoemulsification through incision performed at 2 o'clock meridian. At the 3 month postoperative examination the steep axis of astigmatism was located at 162 degrees and the amount of corneal astigmatism was 0.93 diopters.*

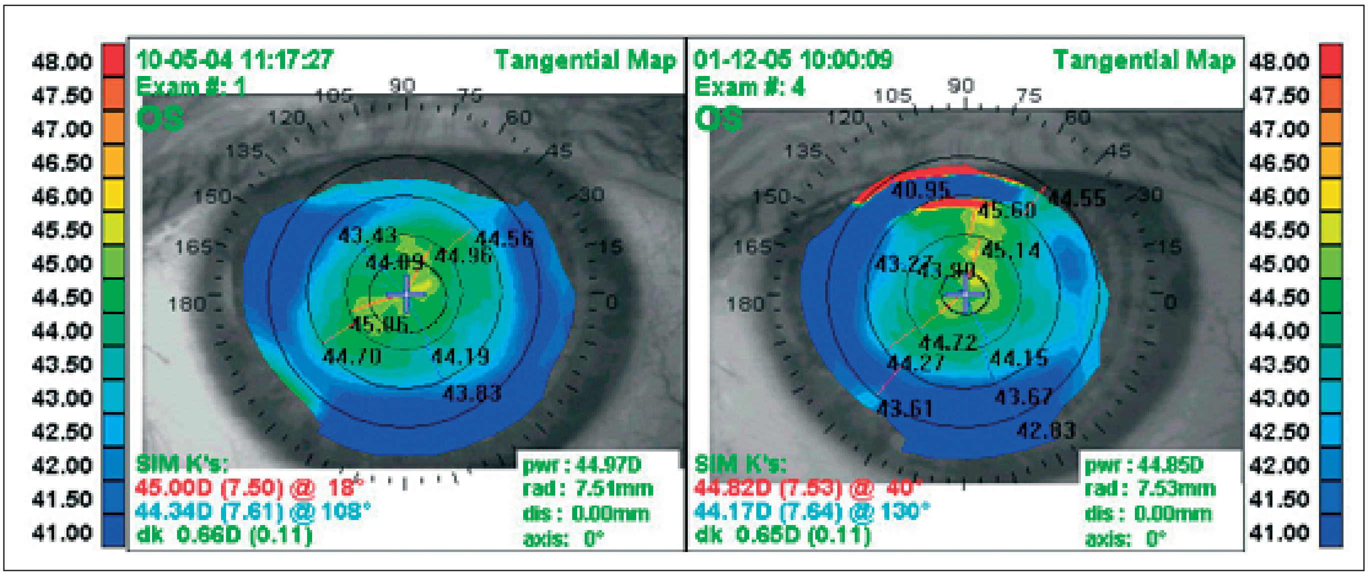

Fig. 2 - *Preoperative (left side) and postoperative (right side) videokeratography of a 69-year-old woman (left eye) with the steep axis of presurgical corneal astigmatism at 18 degrees (0.66 diopters). She underwent phacoemulsification through corneal incision performed at 12 o'clock meridian. At the 3 month postoperative examination the steep axis of astigmatism was located at 40 degrees and the amount of corneal astigmatism was 0.65 diopters.*

min: -1.5 D; max: 2 D) and mean JCC_{45} was -0.2 D (standard deviation: 0.28 D; min: -1.09 D; max: 1.43 D). Baseline values of the two JCCs showed a statistically significant but modest correlation (Pearson correlation coefficient: -0.19, p=0.02). Their baseline value was not associated with either the sine or the cosine (p>0.3 for all pairs) transformations used to model incision site, thus indicating independence of their values.

In a simple regression model in which only incision site and its interaction with time were entered, there was little change of mean JCCs values during follow-up. For the JCC_0, predicted changes at 12 weeks were -0.12 (95%

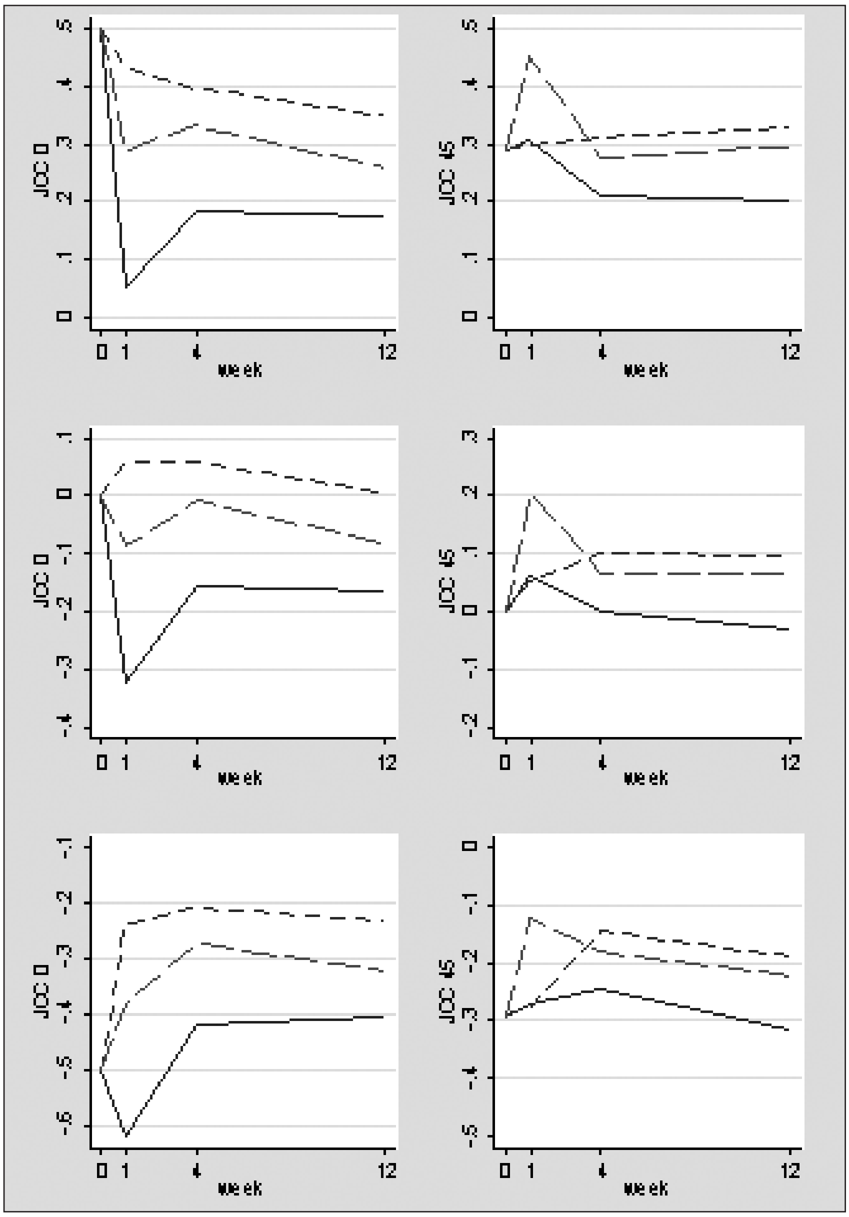

Fig. 3 - *Change from baseline of the JCC_0 (left) and JCC_{45} (right) vectors as predicted by regression models for baseline cylinder values of 0.5 D, 0 D, and -0.5 D for the JCC_0 and of 0.3 D, 0 D, and -0.3 D for the JCC_{45}. The values of 0.5 and 0.3 were used because they were close to the 10th and 90th percentile of the baseline JCC_0 and JCC_{45} distributions. The solid line corresponds to the 12 o'clock incision, while the long-dashed line and the dashed lines are those of the 2 and 8 o'clock incision sites, respectively.*

CI: -0.24, -0.01), 0.04 (95% CI: -0.8, 0.15), and -0.08 (95% CI: -0.20, 0.04) for the 12, 2, and 8 o'clock incision sites, respectively. The correspondent values for the JCC_{45} were -0.05 (95% CI: -0.15, 0.06), 0.06 (95% CI: -0.05, 0.17), and 0.02 (95% CI: -0.09, 0.04). However, changes were influenced by the baseline value of corneal JCCs, including a square term determining a non-linear effect. Age was also retained in the model when JCC_0 was the dependent variable, accounting for a change of this vector component of about -0.10 D per 10 years of age at all follow-up controls with respect to baseline. It was set at the mean value of 75 years for predictions shown in Figure 3 and Table II. When JCC_0 was the dependent variable, JCC_{45} was not retained in the model, as was for the reverse case.

JCC_0 change from baseline for incision sites at 12, 2, or 8 o'clock

Figure 4 presents the change from baseline of the JCC_0 and JCC_{45} vectors as predicted by regression models. The rows correspond to baseline cylinder values of 0.5 D, 0 D, and -0.5 D for JCC_0 and of 0.3 D, 0 D, and -0.3 D for JCC_{45}. The values of 0.5 and 0.3 were used because they were close to the 10th and 90th percentile of the JCC_0 and JCC_{45} baseline distributions, enabling more reliable statistical prediction than more extreme values. In absolute value, they correspond to corneal astigmatism of 1 D and 0.6 D on that axis.

Table II presents the differences from baseline and their 95% confidence intervals. It can be seen that statistically significant changes of the JCC_0 vector that persisted during follow-up were as follows:

A negative change after surgery at 12 o'clock for patients with a 0.5 D positive JCC_0. This baseline value corresponds to a by-the-rule astigmatism of 1 D. The final predicted change was a 0.65 D decrease of this cylinder.

A similar but smaller negative change for a patient with null JCC_0, corresponding to the development of an against-the-rule astigmatism of 0.3 D.

A positive shift for incision sites 2 and 8 o'clock when the patient had a -0.5 baseline JCC_0, corresponding to a 1 D against-the-rule astigmatism. This change corresponded to a 0.4 D and 0.5 D decrease of the astigmatism for the 2 and 8 o'clock incision sites, respectively.

The limits of the 95% confidence intervals of the predicted changes for all incision sites were sufficiently narrow to conclude that differences of change of the JCC_0 vector are not larger than 0.4 D from 4 to 12 weeks after surgery and were actually smaller for most predictions.

Differences of JCC_0 change from baseline among incision sites at 12, 2, or 8 o'clock

In regression models, there was no statistically significant interaction of the sine and cosine functions with baseline values of the JCCs in the regressions. This means that the difference between values of JCCs was estimated to be similar for all incision sites at a given week. These values are presented in Tab. III. As seen in the Table, the 12 o'clock incision site caused a JCC_0 vector change which was significantly more negative than the 2 and 8 o'clock incisions 1 week after surgery. However, the only difference that remained statistically significant throughout follow-up was that of the JCC_0 between incisions sites at 12 vs 8 o'clock. Furthermore, the limits of the 95% confidence intervals of comparisons among incision sites were sufficiently narrow to conclude that differences of change of the JCC_0 vector are not larger than 0.2 or 0.3 D from 4 to 12 weeks after surgery.

Similar models where the change from baseline of the JCC_0 was the dependent covariate were able to explain about 1/3 of both the between and within subject variances, suggesting the other factors influence the change of the main component of corneal astigmatism than those recorded in this study.

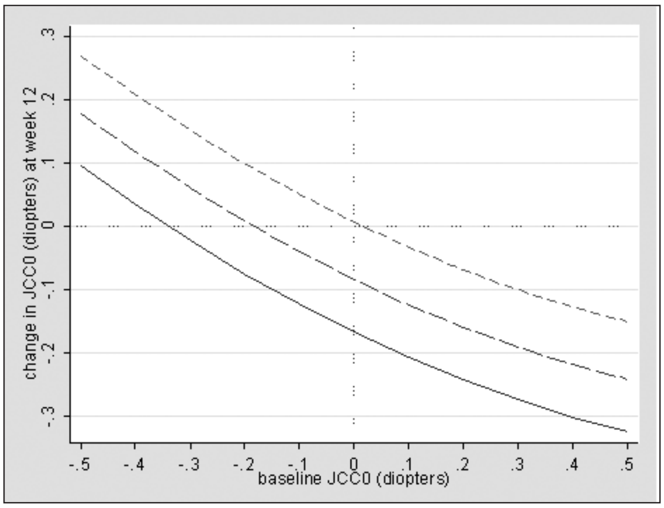

Fig. 4 - *Change of JCC_0 from baseline to week 12 (y axis) according to baseline JCC_0 values (x axis) and incision sites (12 o'clock: lower solid line; 2 o'clock: mid long-dashed line; 8 o'clock: upper dashed line). Values in quadrants with opposite sign (upper left and lower right) mean cylinder reduction, whereas those in quadrants with the same sign (upper right and lower left) mean cylinder increase. It can be seen that mild JCC_0 vector increase can be seen for the 12 o'-clock incision site when the baseline value is around -0.1 D, although only a similar amount of increase is predicted.*

JCC_{45} change from baseline for incision sites at 12, 2, or 8 o'clock

There was no persistent change of this cylinder vector component for the three incision sites. The limits of the 95% confidence intervals ruled out changes in the oblique corneal cylinder component of more than 0.5 D

TABLE I - LOCATION OF THE CORNEAL INCISION FOR RIGHT AND LEFT EYES

Clock hour	Right eye	Left eye
2		34
3		9
7	7	
8	33	
9	15	
11	3	
12	24	25
Total	78	68

TABLE II - MODEL PREDICTED CHANGES FROM BASELINE AND THEIR 95% CONFIDENCE INTERVALS OF THE JCC_0 AND JCC_{45} FOR EVERY INCISION SITE (12, 2, and 8 H)

			JCC_0, Incision site: 12 h	
	JCC_0	**0.5D**	**0**	**-0.5 D**
Week				
1		-0.45 (-0.53; -0.37)*	-0.32 (-0.39; -0.25)*	-0.12 (-0.20; -0.04)*
4		-0.32 (-0.42; 0.21)*	-0.15 (-0.24; -0.07)*	0.08 (-0.03; 0.19)
12		-0.32 (-0.44; 0.21)*	-0.17 (-0.27; -0.06)*	0.10 (-0.04; 0.23)
			JCC_0, Incision site: 2 h	
	JCC_0	**0.5 D**	**0**	**-0.5 D**
Week				
1		-0.21 (-0.28; -0.14)*	-0.09 (-0.15; -0.03)*	0.12 (0.04; 0.20)*
4		-0.17 (-0.27; -0.07)*	-0.01 (-0.10; 0.08)	0.22 (0.11; 0.34)*
12		-0.24 (-0.36; 0.13)*	-0.08 (-0.19; 0.02)	0.18 (0.04; 0.32)†
			JCC_0, Incision site: 8 h	
	JCC_0	**0.5 D**	**0**	**-0.5 D**
Week				
1		-0.07 (-0.14; -0.00)	0.06 (-0.04; 0.15)	0.26 (0.18; 0.34)*
4		-0.10 (-0.21; 0.00)	0.06 (-0.04; 0.15)	0.29 (0.18; 0.40)*
12		-0.15 (-0.27; -0.03)†	0.01 (-0.10; 0.11)	0.27 (0.14; 0.40)*
			JCC_{45}, Incision site: 12 h	
	JCC_{45}	**0.3 D**	**0**	**-0.3 D**
Week				
1		0.02 (0.06; 0.09)	0.06 (-0.01; 0.13)	0.02 -(0.05; 0.10)
4		-0.08 (-0.19; 0.03)	0.00 (-0.09; 0.09)	0.05 (-0.06; 0.15)
12		-0.09 (-0.21; 0.03) -	0.03 (-0.13; 0.08)	-0.02 (-0.14; 0.0)
			JCC_{45}, Incision site: 2 h	
	JCC_{45}	**0.3 D**	**0**	**-0.3 D**
Week				
1		0.16 (0.09; 0.24)*	0.21 (0.14; 0.27)*	0.17 (0.10; 0.24)*
4		-0.01 (-0.13; 0.10)	0.07 (-0.03; 0.16)	0.11 (0.01; 0.22)†
12		0.01 (-0.13; 0.14)	0.07 (-0.05; 0.19)	0.02 (-0.11; 0.15)
			JCC_{45}, Incision site: 8 h	
	JCC_{45}	**0.3D**	**0**	**-0.3D**
Week				
1		0.01 (-0.07; 0.08)	0.05 (-0.01; 0.12)	0.01 (-0.06; 0.09)
4		0.02 (-0.09; 0.13)	0.10 (0.01; 0.20)†	0.15 (0.04; 0.26)*
12		-0.04 (-0.09; 0.16)	0.10 (-0.01; 0.21)	0.10 (-0.02; 0.23)

Values are in diopters; *p<0.01 †p<0.05

for all predictions.

Figure 3 allows appreciation graphically of the temporal trends of JCC_0 and the differences among incision sites. Similar values are obtained at weeks 4 and 12, suggesting stabilization.

Figure 4 presents the continuous relationship between baseline JCC_0 and its change at week 12. It can be seen that a cylinder reduction is almost always predicted, with the 12 o'clock site causing a more negative shift than the 2 or 8 o'clock sites.

TABLE III - MODEL PREDICTED DIFFERENCES AND THEIR 95% CONFIDENCE INTERVALS (D) OF THE JCC_0 AND JCC_{45} FOR RECIPROCAL COMPARISON BETWEEN INCISION SITES AT 12, 2, AND 8 H

	Week predicted difference between 12, 2, and 8 h incision sites		
JCC_0	**12 h – 2 h**	**12 h – 8 h**	**2 h – 8 h**
1	-0.24 (-0.33; -0.15)*	-0.38 (-0.49; -0.27)*	-0.14 (-0.25; -0.04)*
4	-0.15 (-0.24; 0.05)*	-0.21 (-0.32; -0.10)*	-0.06 (-0.18; 0.05)
12	-0.08 (-0.19; 0.02)	-0.17 (-0.30; -0.05)*	-0.09 (-0.22; 0.03)
JCC_{45}	**12 h – 2 h**	**12 h – 8 h**	**2 h – 8 h**
1	-0.15 (-0.23; -0.06)*	0.01 (-0.10; 0.12)	0.15 (0.05; 0.26)*
4	-0.06 (-0.15; 0.03)	-0.10 (-0.21; 0.01)	-0.04 (-0.14; 0.07)
12	-0.09 (-0.10; 0.12)	0.13 (-0.25; -0.01)†	-0.03 (-0.15; 0.09)

*p<0.01
†p<0.05

DISCUSSION

Small incision sutureless cataract surgery has allowed for the creation of a potentially astigmatically neutral incision with less postoperative astigmatism shift.

Our study has shown that a 2.75 clear corneal incision causes a small change of corneal cylinder regardless of incision site. They are less than 0.6 D for the main cylinder component, the vertical or JCC_0 vector, for a patient with a preoperative value of 1 D, regardless of the axis. Furthermore, the shift is always towards a reduction of corneal cylinder. As expected by the study by Tejedor and Murube (6), a 12 o'clock incision tends to reduce a with-the-rule cylinder, whereas temporal incision tends to reduce against-the-rule cylinders.

However, differences of the vertical and lateral sites were small or no longer statistically significant after 1 week. Confidence intervals of the estimates were sufficiently narrow to exclude differences among incision sites of 0.6 D or more, starting from a corneal cylinder of ±1 D, the 95th percentiles for the subjects in our study. For the oblique component, the JCC_{45}, the change was less than 0.4 D for a corneal cylinder within ±0.6 D, which were also the 95th percentiles for this vector component.

Previous studies reported surgically induced astigmatism with corneal sutureless incisions of 3.2 mm or more (6, 8, 9, 10, 12). Rainer et al (12) found a higher amount of SIA after superolateral CCI than after temporal CCI. At 3 months, the extent of corneal flattening was up to 0.7 D in the temporal group and up to 1.2 D in the superolateral group after a CCC of 3.0 mm.

However, with the characteristics of the IOL utilized in that study, they could not be implanted in the capsular bag without enlarging the wound for more than 3.0 mm.

Other studies have shown that a small superior CCI induces higher postoperative astigmatism than a small temporal CCI (3, 4) and a small superolateral CCI (5, 6).

Jacobs et al (8) reported that 3.2 supero-oblique clear corneal incisions did not induce a clinically important amount of oblique astigmatism.

Three months postoperatively, mean refractive error was -0.85 D + 0.30 D x 47.27 and in those older than 80, -0.87 D + 0.94 D x16.85. In contrast, Nielsen (16) found that only the direction of astigmatism, not the amount, was changed by moving the CCI from a superior to temporal position.

Barequet et al (17) found that temporal incisions induced significantly less astigmatism than nasal incisions. At 3 months the mean SIA in the nasal group was 1.41 D and in the temporal group 0.74 D. However, in this study a single radial suture was passed across the wound.

Recently, Tejedor and Murube (6) investigated the best location of 3.5 mm CCI depending on preexisting corneal astigmatism. In 89 patients with negligible corneal astigmatism (≤0.5 D) the average induced refractive change was -0.25 D +0.72 D x 103 in the superior incision and -0.32 D + 0.54 D x 1 in the temporal incision. The vector of corneal astigmatism change showed significant differences in the JCC0 component, which increased in the superior and decreased in the temporal incision group (0.20

D ± 0.29 D compared with 0.16 D ± 0.28 D) and in the JCC_{45} component (0.10 D ± 0.26 D compared with 0.007 D ± 0.07 D).

However, the results of the study of Tejedor et al cannot be compared directly with our results for two main reasons: the groups are different in terms of preoperative astigmatism and size of the incisions.

The reason for the slightly more pronounced incision-related flattening after superior CCI than temporal CCI reported in previous studies (5, 12) is not clear.

A possible explanation is that the superior incisions are located more centrally than temporal ones (18, 19) and another reason might be the pressure on the cornea caused by the upper eyelid (20); however, the results of our study seem to indicate that the differences between lateral and superior access are very little with corneal incisions of 2.75 mm.

A limitation of our study was that assignment of eyes to an incision site was not randomized. However, the same waiting list was used for all three surgeons, one of whom used the vertical approach. Surgeons were well-trained and used a standard procedure and instrument for corneal incision.

Our results do not apply to preoperative cylinders of more than 1 D along the vertical axis. Further studies would be needed to investigate the effect of 2.75 mm corneal incisions in eyes with higher astigmatism.

CONCLUSIONS

In conclusion, this study provides evidence that incisions of 2.75 mm length for cataract surgery performed with superior or temporal access tend to lower the vertical cylinder component in case of small preoperative corneal astigmatism. As expected, the 12 o'clock incision site may be preferable for eyes with a with-the-rule cylinder, whereas the 2 and 8 o'clock sites may be preferred for an against-the-rule cylinder, but differences among sites are small overall. No substantial shift of the oblique cylinder component is caused with any incision site when its preoperative values are negligible.

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Reprint requests to:
Fabrizio Giansanti, MD
Eye Clinic Department of Oto-Neuro-Ophthalmological Surgical Sciences
University of Florence
Viale Morgagni 85
50134 Firenze, Italy
fabriziogiansanti@interfree.it

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