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ORIGINAL PAPER

Lensectomy after radial keratotomy: 1-year follow-up

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Abstract

Purpose To report visual and refractive results in radial keratotomy (RK) patients that underwent a cataract surgery with a monofocal intraocular lens (IOL) implantation with 1 year of follow-up.

Methods Twenty-eight eyes of 15 patients with cataract and the previous RK were included. All eyes underwent phacoemulsification and monofocal IOL implantation. IOL power calculation was done using the Double-K formula of Aramberri. The preoperative versus postoperative corrected distance visual acuity (CDVA) and the uncorrected distance visual acuity (UDVA) values were used to assess the efficacy and safety of the surgery; meanwhile, the achieved versus the expected refractive outcomes postoperatively were used to assess the predictability.

Results Phacoemulsification and IOL implantation was performed successfully in all eyes, and no intra- and postoperative problems occurred. The mean logMAR UDVA significantly improved from 0.7 ± 0.3 to 0.4 ± 0.2 at 6 months, and 0.3 ± 0.2 at 12 months postoperatively. By the end of the follow-up period, about 60% of the eyes achieved 20/25 or better CDVA, 25% of the eyes gained three or more lines of visual acuity, and two eyes had lost one or more lines of visual acuity. The mean spherical equivalent improved from -1 ± 6.00 to -0.75 ± 1.1 D by the end of the follow-up, and about 60% of the eyes were within ± 1 D at 12 months after the surgery. No intra- and postoperative problems occurred.

Conclusions Pseudophakic monofocal IOL implantation offers good visual acuity recovery and acceptable refractive correction in RK patients after 1-year follow-up.

Keywords Radial keratotomy · Phacoemulsification · Cataract · Intraocular lens · Visual acuity

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Introduction

Radial keratotomy (RK) was introduced around 1970, and it was the most common surgery for 20 years, when the corneal laser surgery became more popular. As it was reported, the main postoperative complications after RK were diurnal fluctuations, hyperopic or

myopic shift, and poor predictability [1, 2]. Nevertheless, although RK is not commonly used, patients who had undergone RK in the past have aged and have developed cataract. Unfortunately, there are few challenges to calculate correctly the intraocular lens (IOL) power, such as the hyperopic shift, [3] the difficulties to determine the effective lens position, [4] and the difficulties to calculate the true corneal curvature [5, 6]. In fact, several studies have reported IOL power accuracy in eyes previously had RK using corneal topographers [7, 8] and tomographers [9, 10]. Based on the results published, it seems as if there is no single method that it is superior to other in calculating the IOL power [11]. A recent study assessed the accuracy of several IOL formulas in eyes with RK and concluded that further improvements are needed for IOL power calculations in this group of patients [11].

At the same time, other publications assessed refractive and visual outcomes of IOL implantation in eyes with RK [12–14]. Concretely, these publications are case reports that provide results of multifocal IOL implantation and concluded that this lens design might be beneficial for patients who previously underwent a RK. On the other hand, another study reported visual outcomes and complications after cataract surgery using different incision lengths in eyes with the previous RK [15]. All in all, the results of that study showed that the more RK incisions, the smaller clear incision size. To date, there is only one study assessing the visual and refractive changes in RK patients after cataract surgery during a long follow-up.

The aim of the present study was to report visual and refractive results in RK patients that underwent a cataract surgery with a monofocal IOL implantation during 1-year follow-up. The results of this study might help to elucidate a valid surgical solution for cataract patients who previously had this type of corneal surgery.

Methods

This retrospective study considered the postoperative results from patients who had cataract surgery with a monofocal IOL implantation and previously underwent a RK surgery. All surgeries took place at Fernández-Vega Ophthalmological Institute (Oviedo, Spain), and the written informed consent was obtained from all patients before the surgery in accordance with the Declaration of Helsinki.

Surgical technique

The peribulbar anesthetics used were the lidocaine at 2% and bupivacaine at 0.5%. Thirty minutes before the surgery, cycloplegic (10 mg/ml) and phenylephrine (100 mg/ml) eyedrops were instilled. Before starting with the surgery, the eye was disinfected with povidone-iodine at 5%, and the eyelids were disinfected with the same solution at 10%.

When the RK had four or eight cuts, the main incision was done between the RK cuts. The cataract surgery was done through a scleral incision when the RK had more cuts. In any case, a 2.2-mm keratome was used to create the main incision, and if it was possible, on the steepest meridian to compensate up to 1.25 D of astigmatism. Then, the cohesive viscoelastic was introduced into the eye, and a uniform and centered capsulorhexis of 5 mm of diameter was done to ensure that it covers the optic of the IOL. After this, the dispersive viscoelastic was injected to protect the eye structures during the crystalline lens emulsification. Then, a capsular tension ring and IOL are implanted. Finally, acetylcholine (10 mg/ml) and the antibiotic (cefuroxime, 1 mg/ml) were injected. In order not to use stitches, trapezoidal incisions were used when the surgery was done through the cornea, and tunneled incisions when the surgery was done through the sclera.

Intraocular lens power calculation

The biometers used to calculate the IOL were the Ocuscan (Alcon, USA), and the IOLMaster 500 and 700 (Carl Zeiss Meditec, Jena, Germany); meanwhile, the formula used to calculate the IOL power was the Double-K [4]. This formula uses the pre-refractive surgery *K* value to calculate the effective lens position, and the post-refractive surgery *K* value for the IOL power calculation. In all cases, the target was fixed between − 1.50 and − 1.0 D. If the *K* value pre-RK was not available, this was estimated based on the current *K* and the amount of diopters that the previous surgery had corrected. In this study, the monofocal IOLs implanted were the AcrySof SN60WF ($n = 22$, Alcon, USA), AcrySof SN60AT ($n = 4$, Alcon, USA), and the LUCIA 611 P ($n = 2$, Zeiss, Germany).

Results analysis

The visual acuity was measured during the preoperative examination and at 6 months and 1 year after the cataract surgery. The preoperative versus postoperative corrected distance visual acuity (CDVA) and the uncorrected distance visual acuity (UDVA) values were used to assess the efficacy and safety of the surgery; meanwhile, the achieved versus the expected refractive outcomes postoperatively were used to assess the predictability. At the same time, the safety (postoperative and preoperative CDVA ratios) and efficacy (postoperative UDVA and preoperative CDVA ratios) indexes (decimal notation) were also calculated.

Statistical analysis

Data analysis was performed using MATLAB (MathWorks, Boston, USA). A nonparametric analysis of variance (ANOVA) was used to assess differences among the follow-up and preoperative outcomes. Differences were considered statistically significant when the P values were smaller than 0.05.

Results

In total, 28 eyes of 15 participants were included (ten males and five females). Table 1 depicts the preoperative and postoperative patient demographics. The mean participant age at the time of the RK surgery was 35 ± 9 years old, and two eyes had either four, 12 or 16 incisions, one eye had either six or 18 incisions, and 20 eyes had eight incisions. On the other hand, the mean time between both surgeries was 24 ± 7 years. Figure 1 shows an eye implanted with a monofocal IOL after RK. Phacoemulsification and IOL implantation was performed successfully in all eyes and no intra- and postoperative problems occurred.

Visual acuity results

Figures 2 and 3 show the UDVA and CDVA results, respectively. In both figures, panel A displays the cumulative proportion of eyes having a given UDVA or CDVA, and panel B displays the postoperative change in UCVA or CDVA, respectively.

On average, the mean logMAR UDVA improved from 0.7 ± 0.3 to 0.4 ± 0.2 at 6 months ($P = 0.002$) and 0.3 ± 0.2 at 12 months postoperatively ($P < 0.001$). Nevertheless, comparable UDVA values were obtained between 6 and 12 months postoperatively ($P > 0.05$). As Fig. 2a shows, 25% of the eyes achieved an UDVA of 0.5 or better before the cataract surgery, and that percentage was doubled at 6 and 12 months after the cataract surgery. At the same time, Figure 2b shows that about 50% and 65% of the eyes gained more than three lines of VA at 6 and 12 months postoperatively, respectively. On the contrary, only three eyes lost at least one line of UDVA 12 months after the cataract surgery.

The mean logMAR CDVA before the cataract surgery was 0.3 ± 0.2, and it improved up to 0.1 ± 0.1 after 6 and 12 months postoperatively ($P = 0.057$). As can be observed from Fig. 3a, almost all eyes achieved a CDVA of 0.5 or better at 6 and 12 months after the surgery; meanwhile, almost 65% of the eyes achieved the same CDVA preoperatively. Furthermore, about 30% of the eyes achieved a CDVA of 20/25 before the cataract surgery, and this value was doubled for the same CDVA during the postoperative period. Similarly, 25% of the eyes gained more than three lines of CDVA and less than 10% lost at least one line of CDVA by the end of the postoperative visits (Fig. 3b). Finally, the efficacy indices at 6 and 12 months were 0.75 and 0.85, respectively. On the other hand, the safety indices were 1.26 and 1.30 at 6 and 12 months, respectively.

Refractive results

Figure 4a shows the average spherical equivalent before the surgery and at 6 and 12 months postoperatively; meanwhile, Fig. 4b and c displays the predictability diagrams at 6 and 12 months after the cataract surgery, respectively.

All in all, the mean spherical equivalent changed from -1.00 ± 6.00 D to -0.75 ± 1.1 D at 6 months ($P > 0.05$). At 12 months after the surgery, the mean spherical equivalent was comparable to the value obtained at 6 months ($P > 0.05$). Note that the spherical equivalent before the cataract surgery ranged from -18.50 to $+8.5$ D, and that interval became much tighter by the last postoperative visit (from -2.75 to $+1.0$ D). Regarding the predictability outcomes (Fig. 4b and c), about 60% of the eyes were

Table 1 Preoperative and postoperative patient demographics

	Preoperative	6 months postoperative	12 months postoperative
Age (years)	60 ± 8 (47 to 75)	N/A	N/A
logMAR visual acuity			
UDVA	0.7 ± 0.3 (0.2 to 1.0)	0.4 ± 0.2 (0.05 to 1.0)	0.3 ± 0.2 (0.05 to 0.7)
CDVA	0.3 ± 0.2 (0 to 0.8)	0.1 ± 0.1 (0 to 0.5)	0.1 ± 0.1 (0 to 0.4)
Refraction (D)			
M	− 1.00 ± 6.00 (− 18.5 to + 8.5)	− 0.75 ± 1.10 (− 2.5 to + 1.75)	− 0.80 ± 1.10 (− 2.75 to 1.25)
J0	− 0.20 ± 0.70 (− 1.9 to 0.8)	− 0.10 ± 0.60 (− 1.23 to + 1.23)	− 0.10 ± 0.50 (− 1.23 to + 1.11)
J45	− 0.10 ± 0.40 (− 1.29 to 0.75)	− 0.08 ± 0.41 (− 0.98 to + 1)	− 0.094 ± 0.46 (− 1.08 to 0.77)
Keratometry (D)			
Steep	37.51 ± 2.83 (29.50 to 43.50)	37.45 ± 2.62 (30.50 to 42.25)	37.54 ± 2.68 (30.25 to 41.50)
Flat	35.64 ± 3.00 (29 to 41.50)	36.23 ± 2.75 (30 to 41.23)	36.02 ± 3.09 (30 to 40.75)
Axial length (mm)	27.32 ± 2.07 (24 to 32)	N/A	N/A
ACD (mm)	3.05 ± 0.61 (2.43 to 5.46)	N/A	N/A
IOL power (D)	21.13 ± 6.87 (3 to 33)		

The values are presented as the mean ± standard deviation, with their corresponding minimum and maximum value within brackets

UDVA Uncorrected distance visual acuity, *CDVA* corrected distance visual acuity, *M* spherical equivalent, *J0* Jackson cross-cylinder with the axes at 180° and 90°, *J45* Jackson cross-cylinder with the axes at 45° and 135°, *ACD* anterior chamber depth *N/A* not available

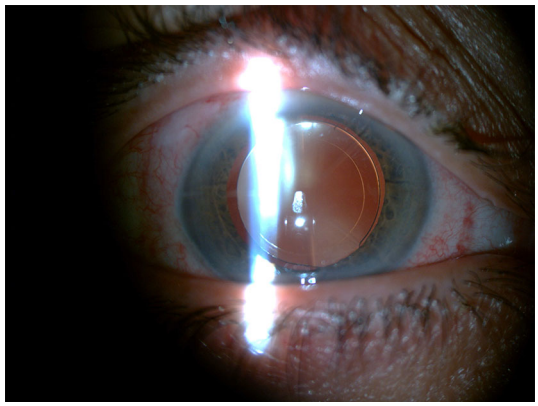


Fig. 1 Eye implanted with a monofocal intraocular lens after radial keratotomy

within ± 1 D at both postoperative visits and about 40% within ± 0.5 D at 6 and 12 months after the surgery.

Discussion

The aim of the present study was to report visual and refractive results in RK patients that underwent a lensectomy with a monofocal IOL implantation during 1-year follow-up.

UDVA and CDVA improved after the cataract surgery. Specifically, the mean UDVA improved from 0.7 logMAR to 0.3 logMAR at 12 months after the surgery; meanwhile, the CDVA improved from 0.3 logMAR to 0.1 logMAR by the end of the follow-up. On the other hand, the mean spherical equivalent after 6 months of the surgery was about − 0.75 D, and it barely changed at 12 months after the surgery. These results are similar to those obtained in a previous study, where the authors assessed visual outcomes and complications after cataract surgery in 30 eyes with the previous RK using different incisions lengths [15]. In that study, the patients were implanted with a monofocal IOL and had a 3-year follow-up. By the first year follow-up, the mean BCVA was 0.13 ± 0.08 logMAR, and the mean spherical equivalent was − 0.51 ± 1.03 D. Unfortunately, that is the only previous study reporting visual outcomes after monofocal pseudophakic implantation in RK patients. Thus, based on these results, it can be concluded that this IOL design offer acceptable visual acuity values in RK patients.

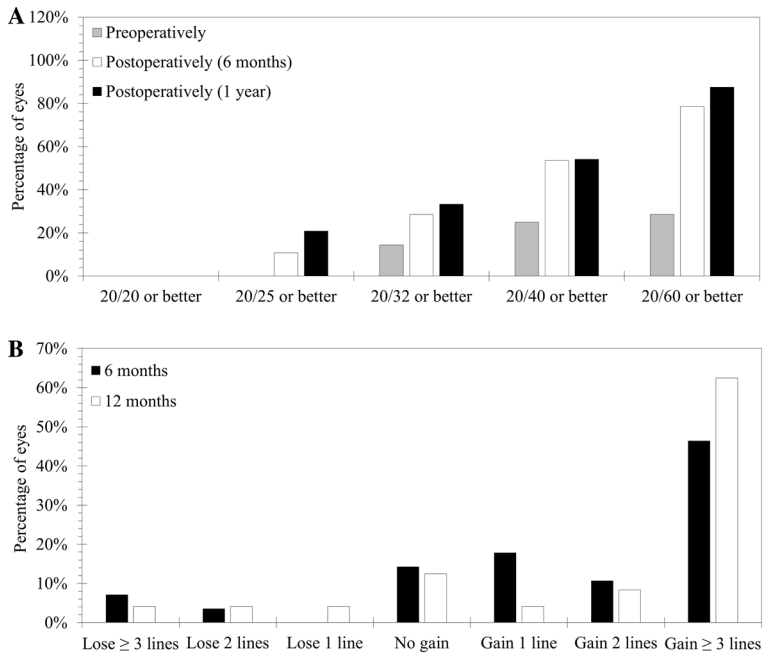
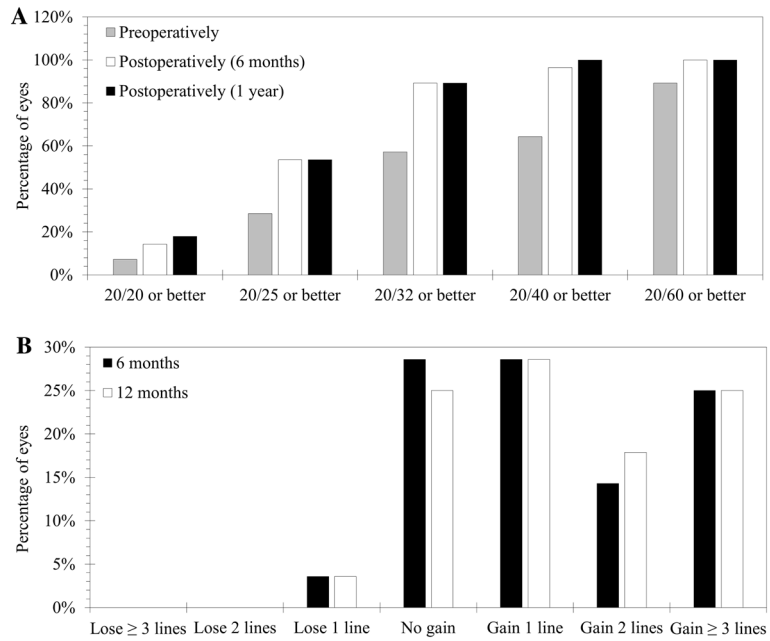


Fig. 2 Uncorrected distance visual acuity (UDVA) results measured preoperatively and at 6 and 12 months after cataract surgery. **a** The cumulative proportion of eyes having a given UDVA and **b** the postoperative change in UDVA

In this study, the Double-K formula [4] was used to calculate the IOL power, and about 60% of the eyes were within ± 1.0 D of the target refraction by the end of the follow-up. In the study published by Zhang et al. [15], the SRK-T formula was used to calculate the IOL power for ten eyes, and the Hoffer-Q modified formula was used for the other 20 eyes. At the last visit, about 84% of the eyes were within ± 1.0 D of the target refraction with the SRK-T formula, and about 88% of the eyes were within ± 1.0 D with the Hoffer-Q modified. On the other hand, Ma et al. [11] assessed the accuracy of several IOL power formulas in eyes with RK using the American Society of Cataract and Refractive Surgery calculator. The eyes included in that study were the previous patients who had cataract surgery. The IOL calculation methods were the Double-K Holladay, the optical coherence tomography (OCT) formula, the True-K formula, and the average of the three formulas. The analyses were done at three different stages: from 3 to 6 weeks after the cataract surgery, from 7 weeks to 3 months and a half after the surgery, and from 3 months and a half to 1 year postoperatively. Focusing on the results obtained for the longest follow-up (up to 1 year), less than 75% of the eyes were within ± 1.0 D with the OCT formula and average methods, and more than 75% of the eyes were within ± 1.0 D with the other two formulas. Finally, these authors concluded that further improvements in the IOL power calculation in RK were desirable. Discrepancies between studies could be related to different follow-up periods or differences in the formula used to calculate the IOL power. Despite all these results, pseudophakic monofocal IOL offers acceptable predictability results in RK patients. Nevertheless, further studies could assess the most efficient IOL formula for this group of patients.

In spite all the previous results, it should be taken into account that patients with RK have weaken corneas [16] and this could cause refractive regressions and visual acuity fluctuations [3]. This could be the reason why less than 50% of the eyes included in the present study were within ± 0.5 D from the target refraction by the end of the follow-up. Besides all this, the results obtained in this study show that monofocal IOL implantation offers acceptable visual acuity and predictability results. It would be interesting to consider that slight myopic residual (target for IOL power calculation) may benefit these patients to compensate future hyperopic shift due to RK. Taking all of this into account, it can be concluded that a pseudophakic monofocal IOL implantation might be a good treatment option for RK patients who need cataract surgery. Nevertheless, further studies could



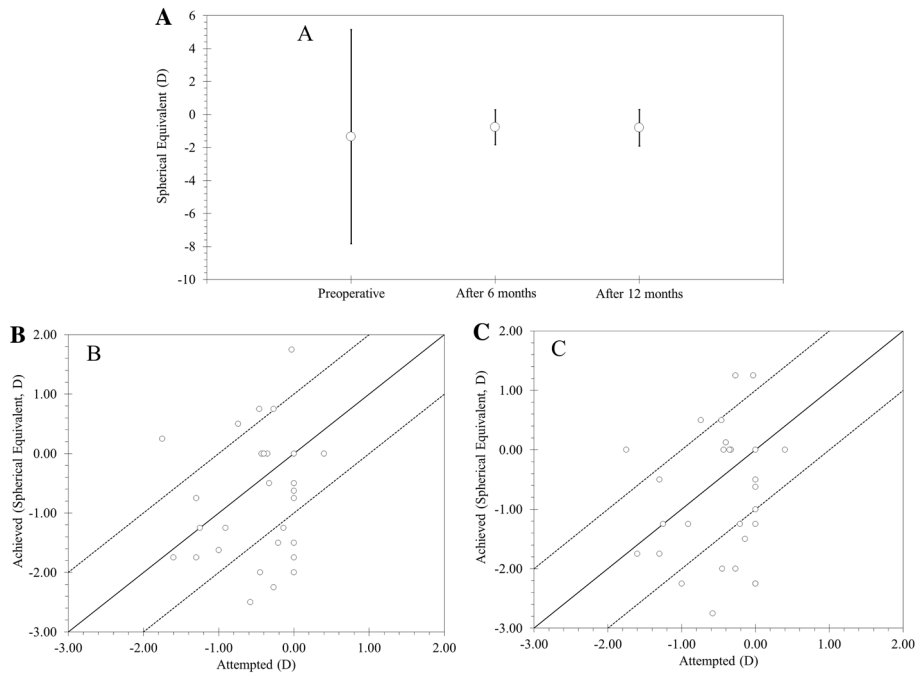


Fig. 3 Corrected distance visual acuity (CDVA) results measured preoperatively and at 6 and 12 months after cataract surgery. **a** The cumulative proportion of eyes having a given CDVA and **b** the postoperative change in CDVA

Fig. 4 Refractive results obtained preoperatively and at 6 and 12 months after the cataract surgery. **a** The stability of the spherical equivalent and **b**, **c** the predictability diagrams at 6 and 12 months postoperatively, respectively

have longer follow-up periods or assess the effect of implanting a multifocal IOL in a large population. In the end, all these studies will report more evidences that could help the selection of the best pseudophakic IOL design that offers the best postoperative results in RK patients.

Complications after cataract surgery can happen in RK patients. With this regard, a patient who

previously had RK developed a corneal ectasia few years after the cataract surgery [17]. The treatment technique consisted on a combined approach based on crosslinking followed by a piggyback technique with an add-on toric IOL implantation. Concretely, the add-on lens consists of implanting an IOL in the sulcus in the presence of a primary lens in the capsular bag. After the follow-up period, which was 14 months, the patient achieved good refractive outcomes and a visual acuity improvement. Thus, based on those results, the authors believed that the combined surgical technique of crosslinking followed with an add-on lens implantation could be safe and effective for the visual and refractive rehabilitation of RK ectasia after cataract surgery.

The residual refraction after RK has been corrected with different techniques, such as contact lenses, phakic IOLs, and corneal laser techniques [13, 18–21]. Unfortunately, these techniques cannot resolve presbyopia and cannot solve crystalline lens opacities. Three case reports provided evidences about the surgical treatment of presbyopia and cataract in patients who previously had a RK [12–14]. On the one hand, Kim et al. [13] reported the results of two post-RK patients who underwent a refractive lens exchange with a multifocal IOL implantation. By the end of the follow-up period, both patients reported high levels of satisfaction, achieved spectacle independency for their daily life activities, and good visual acuity results (about 20/20 at distance vision and J1 at near vision). On the other hand, Gupta et al. [12] assessed the spectacle independency in two RK patients after cataract surgery using a hybrid monovision, in which the dominant eye had implanted a monofocal IOL and the non-dominant eye had implanted a multifocal IOL. These authors reported that by the end of the follow-up, both patients achieved good visual acuity results (about 20/20) and spectacle independency. Finally, in another case report, the authors assessed the possible used of customized toric multifocal IOL in a cataract patient who had a hyperopic shift after RK and crosslinking [14]. After 1-year follow-up, the patient tolerated well the IOL and achieved good visual acuity (10/10) without any refractive regressions. Although these three case reports used different techniques to treat the cataract, it seems as if multifocal IOLs could achieve good postoperative results in patients with a previous RK. Unfortunately, with the exception of these case reports, there are no studies that focus on the assessment of the visual and refractive changes in RK patients after cataract surgery during a long follow-up.

Cataract surgery in patients with the previous RK presents a challenging situation to keep the corneal integrity. Concretely, several studies have reported an incision rupture after conventional phacoemulsification [22–26]. With this regard, Zhang et al. [15] also studied the effect of the incision length on the final result. After 3 years of follow-up, the authors concluded that in order to prevent corneal dehiscence during the cataract surgery, the more number of incisions done on the RK, the smaller corneal incision length should be.

The present study assessed the visual and refractive recovery after a pseudophakic monofocal IOL implantation during 1-year follow-up in patients with the previous RK surgery. In this study, monofocal IOLs were implanted, and further studies could assess multifocal lens implantation in RK patients. Finally, the follow-up in this study was 1 year, and further studies could have longer follow-up periods.

To sum up, pseudophakic monofocal IOL implantation offers good visual acuity recovery and acceptable refractive correction in RK patients after 1-year of follow-up. In other words, a pseudophakic monofocal IOL implantation might be a good treatment option in patients who undergone RK and need a cataract surgery. Finally, the results presented in this study provide evidences that might help to select the IOL design that provides the best postoperative results after cataract surgery in RK patients.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent Informed consent was obtained from all individual participants included in the study.

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