Change in Retinal Nerve Fiber Layer Thickness after Phacoemulsification and its Correlation with Phaco Power and Phaco Duration

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ABSTRACT

Purpose: To determine the change in RNFL thickness after phacoemulsification (Phaco) using OCT and to determine the correlation of RNFL change with phaco duration and phaco power.

Methodology: After getting IRB approval and taking informed consent, a quasi-experimental study was carried out at Eye department of Gujranwala Medical College. Fifty patients of either gender between 50-70 years of age with grade II senile cataract were enrolled in this study. Pre-operatively RNFL thickness was determined using OCT and post-operatively after phacoemulsification, the same procedure was repeated at 1 month and 3 months period. Change in RNFL thickness was determined and paired sample t-test was used to compare mean values pre and post-operatively. Correlation of this change with phaco power and phaco duration was determined using Pearson's correlation test.

Result: Out of 50, 54% were male while 46% were female. Mean age recorded was 60.5±5.42 years. Mean phaco power recorded was 44.4±5.47% while mean phaco duration noted was 9.4±3.51 seconds. Mean pre-operative RNFL thickness was 90.64±4.6µm that increased to 95.62±5.92µm at 1-month post-op. and then declined to 89.66±4.86µm at 3 months post-op. with significant p-value of 0.00 (p-value< 0.05). Pearson's correlation test showed strong positive association of +0.77 b/w phaco power and change in RNFL thickness while weak positive association of +0.031 was determined b/w phaco duration and change in RNFL thickness.

Conclusion: In conclusion, phacoemulsification causes significant change in RNFL thickness post-operatively and this change has strong positive association with phaco power used and very weak positive association with phaco duration.

Keywords: Phacoemulsification, Optical Coherence Tomography, Retinal Nerve Fiber Layer

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INTRODUCTION

Cataract is cloudy crystalline lens which renders people unable to see clearly. It accounts for almost 51% of global blindness that represents about twenty million people worldwide.[1] Around ten million cataract surgeries are performed per year globally, in which cataractous lens is removed and replaced by an artificial intra-ocular lens (IOL). [2]

These techniques have evolved from manual cataract surgeries of intra-capsular cataract extraction (ICCE), extra-capsular cataract extraction (ECCE), manual small incision cataract surgery (MSICS) to newer modalities such as use of phacoemulsification and femtosecond lasers.[3] Among all, phacoemulsification is the standard technique preferably used by many ophthalmologists in which high frequency ultra-sonic vibrations are used to emulsify cataract which is then removed via simple aspiration. [4]

Phacoemulsification and intra-ocular lens implantation cause marked changes on anterior segment,[5] as well as posterior segment configuration, one being a significant change in retinal nerve fiber layer (RNFL) thickness. Retinal nerve fiber layer (RNFL) lies beneath internal limiting membrane which contains axons of ganglion cells and peripapillary RNFL is preferentially affected in glaucoma patients.[6]

RNFL thickness can be determined with the help of optical coherence tomography (OCT), scanning laser polarimetry (SLP) and confocal scanning laser ophthalmoscope (CSLO).[7] Optical coherence tomography is most commonly used for this purpose, which is non-invasive, non-contact, and easy to perform, has sufficient storage capacity for the images and its principle is based on optical reflectometry.[8]

Many researchers are studying the effects of phacoemulsification on retinal RNFL thickness in glaucomatous as well as non-glaucomatous eyes. Amjad, et al. carried out a study in which 64 patients with cataract underwent phacoemulsification. OCT was used to measure RNFL thickness before and after 1 month of surgery with results documenting an increase in geographic RNFL thickness from 84.53 ±4.08µm to 88.02 ±3.63µm 1 month after phacoemulsification.[9]

An interesting study compared RNFL thickness b/w normal and high myopia patients after phacoemulsification using OCT. Pre-operative mean RNFL values were 94.43±9.35µm and 90.68±10.15µm in normal and high myopia groups respectively with significant p-value of <0.001. Post-operative results showed no change in RNFL thickness on the first day while monthly follow up documented gradual increase in RNFL thickness till 3rd month after which it declined till 6th month. And they concluded that phacoemulsification initially caused an increase in RNFL thickness that was due to edema and swelling and later RNFL thinning occurred that was more marked in high myopia group.[10]

As mentioned above, few researchers are investigating the effects of phacoemulsification on retinal nerve fiber layer thickness (RNFL) and documenting change in RNFL thickness post-operatively. But the literature gap found whether this change is related to the phaco power or phaco duration. And if an association is proved, these modifiable factors can help in reducing further progression of RNFL damage after phacoemul-sification especially in glaucoma patients.

METHODOLOGY

While maintaining the ethical standards and getting approval from Institutional Review Board of GMC, a Quasi experimental study was carried out at Eye department of GMC/DHQ-UTH Gujranwala for a duration of 6 months (Dec. 2019- May 2020). The sample size of 50 patients was calculated by the following formula keeping the power of study equal to 90% and level of significance equal to 5%.9

Patients of either gender between 50-70 years of age with grade 2 senile cataract having uneventful phacoemulsification, who were co-operative for good signal strength OCT (>30%), and who completed 3 months post-op follow up were

included in this study through non-probability purposive sampling. Patients with glaucoma, high myopia, other optic nerve or retinal dysfunction, and with previous intra-ocular surgery were excluded from this study.

An informed written consent was taken from every patient and counseled regarding the need, benefits and disadvantages of the procedure. A standardized data collection proforma was used to record the demographic information along with following findings.

After routine ophthalmic examination (VA, BCVA, Applanation tonometry, gonioscopy, anterior segment examination, cataract grading, and fundoscopy), pre-operatively RNFL thickness was measured at the time of admission using optical coherence tomography (Optovue; Model iVue 500) nerve fiber GCC analysis under standardized dark conditions. Scan Quality Index (SQI) was also determined from each OCT scan and documented as pre-operative value on Proforma.

All included patients underwent phacoemulsification and intra-ocular lens implantation under topical anaesthesia. All surgeries were performed by single competent ophthalmologist using "divide and conquer" technique to eliminate any confounding factor. If any included patient developed per-op or post-op complication, he/she was excluded from this study. Phaco duration in seconds was measured directly from phaco machine (CataRhex 3 Oertli) as does phaco power in percentage.

Post-operatively, RNFL thickness as well as scan quality index (SQI) in the same way was measured at one month and then three months after cataract surgery and patients were followed up for any post-op complications. Change in RNFL thickness for every patient was calculated as difference between post-op and pre-op values at 1 month and 3 months respectively.

Data was analyzed using SPSS v20.0. Frequencies and percentages were calculated for categorical variables like gender and laterality while Mean±S.D were computed for numerical variables like age, RNFL values and phaco power etc. Paired sample t-test was used to compare means pre and post operatively. Pearson's correlation test was used to establish the relationship of RNFL thickness change with the phaco duration and phaco power. P value ≤0.05 was considered statistically significant.

RESULTS

Total 50 patients were enrolled in this study, out of which 27 (54%) were male patients and 23 (46%) were female. Mean age recorded was 60.5±5.42 years with range of 50-70 years. Right eye was involved in 28 (56%) patients and left eye in 22 (44%) patients.

Patients with only grade II senile cataract were enrolled into this study. Out of 50 patients, 24 (48%) had preferably posterior sub-capsular (PSC) cataract, 20 (40%) had nuclear sclerotic (NS) cataract and only 6 patients (12%) had cortical cataract.

Mean phaco power recorded was 44.4±5.47% with range of 40-70% while mean phaco duration noted was 9.4±3.51 seconds with range of 4-9 seconds.

Mean pre-operative retinal nerve fiber layer thickness (RNFL) determined was 90.64±4.6µm with minimum value of 84µm and maximum value of 102µm. Mean RNFL values at 1 month post-op. increased to 95.62±5.92µm with range of 87-112µm which further changed to 89.66±4.86µm with range of 82-100µm at 3 month post op. (Fig-1)

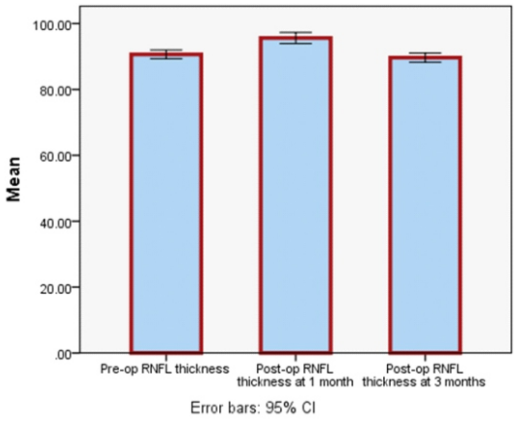

Fig. 1: Error bars showing mean RNFL values pre-op. & post-op.

Mean pre-operative RNFL values in superior and inferior quadrants were 90.46±5.92µm and 90.56±4.92µm respectively that increased to 95.28±5.22µm and 95.94±6.33µm respectively at 1 month post-op. and later on declined to 90.58±4.62µm and 88.96±5.09µm respectively at 3 months post-op. period with change more marked in inferior quadrant. (Table 1)

Table 1: RNFL values (Optovue; Model iVue 500)

RNFL thickness	Minimum (µm)	Maximum (µm)	Mean (µm)	S.D (µm)
Pre-op RNFL thickness	84.00	102.00	90.64	4.60
Post-op RNFL thickness at 1 month	87.00	112.00	95.62	5.92
Post-op RNFL thickness at 3 months	82.00	100.00	89.66	4.86
Pre-op Sup. quadrant RNFL thickness	80.00	102.00	90.46	5.06
Post-op 1 month Sup. quadrant thickness	86.00	110.00	95.28	5.22
Post-op 3 months Sup. quadrant thickness	84.00	100.00	90.58	4.62
Pre-op Inf. quadrant RNFL thickness	84.00	105.00	90.56	4.92
Post-op 1 month Inf. quadrant thickness	85.00	114.00	95.94	6.31
Post-op 3 months Inf. quadrant thickness	82.00	100.00	88.96	5.09

Pre-op. mean scan quality index (SQI) was found out to be 34.5±3.59 (range 30-42) that improved to 51.3±4.62 (range 45-60) and 52.44±4.52 (range 45-62) at 1 month and 3 months post-op. respectively.

Mean change in RNFL thickness at month was found to be +4.98±3.49µm (Range -1.00µm to +12.0µm) while at 3 months it was –0.98±1.05µm (Range -4.00µm to +3.00µm). Paired t-test was applied to compare means pre-operatively and post-operatively at 1 month and 3 months. At 95% confidence interval, 2-tailed significance obtained was 0.000 (p-value< 0.05) at both 1 month and 3 months period that depicts highly significant p-value. (Table 2)

Table 2: Paired sample t-test to compare means pre-op & post-op

		Paired Differences					Sig. (2-tailed)
		Mean	S.D	Std. Error Mean	95% Confidence Interval of the Difference		
					Lower	Upper	
Pair 1	Post-op RNFL thickness at 1 month - Pre-op RNFL thickness	+4.98	3.49	0.49	3.98	5.97	.000*
Pair 2	Post-op RNFL thickness at 3 months - Pre-op RNFL thickness	-0.98	1.05	0.15	-1.28	-0.67	.000*

Pearson's correlation test was used to determine the strength as well as direction of association of phaco power with change in RNFL thickness at 1 month and the value obtained for this correlation was r = +0.77 that denotes strong positive association between the two. (Figure 2)

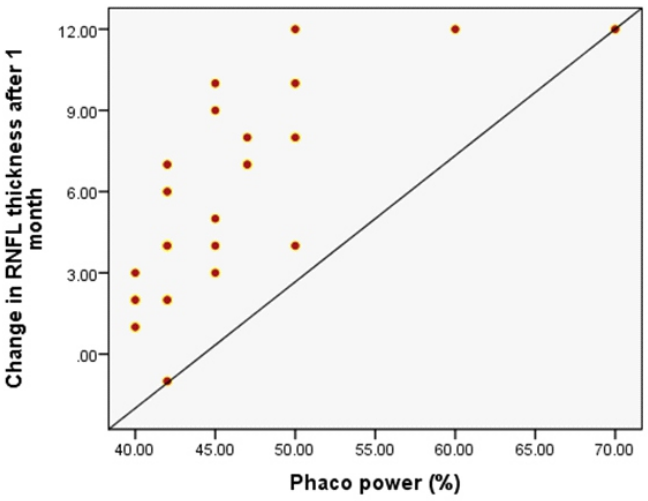

Fig.2: Scatter chart showing correlation b/w phaco power & change in RNFL thickness at 1 month

Pearson's correlation test was also used to determine the strength as well as direction of association of phaco duration with change in RNFL thickness at 1 month and the value obtained for this correlation was r = +0.031 that denotes very weak positive association between the two. (Figure 3)

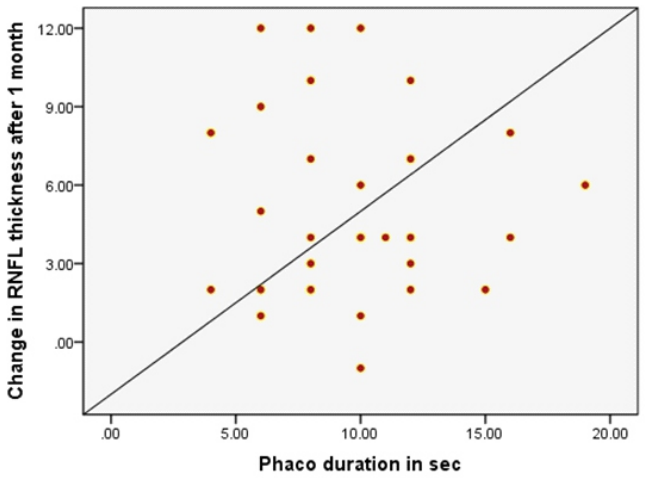

Fig. 3: Scatter chart showing correlation b/w phaco duration & change in RNFL thickness at 1 month

DISCUSSION

Phacoemulsification is most performed procedure for cataract surgery worldwide. Apart from its several advantages, it has some detrimental effects too. One known fact is damage to corneal endothelial cells and second is damage to ganglion cells complex resulting in retinal nerve fiber layer thickness change that can be well monitored by optical coherence tomography.

Optical coherence tomography is a diagnostic as well as monitoring tool that is non-contact, based on interferometry principle, and gives high resolution cross-sectional images of retina as well as choroid. It helps in the quantitative measurement of retinal nerve fiber layer thickness, and it also has the advantage of data reproducibility. [11,12]

Mean age recorded in our study was 60.5±5.42 years, out of which 54% were males and 46% were females. Jha et al. carried out a similar study and reported mean age of 56.6 years with similar male predominance of 70% and females were 30%. [13]

Types of cataracts were also determined in our study that showed posterior sub-capsular cataract being the most common (48%), followed by nuclear sclerosis cataract (40%), and cortical cataract being the least common (12%). These results are not in accordance with a cross-sectional study conducted at central India that reported nuclear sclerosis being the most prevalent followed by cortical and then posterior sub-capsular cataract. This difference can be explained on the basis of difference in age-group being studied. [14]

In this study, we also determined the phaco parameters like phaco power and phaco duration used during phacoemulsification. Mean phaco power was found to be 44.4% and mean phaco duration of 9.4 seconds in divide and conquer technique. Wong et al. reported phaco power of 35.1% and equivalent phaco time of 0.84 minutes with divide and conquer technique that was more than with chop technique. [15]

Our study showed a change in RNFL thickness after phacoemulsification. Mean pre-operative RNFL thickness was 90.64±4.6µm that increased to 95.62±5.92µm at 1 month post-operatively which further changed to 89.66±4.86µm at 3 month post operatively with significant p-values. Degirmencif et al. also determined RNFL thickness change after phacoemulsification and found out mean RNFL thickness of 89.43±23.0 µm preoperatively and postoperatively it was increased to 106.57±12.5 µm at 1 month with statistically significant difference. [16]

There are various approaches to justify this change in RNFL thickness after phacoemulsification. According to Nasar et al. this increase in the RNFL thickness after phacoemulsification is due to improvement in transmittance and reflectivity of RNFL boundary after removal of cataractous lens rather than the actual retinal nerve fiber layer thickening after phacoemulsification.[17] But this holds true partly as the subsequent decrease in RNFL thickness at 3 months postoperatively can't be explained on this basis. Pardianto et al. explained it more logically that phacoemulsification causes the release of inflammatory

cytokines as well as induces intraocular fluctuations. These intraocular fluctuations can create micro-bubbles and produce micro-emboli in retinal vessels that leading to micro-ischemia in RNFL. Thus, initial increase in thickness is due to cytokines induced inflammation and subsequent decrease in retinal nerve fiber layer thickness is due to ischemia induced damage to the retinal ganglion cells.[18] Another explanation is that ultrasonic vibrations and high vacuum used during phacoemulsification can cause indirect damage to ganglion cells resulting in the alteration of RNFL thickness.

In our study, mean change in RNFL thickness at month was found to be +4.98 μm and this change was more pronounced in inferior quadrant. Another local study determined the change in RNFL thickness between glaucomatous and non-glaucomatous eyes and it reported similar value of change in RNFL thickness (4.08μm) in non-glaucomatous eyes while in glaucomatous eyes this change was much more (11.33 μm) with significant p-value.[19]

In this study, we also focused on scan quality index of time domain optical coherence tomography (Optovue iVue 500 Model). Pre-op. mean scan quality index (SQI) was less that improved at 1 month and 3 months post-op period with significant p-value. Kim et al. compared the signals strength (SS) and RNFL thickness of Spectral Domain-OCT versus Time Domain-OCT before & after cataract surgery, and a significant difference was found between pre-operative and post-operative signals strength (SS) values using SD-OCT. RNFL thickness changes after cataract surgery were also more noticeable and frequent for SD-OCT compared to TD-OCT. [20]

The most distinguishing feature of this study is the determination of factors causing change in RNFL thickness after phacoemulsification and it includes phaco power and phaco duration. The results showed strong positive association of phaco power with change in RNFL thickness while very weak positive association was found between phaco duration and change in RNFL thickness.

Limitations of this study being single centered study with small sample size. It included RNFL thickness only in superior and inferior quadrant due to build in software of OCT machine, so this study didn't comment on nasal and temporal quadrants RNFL thickness. Here we included phaco duration directly from phaco machine which is the time in seconds for which phacoemulsification was carried out. It didn't include total duration of surgery starting from eye speculum insertion till its removal. In the end, author suggests a multi-centered study with large sample size to be carried out in the future to fill the remaining gaps in this study.

CONCLUSION

Phacoemulsification causes significant change in RNFL thickness which is manifested as an initial rise in thickness at 1 month due to swelling of RNFL and later decrease in thickness when edema settled at 3 months post-operatively reflecting ganglion cell damage.

And this change in RNFL thickness has strong positive association with phaco power used during surgery and weak positive association with the phaco duration.

Scan quality index for pre-operative optical coherence tomography was less compared to post-operative values which is due to improved transmittance of light after cataract removal.

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