Original article

Postoperative Corneal Edema After Phacoemulsification

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Abstract

Aim: To determine the effect of nuclear opalescence (NO) on intraoperative parameters during phacoemulsification using the WhiteStar Signature® PRO and to show the impact of preoperative and intraoperative parameters on postoperative corneal edema.

Methods: This prospective study included 267 patients selected to undergo phacoemulsification using the WhiteStar Signature® PRO system at the Department of Ophthalmology of the General Hospital "Dr Josip Benčević", Slavonski Brod, Croatia. NO was graded using the Lens Opacities Classification System III. Preoperative parameters were age, sex, NO and preoperative central corneal thickness. Intraoperative parameters of phacoemulsification included in the study were ultrasound time (UST), phaco time using Ellips FX technology (EFX) and average phaco power (AVG). Patients were followed up on postoperative days 1 and 7 and after two months. The state of the cornea was noted in each follow-up.

Results: There was a statistically significant increase of intraoperative parameters with NO. Postoperative corneal edema depended on all measured intraoperative parameters (UST, EFX and AVG, all $p < .001$), patient's age ($p < .05$) and NO ($p < .001$) on postoperative day 1, while on postoperative day 7, it depended on UST ($p = .011$) EFX ($p = .012$) and NO ($p < .05$).

Conclusion: Older patients, higher grade of NO and amount of energy consumed during phacoemulsification using the WhiteStar Signature® PRO are predictive factors for severity of transient corneal edema. We found this information important for better preoperative planning of phacoemulsification, as well as for better postoperative results.

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Introduction

Continuous advances in phacoemulsification have made safer and more efficient cataract surgery possible. There is a need for objective and transparent research in order to observe the impact of new technology on surgery outcomes, patient safety and satisfaction. The most frequent complication after phacoemulsification is corneal edema (1). The main factor that determines the function of the cornea as clear and transparent tissue is a metabolically active monolayer, corneal endothelium (2). Corneal endothelial cell loss after phacoemulsification leads to corneal edema (3), which may be due to perioperative and intraoperative risk factors. Intraoperative risk factors which can lead to acute corneal edema after phacoemulsification are endothelial injury by consumed ultrasound energy, Descemet's membrane detachment, toxic anterior segment syndrome (TASS) and IOL instability with endothelial touch (1).

Around 2010, Abbott Medical Optics (AMO) introduced the new Ellips FX system, which combined both longitudinal and elliptical motion into a single handpiece to improve phaco efficiency. The WhiteStar Signature® PRO was introduced by AMO in 2015 and has demonstrated improved nucleus followability, cutting efficiency and proactive intraocular pressure management with automatic occlusion sensing (4, 5).

In a previously published article by Sekelj et al., corneal edema recovery was compared between patients with type 2 diabetes mellitus and patients without type 2 diabetes (6). After that, we wanted to analyze the use of the new phaco technology in our hospital on postoperative corneal edema recovery. The aims of this study were to determine the effect of nuclear opalescence (NO) on intraoperative parameters during phacoemulsification using the WhiteStar Signature® PRO with the Ellips FX handpiece and to determine the impact of preoperative and intraoperative parameters on postoperative corneal edema recovery.

Patients and Methods

This prospective study included 267 patients selected to undergo phacoemulsification using the WhiteStar Signature® PRO system. The phacoemulsification surgery was performed on all patients by a single experienced surgeon during the study period of 7 months at the Department of Ophthalmology in our hospital. The study was performed in accordance with the principles of the Helsinki Declaration. Informed consent was obtained from all study participants. Out of 267 patients who were included in the study, 266 patients came to checkup on the first postoperative day, 265 patients came to checkup on the seventh postoperative day and 205 patients came to checkup after 2 months. Other study participants were under care in other hospitals.

We performed preoperative examination and used exclusion criteria (previous ocular infection or ocular surgery and Fuchs' endothelial corneal dystrophy) on all patients using the previously described methods.6 Three independent observers graded cataracts using a slit lamp and the findings were compared based on the Lens Opacities Classification System III (LOCS III).7 Eyes with NO grades between 1 and 6 were included in the study and were subdivided into mild (NO1, NO2), moderate (NO3, NO4) and hard (NO5, NO6) cataracts.

Phacoemulsification was performed with a 2.75 mm clear corneal incision. Sodium hyaluronate (Healon GV) was injected in the anterior chamber. One side port was created using a 30 degree knife, followed by continuous curvilinear capsulorhexis and hydrodissection. Phacoemulsification was performed using the WhiteStar Signature® PRO system, using the phaco chop technique with the Ellips FX handpiece (AMO, Inc.).

Coaxial irrigation/aspiration of the remaining cortical lens material was performed. Intraocular lens was implanted in the capsular bag after injecting hydroxypropyl methylcellulose 2.0% (Celoftal). The "rock 'n' roll" (RNR) technique was used for removing ophthalmic viscosurgical devices at the end of the surgery. The clear corneal incision wound was hydrated and prophylactic intracameral injection of cefuroxime or vancomycin was given. Postoperative treatment included the use of dexamethasone/neomycin/polymyxin B (Maxitrol) drops and bromfenac drops in all type 2 diabetic patients based on our previously described protocol (6).

Ultrasound time (UST), phaco time using Ellips FX technology (EFX) and average phaco power (AVG) were intraoperative parameters for phacoemulsification. The EFX is a parameter of effective phaco time (EPT), with the specific coefficient for transversal movement expressed in seconds. Patients were followed up on postoperative days 1 and 7 and after 2 months. Two independent observers graded postoperative corneal edema recovery using three grading scales: clear cornea, focal corneal edema and diffusive corneal edema, as previously described (6).

Statistical analysis was performed using SPSS software (version 24, SPSS INC, IBM Corporation, Chicago, USA). The Shapiro–Wilk test was used to check if a continuous variable follows a normal distribution. Significance was tested using the Wilcoxon signed-rank test, the Kruskal–Wallis H test, the Friedman test and the chi-squared test. A P value of less than 0.05 was considered statistically significant.

Results

The study was conducted in order to determine the effect of NO on intraoperative parameters (UST, EFX, AVG) during phacoemulsification using the WhiteStar Signature® PRO with the Ellips FX handpiece. The other reason was to establish the impact of preoperative (age, sex, NO, preCCT) and intraoperative parameters on postoperative corneal edema recovery.

There were 267 patients included in the study; 164 were females (61%) and 103 were males (39%). The average age of the study population was 73.0 ± 8.76 years. Most patients had moderate cataract (67%). Mean preCCT was 556 (range 445–697). Intraoperative parameters are shown in Table 1. UST, EFX and AVG were statistically significantly different based on estimated nuclear hardness (Kruskal–Wallis H test, all $p < .001$) (Table 1); all intraoperative parameters increased significantly with NO. UST, EFX and AVG were statistically significantly different between mild and moderate cataract (Wilcoxon signed-rank test, all $p < .001$, post hoc test), moderate and hard cataract (Wilcoxon signed-rank test, all $p < .001$, post hoc test), as well as mild and hard cataract (Wilcoxon signed-rank test, all $p < .001$, post hoc test). Significantly higher mean UST, EFX and AVG were observed in hard cataracts, indicating a greater amount of energy during phacoemulsification.

Table 1. Ultrasound time (UST), elliptical motion energy (EFX) and average phaco power (AVG) values for various grades of cataract (n = 267)

	Mild cataract (average ± SD)	Moderate cataract (average ± SD)	Hard cataract (average ± SD)	Kruskal–Wallis H test
UST (seconds)	5.6 ± 8.25	37 ± 20.25	87.2 ± 33.3	$p < .001$
EFX	1.3 ± 2.25	12.7 ± 9.33	38.7 ± 17.45	$p < .001$
AVG (%)	1.8 ± 2.25	5.8 ± 2.32	8.2 ± 1.54	$p < .001$

Table 2. Intraoperative parameters (UST, EFX, AVG) in connection with postoperative corneal edema on postoperative day 1 (n = 266)

	+ (*n* = 173) average ± SD	++ (*n* = 68) average ± SD	+++ (*n* = 25) average ± SD	Kruskal–Wallis H test
UST (sec)	30.8 ± 28.22	49.2 ± 30.85	68.4 ± 32.88	*p* < .001
EFX	11.0 ± 12.59	19.7 ± 17.14	25.4 ± 15.71	*p* < .001
AVG (%)	4.8 ± 2.94 (5)	6.4 ± 2.74	7.0 ± 1.92	*p* < .001

+ Clear cornea, ++ Focal corneal edema, +++ Diffusive corneal edema

Another area of interest was postoperative corneal edema, as well as determining the impact of preoperative and intraoperative parameters on postoperative corneal edema recovery. In our study, postoperative corneal edema depended on all measured intraoperative parameters on postoperative day 1 (all Kruskal–Wallis H test, p < .001) (Table 2), while on postoperative day 7, it depended on UST and EFX (Wilcoxon signed-rank test, p = .011, p = .012), with no correlation with AVG (Wilcoxon signed-rank test, p = .179) (Table 3).

Table 3. Intraoperative parameters (UST, EFX, AVG) in connection with postoperative corneal edema on postoperative day 7 (n = 265)

	+ (*n* = 255) average ± SD	++ (*n* = 10) average ± SD	Wilcoxon signed-rank test
UST (seconds)	37.4 ± 30.42	72.2 ± 43.61	*p* = .011
EFX	13.9 ± 14.54	27.9 ± 19.72	*p* = .012
AVG (%)	5.4 ± 2.94	6.6 ± 2.41	*p* = .179

+ Clear cornea, ++ Focal corneal edema

In the study, we observed a statistically significant reduction in postoperative corneal edema (Friedman test = 126.4, p < .001). There were statistically significant differences between postoperative days 1 and 7 (Wilcoxon signed-rank test = -8.514, p < .001), as well as between postoperative day 7 and two months after the operation (Wilcoxon signed-rank test = -2.828, p < .01). In a previously published article, we compared corneal edema recovery and visual acuity between patients with type 2 diabetes mellitus and patients without type 2 diabetes (6).

Furthermore, in this study, we analyzed the impact of preoperative parameters on postoperative corneal edema. Corneal edema depended on the patient's age and NO on postoperative day 1 (Table 4), while on postoperative day 7, it depended only on NO (Table 5). In this study period, there were no cases of bullous keratopathy.

Table 4. Preoperative parameters (sex, patient's age, NO, preCCT) in connection with postoperative corneal edema on postoperative day 1 (n = 266)

	+ (*n* = 173) %	+ (*n* = 173) average ± SD	++ (*n* = 68) %	++ (*n* = 68) average ± SD	+++ (*n* = 25) %	+++ (*n* = 25) average ± SD	
Sex							
female	64.0		28.7		7.3		$p = .162$*
male	66.7		20.6		12.7		
Patient's age		72.2 ± 8.13		73.6 ± 9.89		76.8 ± 8.75	$p < .05$**
NO							
mild	91.5		8.5		0		
moderate	63.7		27.9		8.4		$p < .001$*
hard	40.0		35.0		25.0		
preCCT		555.9 ± 37.37		558.1 ± 41.09		552.9 ± 30.52	$p = .791$**

+ Clear cornea, ++ Focal corneal edema, +++ Diffusive corneal edema, $\chi 2$*, Kruskal–Wallis H test**

Table 5. Preoperative parameters (sex, patient's age, NO, preCCT) in connection with postoperative corneal edema on postoperative day 7 (n = 265)

	+ (*n* = 255) %	+ (*n* = 255) average ± SD	++ (*n* = 10) %	++ (*n* = 10) average ± SD	
Sex					
female	96.9		3.1		$p = .462$*
male	95.1		4.9		
Patient's age		73.1 ± 8.7		70.7 ± 10.39	$p = .58$**
NO					
mild	100		0		
moderate	96.6		3.4		$p < .05$*
hard	89.7		10.3		
preCCT		555.7 ± 38.03		568.9 ± 28.24	$p = .2$**

+ Clear cornea, ++ Focal corneal edema, +++ Diffusive corneal edema, $\chi 2$*, ** Wilcoxon signed-rank test

Discussion

Transient postoperative corneal edema leads to dissatisfied patients, which is why there is a need to evaluate preoperative and intraoperative risk factors for endothelial pump failure in the use of modern phaco technology. In the present study, 67% of the patients had moderate cataracts, 17.6% of the patients had mild cataracts and 15% of the patients had hard cataracts. Significantly higher mean UST, EFX and AVG (mean 87.2, 38.7 and 8.2, respectively) were observed in hard cataracts than in mild cataracts (mean 5.6, 1.3 and 1.8, respectively) or moderate cataracts (mean 37, 12.7 and 5.8, respectively). This is consistent with what has been found in previous studies, showing that the average phacoemulsification time increases due to increasing grades of lens hardness (1, 2, 8-15). In conclusion, we can assume that cataract density is a predictive factor for the amount of energy used during phacoemulsification.

Cataract surgery is one of the most common surgical procedures in the world, with a positive effect on the patients' quality of life. Since postoperative corneal edema leads to dissatisfied patients, another area of interest was postoperative corneal edema and the time needed for corneas to become clear after phacoemulsification using the WhiteStar Signature® PRO with the Ellips FX handpiece. Postoperative corneal edema was present in 93 eyes (35%) on postoperative day 1, and most of the patients had focal corneal edema (25.6%), which decreased to 3.8% on postoperative day 7. A similar pattern of results was observed by Kausar et al., who showed that postoperative corneal edema was present in 44% of the patients and that most of the patients had focal corneal edema (24.7%) (8).

Based on the results of our study, predictive factors for assessment of postoperative corneal edema are NO and the patient's age. This is consistent with what has been found in a previous study (8). This observation might be explained by the theory that significant factors for corneal clarity are the number and condition of endothelial cells. Other than quantity, the quality of endothelial cells is also an important factor for corneal clarity (2). Gradual corneal endothelial cell loss occurs with increasing age and studies estimate the cell loss rate at 0.3% to 0.5% per year (3, 16). With regard to the corneal endothelial barrier and pump function, our study suggests that there is a higher risk of transient postoperative corneal edema in older patients. The limitation of the present study is subjective evaluation of postoperative corneal edema using slit lamp biomicroscopy due to a lack of resources.

One of the intraoperative risk factors which can lead to transient corneal edema after phacoemulsification is endothelial injury caused by consumed ultrasound energy (1). In order to reduce the amount of energy used during phacoemulsification, we used the phaco chop technique, since it has been shown in previous studies that less ultrasound energy is needed when using phaco chop in comparison with other techniques (8, 17,18). In our study, we used the Ellips FX handpiece with a combined longitudinal and transversal movement of the tip, which demonstrates safe performance in comparison with the standard longitudinal phaco handpiece, especially when dealing with hard cataracts (5). Likewise, in our study, only 3.8% of the patients had focal corneal edema on postoperative day 7, and all the patients had clear cornea two months after the operation, which confirmed the surgical efficiency of the Ellips FX handpiece. The results of this study showed that corneal edema depend on measured intraoperative parameters (UST, EFX and AVG), showing that consumed energy is a predictive factor for the severity of corneal edema, as shown in the study by Kausar et al (8). On the other hand, the study by Tsaosus and al. showed that ultrasound energy is not the determining factor for corneal edema (2).

This study aimed to analyze the use of advanced phaco technology with the WhiteStar Signature® PRO system with the Ellips FX handpiece, based on cataract density and its effect on postoperative corneal edema. To conclude, using advanced technology makes every surgeon's life easier. The WhiteStar Signature® PRO with the Ellips FX handpiece showed effective surgical performance with good corneal edema recovery in our study population. Despite continuous advances in cataract surgery, there is still a higher risk of transient postoperative corneal edema in harder cataracts, which require a greater amount of energy use during phacoemulsification, especially in the older population. Further research is needed to better understand the risks associated with postoperative corneal edema.

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Competing interests. None to declare.

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