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CORNEAL ENDOTHELIUM OUTCOME AFTER TORSIONAL PHACOEMULSIFICATION SURGERY

Hassan Shamselden Yousef*

Sohag El-Balyina, Lecturer of Ophthalmology, AL-Azhar University.

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***Corresponding Author**
Hassan Shamselden Yousef
Sohag El-Balyina, Lecturer of Ophthalmology, AL-Azhar University.

ABSTRACT

Purpose: Corneal Endothelium Outcome After Torsional Phacoemulsification surgery. **Desigen:** prospective randomized study. **Methods:** This is a prospective study that was performed on 20 patients to estimate postoperative corneal endothelial outcome after cataract surgery performed with torsional phacoemulsification in senile cataracts. The current study has been conducted at Al-Azhar University Hospital Asyuit. **Results:** This is a prospective study that was performed on 20 patients to estimate postoperative corneal endothelial outcome after cataract surgery performed with torsional phacoemulsification in senile cataracts. Preoperative data including age, sex and grading of nucleus are Presented in Table (3). The Age group ranges from 55-65 years, including 12 males & 8 Females, all have Nuclear cataract grade II-III. In our trial we also conducted a more detailed study about the corneal endothelial cells as regard, Endothelial cell Count (Endothelial density) (CD), Average cell size (AVE), Maximum cell size (MAX), Minimum cell size (MIN), Coefficient of variation in cell size (CV), Standard deviation in cell density (SD), Pachymetry (PACHY), Best corrected visual acuity (BCVA), as well as the Percentage of the hexagonal cells (6A). **Conclusion:** Our results indicate that the torsional phacoemulsification is a safe method of removing uncomplicated senile cataract with *less endothelial cell loss.* Torsional phacoemulsification has the advantage of reducing UST as well as effective energy used. Phaco duration was the most significant intraoperative factor affecting the corneal endothelium. So Specular microscopy is a useful tool in preoperative assessment of cataract patients especially in cases undergoing phacoemulsification. This study is limited by a small sample size in hard cataracts. Nevertheless, the findings have meaningful clinical relevance to support the efficiency and safety of torsional phacoemulsification in medium density cataracts.

KEYWORDS: Corneal Endothelium, Torsional Phacoemulsification, Specular microscopy.

INTRODUCTION

Phacoemulsification has transformed cataract surgery into an operation following which visual rehabilitation is almost immediate and postoperative restrictions are few. The principal advantage is a smaller incision size which decrease the amount of postoperative pain and inflammation, and provides a more rapid anatomical healing and refractive stabilization with less astigmatism induced by the procedure.[1] Endothelial injury may occur during cataract surgery due to a number of factors, such as corneal distortion, aspiration of nuclear fragments, intraocular lens contact, and release of free radicals.[2]

The corneal endothelial cell layer cannot regenerate after injury. Repair process involve enlargement of the residual cells, a mitotic nucleus division, migration, and the rosette phenomenon, which leads to a reduction in cell density, a proportional increase in mean cell size, and disruption of the normal hexagonal cell pattern. The normal corneal endothelial cell density is approximately 2500 cells per mm².Corneal decompensation occurring when cell density falls to 700 cells per mm² or more.[3] One of the goals of ocular surgery is to minimize iatrogenic effects on the delicate structures of the eye.[4]

Assessing postoperative changes in corneal curvature as well as endothelial cell dysfunction can indicate the quality of surgery performed.[5,6] Torsional phacoemulsification using an angled tip required shorter cumulative tip travel and less procedure time imply increased nuclear followability, and increased phacoemulsification efficiency and safety.[7] Corneal endothelial cells are very sensitive to trauma, which affect cell density as well as cell morphology. Endothelial cell loss during surgery affects the functional capacity of the cornea to maintain transparency with subsequent visual deterioration.[8] When the endothelium is stabilized after a period of rearrangement, the coefficient of variation (CV) and the hexagonality shift toward the preoperative status. Specular microscopy should be performed 3 months postoperatively when cell loss and reorganization have stabilized.[9]

In general, changes in the CV and the percentage of hexagonal cells are thought to be the early changes that precede a decrease in the endothelial cell density. Pleomorphism and polymegathism indicates that the cornea is under stress, and endothelial cell density decrease indicates that cell death has happened.[10]

PATIENTS AND METHODS

This is a prospective study that was performed on 20 patients to estimate postoperative corneal endothelial outcome after cataract surgery performed with torsional phacoemulsification in senile cataracts.

Written informed consent was obtained from all participants or a legally responsible person after approval by the Institutional Ethic Committee.

Case selection

INCLUSION CRITERIA

- Patient with senile nuclear cataract (n II- III).
- Preoperative endothelial cell count (not less than 1500 cells/mm2).
- Age group ranges from 55-65 years.

EXCLUSION CRITERIA

- Patients with any other types of cataract.
- Patients with any type of glaucoma.
- Patients with previous history of ocular surgeries.
- Patients with previous history of ocular trauma.
- Patients with corneal dystrophies.
- Patients with any medical disease that can affect the eye.
- Patients with an endothelial cell count of < 1500 cells/mm2 before surgery.

Pre-operative evaluation

- Full medical history.
- Best corrected visual acuity (BCVA).
- Slit-lamp biomicroscopy. Nuclear hardness was evaluated according to the color of nucleus and retroillumination using the Lens Opacities Classification System III (LOCS.III).

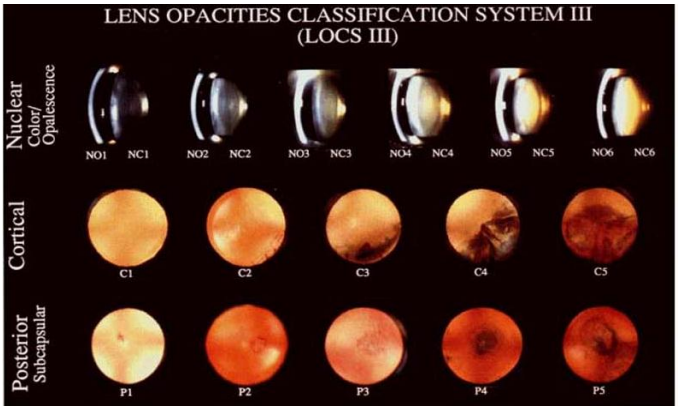


Figure 1: Lens Opacities Classification System III.[11]

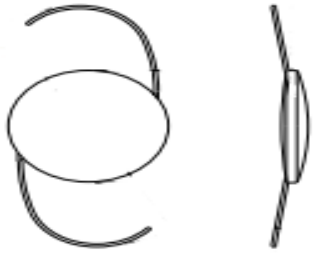
1. Nuclear opalescence and color is visualized through oblique illumination and compared with the standard nuclear images (grades 1-6).
2. Cortical cataract is visualized through retroillumination and compared with standard grades 1-5 cortical opacities.
3. Posterior subcapsular opacities are graded for posterior focused retroillumination and compared with standard grades of 1-5 posterior subcapsular opacities
4. Intraocular pressure measurement using applanation tonometry.
5. Fundus examination using indirect ophthalmoscope
6. Specular microscopy to detect endothelial cell count.
7. Biometry for IOL power calculation.

Preoperative Preparations

Preoperative medications

- Includes topical administration of an antibiotic (Ofloxacin 0.3% eye drops) five times daily for two days before surgery.
- Patients were dilated using cyclopentolate hydrochloride 1% given twice (30 minutes apart) and tropicamide 0.5 % once prior to surgery to achieve proper papillary dilatation during this operation. Phenylephrine hydrochloride 10% was also used twice (10 minutes apart) 30.
- Surgeries were performed under local peribulbar anesthesia using Xylocaine 2% and Bupivacaine 0.5%. Supine position, plastic sterile drape, eye speculum. A 2mm long, 2mm wide clear corneal tunnel incision was performed superiorly between 10 and 12 o'clock using the bevel up crescent knife (8065-940002, Alcon surgical, Fortworth, Texas, USA).

- This is followed by entry into the anterior chamber using a 2.8mm keratome (2.8mm angled slit knife 8065-993261, Alcon surgical, Fortworth, Texas, USA).
- Then 2 MVR incisions using MVR a 19 gauge (1.6 mm) blade, were done at 3 and 9 o'clock position (V- Lance 8065-911901, Alcon Surgiacl, Fortworth, Texas, USA).
- Then Viscoelastic (sodium hyaluronate 10mg/ml) was injected through the side port into the anterior chamber (Ophthalin. Fermetech medical limited research, Scotland, distributed by CIBA Vision).
- A central opening in the anterior capsule is performed using a cystitome (25 gauge bent insulin needle tip) to raise a small flap of the anterior capsule.
- A Continous Curvilinear Capsulorhexis using rhexis forceps ranging in size from 5 to 6 mm in diameter.
- Viscoelastic (sodium hyaluronate 10mg/ml) was again injected into the anterior chamber from the main incision to reform the anterior chamber.



Foldable three piece hydrophobic acrylic IOL (Acrysof MA60BM, Alcon Surgical, Fortworth, Texas, USA)

- **Tabel-2.**

Characteristic	*Acrysof*
Model	*MA60BM*
Optic material	*UV- absorbing acrylate /methacylate copolymer*
Index of refraction	*1.55*
Optic configuration	*biconvex*
Optic diameter (mm)	*6mm*
Optic edge	*Square edge*
Total diameter (mm)	*13mm*
Haptic material	*PMMA*
Haptic configuration	*Modified C*

Postoperative treatment

- Topical steroid and antibiotic eye drops 6 times daily for 1 week then tapered gradually over a month.
- Topical steroid ointment at bedtime.

Postoperative follow-up

Complete ocular examination was done on the first day, 1 week and one month postoperatively including the following.

1. Slit lamp biomicroscopy for:
   - Corneal edema
   - Anterior chamber flare and cells
   - State of the IOL
2. Refraction
3. Best corrected visual acuity (BCVA)
4. Specular microscopy and at 1 week, then 1 month, then 3 month follow up.

Machine

All surgeries were performed using the **INFINITI® Vision System** using a high performance Infiniti™ U/S handpiece: piezoelectric, slim, Lightweight, autoclavable.

Figure 2: OZil® Torsional Handpiece (Alcon Handpieces, 2011).

Figure 3: INFINITI® Ultrasound Handpiece (Alcon Handpieces, 2011).

Figure 4: INFINITI® Vision System Handpieces (Alcon Handpieces, 2011).

RESULTS

This is a prospective study that was performed on 20 patients to estimate postoperative corneal endothelial outcome after cataract surgery performed with torsional phacoemulsification in senile cataracts.

Preoperative data including age, sex and grading of nucleus are Presented in Table 4. The Age group ranges from 55-65 years, including 12 males & 8 Females, all have Nuclear cataract grade II-III.

- **Tabel-3.**

No. of Patients	***20***
Males	***12***
Females	***8***
Age range	***55 - 65***
Nuclear Grading	***II - III***

In our trial we also conducted a more detailed study about the corneal endothelial cells as regard, Endothelial cell Count (Endothelial density) (CD), Average cell size (AVE), Maximum cell size (MAX), Minimum cell size (MIN), Coefficient of variation in cell size (CV), Standard deviation in cell density (SD), Pachymetry (PACHY), Best corrected visual acuity (BCVA), as well as the Percentage of the hexagonal cells (6A).

During the follow up, There was significant Endothelial Cell Loss, significant increase in the Average cell size between Pre-Operative & 1 week post-operative, Pre-Operative & 1Month post-operative, pre-operative & 3 months post-operatively.

Significant increase in the Maximum cell size and the Standard Deviation between Pre-Operative & 1Month post-operative, pre-operative & 3 months post-operatively.

Significant increase in the Coefficient of variation between Pre-operative & 3 months post-operatively.

Significant Improvement in the visual acuity between Pre-Operative & 1 week post-operative, Pre-Operative & 1Month post-operative, pre-operative & 3 months post-operatively.

Otherwise, there was no significant difference concerning other parameters, as shown in table (5) & (6) & (7).

Table 4: Showing range of endothelial cell count in the study cases pre operative and post operative by 1 week, 1month, and 3 months and also the mean and the standard deviation of each item.

Torsional phaco		Range			Mean	±	SD
CD	Pre	2155	-	3558	2631.80	±	353.68
	Post 1 week	1712		2881	2272.70	±	337.92
	Post 1 month	1356	-	2865	2008.50	±	384.94
	Post 3 month	1204	-	2560	1764.40	±	338.04

Table 5: Comparison between endothelial cell parameters throughout the study.

	1 Week		*1 Month*			*3 Months*		
	Mean	*StDev*	*Mean*	*StDev*	*P value*	*Mean*	*StDev*	*P value*
Endoth. Count(CD)	2272.70	337.92	2008.50	384.94	0.094	1764.40	338.04	0.0001
exagonality(6A)	57.65	16.87	51.40	7.46	0.4325	50.95	10.31	0.3702
Pachymetry	579.35	40.90	557.20	47.54	0.4357	569.35	50.69	0.9035
Max.cell size(MAX)	899.90	213.07	1,023.55	280.51	0.6112	1,175.55	477.70	0.0378
Min. cell size(MIN)	208.85	110.80	217.30	87.24	0.9892	235.30	76.42	0.7597
Average cell size(AVE)	472.15	97.64	530.45	113.08	0.2089	527.10	101.12	0.2559
Cof. Of variation(CV)	39.30	10.22	37.60	8.13	0.9657	44.60	16.24	0.466
Standard Deviation(SD)	184.35	55.47	198.75	62.81	0.9187	256.75	106.03	0.01
BCVA	0.80	0.09	0.85	0.09	0.1959	0.87	0.09	0.0604

Table 6: Comparison between endothelial cell parameters throughout the study.

	1 Week		1 Month			3 Months		
	Mean	StDev	Mean	StDev	P value	Mean	StDev	P value
Endoth. Count(CD)	2272.70	337.92	2008.50	384.94	0.094	1764.40	338.04	0.0001
Hexagonality(6A)	57.65	16.87	51.40	7.46	0.4325	50.95	10.31	0.3702
Pachymetry	579.35	40.90	557.20	47.54	0.4357	569.35	50.69	0.9035
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BCVA	0.80	0.09	0.85	0.09	0.1959	0.87	0.09	0.0604

Table 7: Comparison between endothelial cell parameters throughout the study.

	1 Week		1 Month			3 Months		
	Mean	StDev	Mean	StDev	P value	Mean	StDev	P value
Endoth. Count(CD)	2272.70	337.92	2008.50	384.94	0.094	1764.40	338.04	0.0001
exagonality(6A)	57.65	16.87	51.40	7.46	0.4325	50.95	10.31	0.3702
Pachymetry	579.35	40.90	557.20	47.54	0.4357	569.35	50.69	0.9035
Max.cell size(MAX)	899.90	213.07	1,023.55	280.51	0.6112	1,175.55	477.70	0.0378
Min. cell size(MIN)	208.85	110.80	217.30	87.24	0.9892	235.30	76.42	0.7597
Average cell size(AVE)	472.15	97.64	530.45	113.08	0.2089	527.10	101.12	0.2559
Cof. Of variation(CV)	39.30	10.22	37.60	8.13	0.9657	44.60	16.24	0.466
Standard Deviation(SD)	184.35	55.47	198.75	62.81	0.9187	256.75	106.03	0.01
BCVA	0.80	0.09	0.85	0.09	0.1959	0.87	0.09	0.0604

Taking one patient as example:- A 50 years old patient with senile nuclear cataract (n II-III), Preoperative endothelial cell count 2754 (not less than 1500 cells/mm2), no past history of ocular surgeries or ocular trauma, without any type of glaucoma or corneal dystrophies.

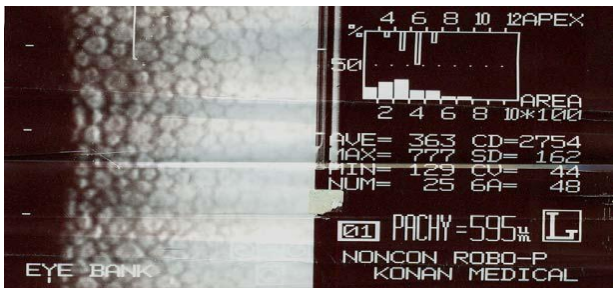

Fig (5-a): Left preoperative specular microscope of 50 years old patient showing that, Endothelial cell Count (Endothelial density) (CD) is 2754, Average cell size (AVE) is 363, Maximum cell size (MAX) is 777, Minimum cell size (MIN) is 129, Standard deviation in cell density (SD) is 162, Coefficient of variation in cell size (CV) is 44, Pachymetry (PACHY) is 595, the Percentage of the hexagonal cells (6A) is 48, as well as the Number of cell (NUM) is 25.

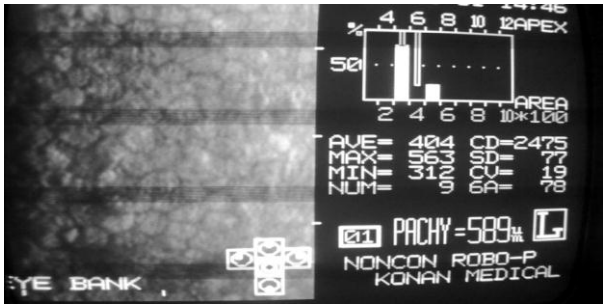

Fig (5-b):- Left postoperative 1 week specular microscope of 50 years old patient who had Phaco showing that, Endothelial cell Count (Endothelial density) (CD) is 2475, Average cell size (AVE) is 404, Maximum cell size (MAX) is 563, Minimum cell size (MIN) is 312, Standard deviation in cell density (SD) is 77, Coefficient of variation in cell size (CV) is 19, Pachymetry (PACHY) is 589, the Percentage of the hexagonal cells (6A) is 78, as well as the Number of cell (NUM) is 9.

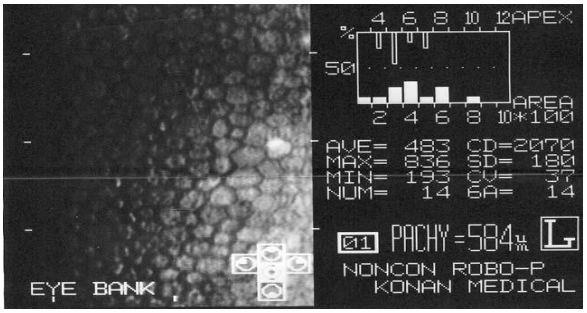

Fig (5-c):- Left postoperative 1 month specular microscope of 50 years old patient who had Phaco showing that, Endothelial cell Count (Endothelial density) (CD) is 2057, Average cell size (AVE) is 486, Maximum cell size (MAX) is 883, Minimum cell size (MIN) is 185, Standard deviation in cell density (SD) is 175, Coefficient of variation in cell size (CV) is 36, Pachymetry (PACHY) is 638, the Percentage of the hexagonal cells (6A) is 30, as well as the Number of cell (NUM) is 23.

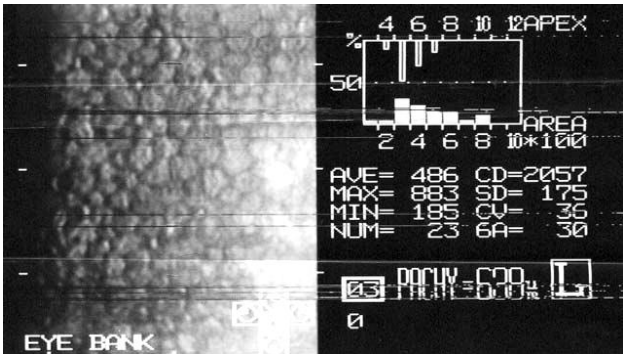

Fig (5-d):- Left postoperative 3 month specular microscope of 50 years old patient who had Phaco showing that, Endothelial cell Count (Endothelial density) (CD) is 2070, Average cell size (AVE) is 483, Maximum cell size (MAX) is 836, Minimum cell size (MIN) is 193,

Standard deviation in cell density (SD) is 180, Coefficient of variation in cell size (CV) is 37, Pachymetry (PACHY) is 584, the Percentage of the hexagonal cells (6A) is 14, as well as the Number of cell (NUM) is 14.

DISCUSSION

For the lens to be removed efficiently and safely, the risk of ultrasound induced endothelial cell loss should be minimized. Reducing phacoemulsification energy and time are the main objectives of future improvement.[12]

The purpose of this prospective, randomized study is to study the effect of torsional phacoemulsification as regards: Endothelial cell Count (Endothelial density) (CD), Average cell size (AVE), Maximum cell size (MAX), Minimum cell size (MIN), Coefficient of variation in cell size (CV), Standard deviation in cell density (SD), Pachymetry (PACHY), Best corrected visual acuity (BCVA), as well as the Percentage of the hexagonal cells (6A).
Kim et al (2010)[13] reported that using torsional phacoemulsification showed less endothelial cell loss and central corneal thickening at postoperative day seven in moderate cataracts. They found that in moderate cataract group percentage endothelial cell loss at 1 week postoperative was 5.12% in torsional group, which turned out to be not significantly different by one month after operation 3.19%, while in hard cataract group percentage endothelial cell loss was 23.52%.

Kim et al (2010)[13] concluded that torsional phacoemulsification showed superior efficiency for moderate cataracts. Based on these studies, we used torsional phaco only to minimize intraoperative factors affecting the corneal endothelium.

Walkow et al (2000)[6] found a significant correlation between phaco time and central endothelial cell loss, but not between phaco energy and cell loss. ***O'Brien et al (2004)***[14] found a significant association between phaco time, mean US power and endothelial cell loss.

As regarding the BCVA at 30 days postoperative there was no statistically significant difference. Similar results were encountered in ***Kim et al (2010),***[13] ***Vasavada et al (2010)***[15] *and* ***Reushel et al (2010)***[16]

Our results demonstrate that torsional phacoemulsification produces a safe and efficient mode of phacoemulsification with reduced mean ultrasound time and Cumulative Dissipiated Energy CDE and percentage endothelial cell loss in grade III nuclear opacity.

Our results also matched with *Liu* ***et al*** [17] they reported that The torsional mode may provide more effective lens removal with less endothelial cell loss. At 7 days and 30 days, the mean central corneal endothelial cell count was 2272.7 ± 337.92 cells/mm2 and 2008.50 ± 384.94 cells/mm2 ($P < 0.001$). Also matched with what *Fakhry* ***et al (2011)***[18] found ($P < 0.001$).

Gonen T ***et al (2012)***[19] concluded that the percentage of mean endothelial cell loss was between 35.4% and 39.1%.

Gogate and associates (2010)[20] conducted a study to compare endothelial cell loss in cataract surgery by phacoemulsification surgery over 6 weeks, the study evaluated 100 patients. The mean endothelial cell loss in percent after 1 week postoperative was 13.2 % and after 6 weeks postoperatively it was 15.5 %, also they found that best corrected visual acuity at 6 weeks was better than 6/18 in 98.5 % of eyes which is matched with our study.

CONCLUSION

Cataract extraction constitutes the largest surgical workload in ophthalmic units throughout the world. *The torsional mode provides an effective and safe method for cataract removal with lower energy usage.*

Our results indicate that the torsional phacoemulsification is a safe method of removing uncomplicated senile cataract with *less endothelial cell loss.* Torsional phacoemulsification has the advantage of reducing UST as well as effective energy used.

Phaco duration was the most significant intraoperative factor affecting the corneal endothelium. So Specular microscopy is a useful tool in preoperative assessment of cataract patients especially in cases undergoing phacoemulsification.

This study is limited by a small sample size in hard cataracts. Nevertheless, the findings have meaningful clinical relevance to support the efficiency and safety of torsional phacoemulsification in medium density cataracts.

RECOMMENDATION

1- Proper preoperative assessment of the corneal endothelium using specular microscopy in patients having one or more of the risk factors for corneal endothelial dysfunction.

2- Proper choice of the surgical procedure for cataract extraction in patients having compromised corneal endothelium to avoid more endothelial damage. For example; using phacoemulsification technique with the least possible Phaco duration.

REFERENCES

1. ***Neumann AC., McCarty GR., Sanders DR., et al:*** *Small incision to control astigmatism during cataract surgery. J. Cataract Refractive Surgery, 1989 Jan; 15(1): 78-84.*
2. ***Cameron MD., Poyer JF. and Aust SD.:*** *Identification of free radicals produced during phacoemulsification. J Cataract Refract Surg, 2001 mar; 27(3): 463-470.*
3. ***Bourne RRA., Minassian DC., Dart JKG., et al:*** *Effect of cataract surgery on the corneal endothelium; modern phacoemulsification compared with extracapsular cataract surgery. Ophthalmology, 2004; 111(4): 679-685.*
4. ***Vasavada V., Raj SM. and Vasavada AR.*** *Intraoperative performance and postoperative outcomes of microcoaxial phacoemulsification; observational study. J Cataract Refract Surg, 2007; 33: 1019-1024.*
5. ***Davison JA., Cionni RJ., Snowdon JR., et al:*** *Simultaneous surgeon and side view videoanalysis comparing in situ fracture and stop-and-chop phacoemulsification. J Cataract Refract Surgery, 2005 Feb; 31(2): 274-279.*
6. ***Walkow T., Anders N. and Klebe S.*** *Endothelial cell loss after phacoemulsification: relation to preoperative and intraoperative parameters. J Cataract Refract Surg, 2000; 26: 727-732.*
7. ***Davison JA.*** *Cumulative tip travel and implied followability of longitudinal and torsional phacoemulsification. J Cataract Refract Surgery, 2008 Jun; 34: 986-90.*
8. ***Kohlhaas M., Klemn M., Kammann J., et al:*** *Endothelial cell loss secondary to two different phacoemulsification techniques. Ophthalmic Surgery and Lasers, 1998; (29): 890-895.*
9. ***Mishima S.:*** *Corneal thickness. Surv. Ophthalmol, 1968; 13: 57-96. Quoted from Mishima S.: Clinical investigations of the corneal endothelium. XXXVIII Edward Jackson Memorial Lecture. Am. J. Ophthalmol, 1982 Jan; 93(1): 1-29.*
10. ***MacRae SM., Matsuta M., Shellans S., et al:*** *The effects of hard and soft contact lenses on the corneal endothelium. Am J Ophthalmol, 1986; (102): 50–7.*
11. ***Chylack LT., Wolfe JK., Singer DM., et al:*** *Lens Opacities Classification System III. Arch Ophthalmol, 1993 Jun; 111(6): 831-836.*

12. ***Waring GO.:*** *Posterior collagenous layer of the cornea. Ultrastructural classification of abnormal collagenous tissue posterior to Descemet's membrane in 30 cases. Arch Ophthalmol, 1982; 100: 122–134.*
13. ***Kim DH., Wee WR., Lee JH., et al:*** *The comparison between torsional and conventional mode phacoemulsification in moderate and hard cataracts. Korean J Ophthalmol, 2010; 24(6): 336-340.*
14. ***O'Brien PD., Fitzpatrick P., Kilmartin DJ., et al:*** *Risk factors for endothelial cell loss after phacoemulsification by a junior resident. J Cataract Refract Surg, 2004; (30): 839-843.*
15. ***Vasavada AR., Raj SM. and Vasavada VL.:*** *Comparison of torsional and microburst longitudinal phacoemulsification: A prospective, randomized, masked clinical trial. Ophthalmic Surgery, Lasers and Imaging, 2010; 41(1): 109-114.*
16. ***Reuschel A., Bogatsch H., Barth T., et al:*** *Comparison of endothelial changes and power settings between torsional and longitudinal phacoemulsification. J Cataract Refract Surg, 2010 Nov; 36: 1855-1861.*
17. ***Liu Y., Zeng M., Liu X., et al:*** *Torsional mode versus conventional ultrasound mode phacoemulsification; randomized comparative clinical study. J Cataract Refract Surg, 2007 FEB; 33(2): 287-292.*
18. ***Fakhry MA. and El Shazly MI.:*** *Torsional ultrasound mode versus combined torsional and conventional ultrasound mode phacoemulsification for eyes with hard cataract. Clin Ophthalmology, 2011; 5: 973- 8.*
19. ***Gonen T., Sever O., Horozoglu F., et al:*** *Endothelial cell loss: Biaxial small-incision torsional phacoemulsification versus biaxial small-incision longitudinal phacoemulsification. J Cataract Refract Surg, 2012 Nov; 38(11): 1918-24.*
20. ***Gogate P., Ambardekar P., Kulkarni S., et al:*** *Comparison of endothelial cell loss after cataract surgery: Phacoemulsification versus manual small- incision cataract surgery six week results of a randomized control trial. J Cararact Refract Surg, 2010 Feb; 36(2): 247-253.*