Original Article

Evaluation of striate keratopathy after manual small-incision cataract surgery and its final outcomes in a tertiary hospital

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Purpose: To study the demographic profile, contributing and precipitating factors, the severity of striate keratopathy and its relation with endothelial cell count, and evaluate the final treatment outcome of striate keratopathy. **Methods:** This observational analytical cohort study was conducted on 75 patients developing striate keratopathy after MSICS in the immediate postoperative period. Demographic profile, preoperative risk factors, and intraoperative complications were evaluated retrospectively. Postoperatively, slit-lamp grading of striate keratopathy was done, and specular microscopy of both eyes was taken. Treatment of striate keratopathy was initiated, and patients were followed up for 6 to 10 weeks for improvement. **Results:** Striate keratopathy was most commonly associated with surgeries performed by resident surgeons (92%), longer duration of surgery, associated predisposing factors, and intraoperative or postoperative complications. On postoperative day 1, the majority of patients had moderate and severe striate keratopathy (66% and 32%, respectively). It was associated with significant endothelial cell loss (ECL) at the final follow-up ($P = 0.0016$). Striate keratopathy resolved in 97.3% of patients, irrespective of the treatment with hypertonic saline. At 6 to 10 weeks, 92% of patients achieved a BCVA of ≥6/9. **Conclusion:** A careful preoperative evaluation, adequate training of resident surgeons, meticulous surgical technique, and prompt management of postoperative complications can lead to a decrease in the incidence of striate keratopathy in the majority of cases. The use of hypertonic saline eye drops does not change the final outcome, and most cases resolve spontaneously during follow-up.

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Striate keratopathy is a form of corneal edema seen after eyeball operations, characterized by folds in Descemet's membrane (DM).[1] Two potent factors crucial in sustaining corneal transparency are the number and integrity of corneal endothelial cells.[2] The goal of modern cataract surgery is to minimize corneal endothelial cell loss (ECL).[3] Many factors are involved in causing striate keratopathy and thorough knowledge about them is required to minimize the occurrence. Topical hypertonic saline solutions used in the treatment of postoperative corneal edema act by creating a hypertonic environment of tear film that draws the fluid out of the cornea.[4] However, their roles in different forms of corneal edema are not yet established. This study comprehensively describes the precipitating factors of striate keratopathy and the role of hypertonic saline in its management.

Methods

An observational analytical cohort study was conducted on 75 patients who had undergone cataract surgery with the MSICS technique between November 2019 and June 2021 at our institution and developed striate keratopathy in the immediate postoperative period. Surgeries were done by senior experienced surgeons and resident surgeons. The study was performed according to the Declaration of tenets of Helsinki and informed consent was taken from each patient after explaining the details of the study. Patients above 30 years of age and of either sex who developed striate keratopathy following cataract surgery were included in the study. Patients with congenital or traumatic cataract, evidence of old iridocyclitis, patients with glaucoma, pre-existing corneal dystrophies or corneal scars, or any other pre-existing corneal pathology that affects the corneal endothelium were excluded from the study. Postoperatively, the demographic profile of patients was assessed from patients' records. Each patient underwent a complete eye examination including visual acuity (VA) assessment, intraocular pressure (IOP) measurement with a non-contact tonometer, slit-lamp examination of the anterior segment for grading of striate keratopathy, and the presence of any associated findings such as DM detachment, residual cortical matter, or vitreous strands in the anterior chamber (AC). Striate keratopathy was noted based on areas of the cornea involved as only central, only paracentral, central and paracentral, or diffusely involving the whole cornea. Further grading was done as shown in Table 1.

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Table 1: Grading of striate keratopathy

	Score
Number of DM folds	
<10 DM folds	1
>10 DM folds	2
Diameter of corneal edema	
Localized edema involving <3 mm diameter	1
Localized edema involving 3-5 mm diameter	2
Localized edema involving >5 mm diameter but not involving the whole cornea	3
Edema involving the whole cornea diffusely	4
Based on iris and anterior chamber (AC) details visibility	
Minimally obscured (hazy, but details can be easily made out)	1
Moderately obscured (details can be made out but with difficulty)	2
Severely obscured (details cannot be made out)	3
Based on the depth of edema	
Only stromal edema	1
Stromal and epithelial edema	2

A cumulative score of all parameters was taken. A total score of ≤ 5 was graded as mild, a score of 6–9 as moderate, and a score ≥ 10 as severe striate keratopathy. Anterior segment optical coherence tomography (ASOCT) was undertaken for patients with very hazy cornea precluding AC view, cases not improving with treatment on follow-up, or in clinically suspicious cases (e.g., localized edema). Corneal endothelial evaluation using a TOMEY EM-3000 specular microscope was done in patients when counts were recordable during follow-up. Treatment of striate keratopathy with hypertonic saline 5% drops (four times a day) was initiated randomly in different grades of striate keratopathy and follow-up was done up to 6 to 10 weeks. The best corrected visual acuity (BCVA) was taken at 6 to 10 weeks of final follow-up.

Statistical analysis

The sample size was calculated using an appropriate formula for the study design. Data were entered using MS Excel 2010 and analyzed using the IBM SPSS 25 software. Descriptive statistics were used and data are represented as frequency, percentage, or proportion. Mean and standard deviation were calculated for continuous variables. Categorical variables were grouped and presented. Categorical variables were compared using the Chi-square test. A *P* value less than 0.05 was considered statistically significant.

Results

Our study included 75 eyes of 75 patients, who developed striate keratopathy after MSICS. The mean age of patients was 62.32 ± 8.08 years (range 47 to 90 years), and the majority of patients belonged to the 60–69 years (50.7%) age group. Also, 40 were male (53.5%) and 35 were female (46.7%). Next, 46 patients (61.3%) were operated on for cataract in the right eye, whereas 29 patients (38.7%) were operated on in the left eye. Resident surgeons pursuing their post-graduation at our institute operated on 69 cases (92%), whereas only 6 cases (8%) were operated by senior experienced surgeons. Pre-operative grades of cataract in these patients were nuclear sclerosis (NS) 1 and 2 in 25 patients (33.33%), NS ≥3 in 17 patients (22.66%), cortical immature cataract in 8 patients (10.66%), cortical mature cataract in 22 patients (29.33%), and hypermature cataract in 3 patients (4%). The common precipitating factors for striate keratopathy evaluated retrospectively were hard or big nucleus (NS ≥3, cortical or any other cataract with big nucleus nearly occupying the entire AC) in 39 patients, small pupillary diameter or non-dilating pupil in 12 patients, pseudoexfoliation in 9 patients, a premature entry in 14 patients, posterior capsular rent with vitreous prolapse in AC in 9 patients, and DM detachment in 22 patients. Immediate post-operative findings showed an IOP spike (IOP ≥ 24 mmHg) in 15 patients, residual lens fragments in AC in 8 patients, vitreous in AC in 6 patients, and toxic anterior segment syndrome (TASS) in 6 patients. All intraoperative and post-operative complications were appropriately managed by experienced surgeons, either medically or surgically. An intracameral air bubble was injected in cases of significant DM detachment. The mean surgical duration for cases operated by resident surgeons was higher (56.04 minutes) than those cases operated by experienced surgeons (23.33 min).

Out of 75 patients, 50 patients (66.6%) had moderate, 24 patients (32%) had severe, and only 1 patient (1.3%) had mild-grade striate keratopathy at postoperative day (POD) 1. All patients were started on a topical antibiotic-steroid eye drops combination (gatifloxacin 0.3% with dexamethasone 0.1%) eight times per day. Additional treatment was individualized as per the grade of striate keratopathy and other associated anterior segment findings. Hypertonic saline (0.5%) eye drops were started for 28 patients (37.33%). Regular follow-ups were taken at 1 week, 3–4 weeks, and 6–10 weeks for improvement in striate keratopathy. At 1 week of follow-up, 25 patients (33.3%) showed resolution of striate keratopathy, whereas 26 patients (34.6%) had mild, 22 patients (29.3%) had moderate, and 2 patients (2.6%) had severe striate keratopathy. Resolution of striate keratopathy was noted in 67 patients (89.35) and 73 patients (97.35) at 3–4 weeks and 6–10 weeks, respectively. At 3–4 weeks of follow-up, eight patients (10.6%) showed persistent striate keratopathy (four each with mild and moderate grade), whereas two patients (2.6%) (1 each with mild and moderate grade) with persistent DM detachment showed persistent striate keratopathy at 6–10 weeks of follow-up.

Out of 75 patients in our study, specular microscopy was undertaken for 46 patients and compared with the other eye that had not undergone any operative procedure previously. The average endothelial cell count (ECC) in the operated eye at 3–4 weeks was 1786.78 ± 498.03 cells/mm^2, the average coefficient of variance (CV) was 46.58 ± 8.22%, whereas the average hexagonality (6A) was 33.65 ± 6.63%. The average ECC in the operated eye at 6–10 weeks was 1881.34 ± 493.28 cells/mm^2, the average CV was 45.93 ± 7.44%, whereas the 6A was 33.78 ± 5.73%. The average ECL was 21.49% and 17.33% at 3–4 weeks and 6–10 weeks (P = 0.00012 and 0.00165, respectively; statistically significant) as compared to the opposite non-operated eye [Table 2].

Out of 46 patients for whom specular microscopy readings were taken, 36 patients (78.26%) had moderate, whereas 10 patients (21.47%) had severe grade striate keratopathy at POD 1. In patients with moderate striate

keratopathy, the ECC in the operated eye at 3–4 weeks and 6–10 weeks of follow-up were 1800.61 ± 492.02 cells/mm^2 and 1887.52 ± 499.27 cells/mm^2, respectively [Table 3]. There was a reduction in ECC by 398.05 (18.1%) cells/mm^2 at 3–4 weeks of follow-up and by 311.14 (14.15%) cells/mm^2 at 6–10 weeks of follow-up as compared to the fellow eye. In patients with severe striate keratopathy at POD 1, the ECC in the operated eye at 3–4 weeks and 6–10 weeks follow-up were 1737 ± 516 cells/mm^2 and 1859.1 ± 470.40 cells/mm^2, respectively. There was a reduction in ECC by 817.3 (31.9%) cells/mm^2 at 3–4 weeks of follow-up and by 695.2 (27.21%) cells/mm^2 at 6–10 weeks of follow-up as compared to the fellow eye. The ECL was statistically significant in both groups (moderate and severe) at 3–4 weeks (P = 0.0081, P = 0.0009, respectively) and 6–10 weeks (P = 0.037, P = 0.0014, respectively) follow-up, as compared to their fellow non-operated eye.

The average central corneal thickness (CCT) was recorded using specular microscopy in the same 46 patients on day 1, 1 week, 3–4 weeks, and 6–10 weeks post-operative. The average CCT in the non-operated eye in patients of moderate and severe grade striate keratopathy at POD 1 was 512.30 ± 28.88 µm and 517.23 ± 42.90 µm, respectively. In patients with moderate striate keratopathy on day 1, it was 634.73 ± 71.52 µm, which reduced to 547.04 ± 33.37 µm at 1 week, 525.12 ± 32.29 µm at 3–4 weeks, and 517.08 ± 26.85 µm at 6–10 weeks of follow-ups. Approximately 87% reduction in CCT was noted in the postoperative first week. Average CCT in most of the patients with severe grade striate keratopathy on day 1 was >800 µm, which reduced to 580.27 ± 59.06 µm at 1 week, 522.0 ± 42.23 µm at 3–4 weeks, and 521.75 ± 38.61 µm at 6–10 weeks follow-ups. Approximately 70% reduction in CCT was noted in the postoperative first week.

Out of 73 patients who showed resolution of striate keratopathy at 6–10 weeks of follow-up, 26 patients belonged to the treatment group (treated with hypertonic saline drops along with antibiotic-steroid eye drops) and 47 belonged to the non-treatment group (treated with only antibiotic-steroid eye drops). In the treatment group, 16 patients had moderate and 10 patients had severe striate keratopathy at POD 1, whereas in the non-treatment group, 33 patients had moderate and 14 patients had severe striate keratopathy at POD 1 [Table 4].

The average duration for resolution of moderate striate keratopathy in treatment and non-treatment groups was 25.81 ± 10.11 days and 17.5 ± 10.5 days, respectively. The average duration for the resolution of severe striate keratopathy in treatment and non-treatment groups was 28.7 ± 9.1 days

Table 2: Specular microscopy findings comparison at 3-4 and 6-10 week post-operative follow-up with non-operated eye

	Non-operated eye	Operated eye at 3-4 weeks	Operated eye at 6-10 weeks
Number of patients	46	46	46
Mean ECC±standard deviation (cells/mm^2)	2275.97±647.80	1786.78±498.03	1881.34±493.28
	-	P=0.00012	P=0.00165
Endothelial cell loss (percentage)	-	489.19 (21.49%)	394.63 (17.33%)
Mean CV±standard deviation	37.82±10.28%	46.58±8.22%	45.93±7.44%
Mean hexagonality±standard deviation	44.36±4.86%	33.65±6.63%	33.78±5.73%

Table 3: 3-4 and 6-10 weeks follow-up specular microscopy findings among moderate and severe grade striate keratopathy patients

	Non-operated eye with the other eye striate keratopathy at day 1		Operated eye			
	Moderate grade	Severe grade	3-4 weeks		6-10 weeks	
			Moderate	Severe	Moderate	Severe
Number of patients	36	10	36	10	36	10
Mean ECC±SD (cells/mm^2)	2198.66±707.96	2554.30±164.43	1800.61±492.02	1737±516	1887.52±499.27	1859.1±470.40
			P=0.0081	P=0.0009	P=0.0375	P=0.0014
Endothelial cell loss (cells/mm^2)	-	-	398.05 (18.1%)	817.3 (31.9%)	311.14 (14.15%)	695.2 (27.21%)
Mean CV±SD	36.55±5.35%	42.4±18.89%	45.66±8.70%	49.9±4.98%	44.05±5.94%	52.7±8.33%
Mean hexagonality±SD	44.52±5.05%	43.8±4.06%	34.27±7.30%	31.4±1.85%	34.88±5.81%	29.8±3.02%

Table 4: Average duration of clearance of striate keratopathy in treatment and non-treatment groups

	With treatment		Without treatment		P value
	No. of patients	Average duration±SD (Days)	No. of patients	Average duration±SD (Days)	
Moderate	16	25.81±10.11	33	17.5±10.5	P=0.0149
Severe	10	28.7±9.1	14	22±15.62	P=0.219
Total	26	26.92±9.84	47	18.61±12.44	

and 22 ± 15.62 days, respectively. There was a statistically significant lower duration of resolution of moderate striate keratopathy in the non-treatment group compared to the treatment group (P = 0.0149), whereas this difference was not statistically significant in the resolution of severe striate keratopathy between both groups (P = 0.219).

Out of 75 patients, 34 patients (45.0%) had unaided VA between counting fingers 5 m to hand movements at POD 1, 24 patients (32.0%) had VA between 6/36 and counting fingers at 6 meters, 14 patients (18.66%) had VA between 6/12 and 6/24, and 2 patients (2.66%) had VA of ≥ 6/9 on Snellen visual acuity chart [Table 5]. Only one patient (1.33%) had severe VA reduction to the only perception of light. At 6–10 weeks of follow-up, 69 patients (92.0%) achieved a final BCVA of ≥ 6/9, 2 patients (2.66%) achieved a final BCVA between 6/12 and 6/24, 3 patients (4.0%) achieved a final BCVA between 6/36 and counting fingers 6 m, whereas only 1 patient (1.33%) had a final BCVA of counting fingers 1 m.

Discussion

In a developing country such as India, even though phacoemulsification is the preferred surgery for cataract removal, MSICS still remains a cost-effective alternative to meet the treatment of the cataract backlog. Studies suggest MSICS is an economical and safer technique with low rates of complication and good visual outcomes.[5-7] However complications such as striate keratopathy can give early postoperative visual dissatisfaction and can lead to late corneal decompensation in a few patients.[8]

Various studies used different grading schemes for postoperative corneal edema. The Oxford Cataract Treatment and Evaluation Team (OCTET)-graded edema based on an increase in the central corneal thickness and DM folds.[9] Kausar *et al*.[8] classified striate keratopathy based on slit-lamp examination using parameters such as corneal thickness, clarity of iris details, and the presence of DM folds. However, we undertook a detailed evaluation of striate keratopathy based on the number of DM folds, area of cornea involved, the diameter of the cornea involved, layers of the cornea involved (stroma, epithelium), and visibility of anterior chamber structures. This is because we believe that all these factors indicate the extent and area of endothelial damage and also give a clue about the associated precipitating factors such as nucleus touch with the endothelium, DM detachment, and vitreous touch with endothelium. These factors have an impact on post-operative visual outcomes and might indicate a need for reoperation.

Our study showed a mean reduction in the ECC by 489.19 (21.49%) cells/mm^2 and 394.63 (17.33%) cells/mm^2 at 3–4 weeks and 6–10 weeks follow-up, compared to the non-operated fellow eye. In a study conducted by Jagani *et al*.,[2] the mean endothelial cell loss in the MSICS group at 6 weeks was reported to be 385.22 cells/mm^2 (15.12%). In another study conducted by Thakur *et al*.,[10] the mean ECC at 1 month postoperative was 15.83% (423.27 cells/mm^2). In both these studies, surgeries were performed by skilled experienced surgeons. Our study shows a slightly higher ECC as compared to these studies as our study specifically included patients with striate keratopathy. Also, the impact of surgeon experience has to be kept in mind where most of the surgeries in our study were performed by trainee resident surgeons. Our study showed a slight increase in the ECC by 95 cells/mm^2 (5.02%) between 3–4 weeks and 6–10 weeks of follow-up. However, this increase was statistically insignificant (P = 0.3678). The loss of endothelial cells for any reason results in the enlargement of the remaining neighboring cells and their spreading to cover the defective area, without an increase in cell number. This results in polymegathism and pleomorphism with a resultant increase in the cell size and coefficient of variance and a decrease in the percentage of hexagonal cells.[11] This finding is consistent in our study as there is an increase in CV by 8.76% and 8.11% and a decrease in hexagonality by 10.71% and 10.58% at 3–4 weeks and 6–10 weeks follow-up as compared to the non-operated fellow eye. To the best of our knowledge, no studies have shown a correlation between different grades of striate keratopathy with changes in the endothelial cell parameters.

Our study showed an increase in the mean postoperative CCT by 18.53% in patients with moderate striate keratopathy and 35.74% in patients with severe striate keratopathy from baseline (recorded in the non-operated eye). However, at 1-week post-operative follow-up, the mean CCT was reduced by 87% and 70% in patients with moderate and severe striate keratopathy, respectively. The mean CCT values returned to near baseline values at 3–4 weeks in both groups. This is similar to the study conducted by Lundberg *et al*.[12] who found that the corneal edema was entirely reversed at 1 month of follow-up. They also found a higher ECL in corneas that were not clear on the first postoperative day compared to corneas that were clear.

In our study, we evaluated the efficacy of hypertonic saline 5% eye drops and documented the outcomes in successive follow-ups. We found that striate keratopathy resolved early in patients with moderate and severe striate keratopathy (mean duration: 17.5 and 22 days, respectively) in the non-treatment group compared to the treatment group (mean duration:

Table 5: Postoperative day 1 unaided VA and final BCVA at 6-10 weeks of follow-up

Visual acuity	Post-operative day 1		Final BCVA	
	Number of patients	Percentage	Number of patients	Percentage
≥ 6/9	2	2.66%	69	92.0%
6/12 to 6/24	14	18.66%	2	2.66%
6/36 to CF 6 meters	24	32.0%	3	4.0%
CF 5 meters to CF 3 meters	14	18.66%	0	0
CF 2 meters to Hand movements	20	26.66%	1	1.33%
Only Perception of light	1	1.33%	0	0
Total	75	100%	75	100%

25.81 and 28.7 days, respectively). However, this difference was not statistically significant in patients with severe striate keratopathy. Tzamalis *et al*.[13] evaluated the safety and efficacy of hypertonic saline eye drops (5%) in post-operative corneal edema after phacoemulsification and found no statistically significant difference in BCVA, corneal edema score, central corneal thickness, and endothelial cell density in both the treatment and placebo group at 1 month of follow-up. Knezović *et al*.[14] included 70 eyes with bullous keratopathy and reported the outcomes of hypertonic saline 5% in early and late cases of corneal edema. They found that hypertonic saline 5% was significantly useful only in the initial stages (stromal edema with 613–694 µm in the central cornea and 633–728 µm at the periphery) of bullous keratopathy for improving the visual acuity and reducing the corneal thickness, but was not useful in the advanced disease (epithelial with stromal edema). Our study shows results similar to these studies. Hypertonic saline penetrates the epithelium poorly and therefore, can attract the more easily diffusible water from the epithelial bullae. This treatment is thus most effective for epithelial edema, as stromal edema is usually caused by endothelial dysfunction.[15]

Despite having moderate or severe grade striate keratopathy and irrespective of treatment given with hypertonic saline, at 6–10 weeks follow-up, 92% of patients achieved the BCVA of 6/9 or better, 2.66% had visual acuity between 6/12 and 6/24, and only 5.3% had visual acuity 6/36 or worse.

Conclusion

The occurrence of striate keratopathy is associated with significant ECL and morphological changes in the endothelium. With an appropriate preoperative evaluation, meticulous surgical technique, reduced surgical duration, and adequate training of resident surgeons, striate keratopathy can be avoided in the majority of cases. Pre-operative ECC measurement can help to plan the surgery. The use of hypertonic saline eye drops does not change the final visual outcome. The majority of the cases achieve good vision at follow-up visits even without treatment. Hence, imposing a financial burden on the patients can be avoided, especially in a developing country such as India.

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Conflicts of interest

There are no conflicts of interest.

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