*Available online at http://www.journalcra.com*

*International Journal of Current Research*
*Vol. 7, Issue, 11, pp.22753-22757, November, 2015*

**INTERNATIONAL JOURNAL OF CURRENT RESEARCH**

**ISSN: 0975-833X**

**RESEARCH ARTICLE**

# THE FACTORS AFFECTING SPECULAR MICROSCOPIC CHANGES IN CORNEAL ENDOTHELIUM IN RELATION TO CATARACT SURGERY

**[1]*Indu Singh and [2]Deepesh Kumar**

[1]Department of Ophthalmology, SMMH Medical College Saharanpur UP, India
[2]Department of Microbiology, LLRM Medical College Meerut UP, India

**ARTICLE INFO**

***Article History:***
Received 20th August, 2015
Received in revised form
01st September, 2015
Accepted 20th October, 2015
Published online 30th November, 2015

***Key words:***
Cataract surgery,
Specular microscope,
Corneal endothelium.

**ABSTRACT**

**Purpose:** To study the factors affecting specular microscopic changes in corneal endothelium in relation to cataract surgery.
**Material and Methods:** Four hundred fifty seven patients were included in this study, the patients who underwent cataract surgery. The patients were examined before surgery & after 6 weeks of surgery on follow up visits. Corneal endothelial examination was done with non-contact Specular Microscope (TopconSP- 2000P) after detailed ocular examination.
**Result:** ACS increased in all three types of surgery. Maximum increase in ACS was seen in ACIOL patients (131.5± 222.6μ $m^2$) least increase in ACS was seen in patients undergoing ECCE (67.4 ± 141.2μ $m^{2)}$.
**Conclusion:** In absence of significant corneal changes the visual recovery after cataract surgery was satisfactory.



***Citation***: Indu Singh and Deepesh Kumar, 2015. "The factors affecting specular microscopic changes in corneal endothelium in relation to cataract surgery", *International Journal of Current Research*, 7, (11), 22753-22757.

## INTRODUCTION

Cataract is the commonest cause of blindness in India accounting for 80.1%cases of blindness. Fortunately vision of the patients suffering from cataract blindness can be restored by simple surgical technique of extra capsular cataract extraction with posterior chamber intraocular lens implantation .although more than 3.8 million cataract surgeries are done in India every year there is felt need to improve surgical outcomes. Specular microscopy helps in evaluation of corneal endothelium cell layer .with the help of specular microscope endothelial cell layer can be photographed to provide permanent reproducible record which can be used for comparative or computer assisted analysis of characteristic of endothelial cells. the estimation of an eye's corneal endothelial reserve is made by comparing endothelial cell count to the normal range of 1500-3500 cells/$mm^2$ .this study was undertaken to document the effect of cataract surgery on specular microscopic corneal status of patients and to study the various factors which affect the corneal endothelium in eyes of patients undergoing cataract surgery so that necessary steps can be taken to improve surgical and visual outcome.

***Corresponding author: Indu Singh***
*Department of Ophthalmology, SMMH Medical College Saharanpur UP, India*

## MATERIAL AND METHODS

Four hundred fifty seven patients were included in this study, conducted in department of Ophthalmology, Kasturba Hospital, Mahatma Gandhi Institute of Medical Science (MGIMS) Sevagram, undertaken on the patients who underwent cataract surgery. The patients were examined before surgery & after 6 weeks of surgery on follow up visits. Corneal endothelial examination was done with non-contact specular microscope (TopconSP- 2000P) after detailed ocular examination. The following specular morphological parameters were quantitated. ECD (Endothelial Cell Density) was estimated by counting endothelial cell number by a computer assisted measuring system after counting 20 cells in a cluster. ECD is one of the indices. It was measured in cells/mm2.

**H(Hexagonality)** difference in the shape of endothelial cells are commonly investigated by assessing the proportion of cells that are six sided("percentage of hexagonality").the variation of cell shape or pleomorphism is an indicator of corneal health The percentage of hexagonal cell is a quantitative measure of pleomorphism. It was given as %. CCT (Central Corneal Thickness) in the specular microscopy: the thickness of the cornea is measured by focusing the device on the epithelial and endothelial surfaces on the cornea, this is done automatically in the noncontact Specular microscope (Topcon SP 2000P) used and digital read out is displayed. It was measured in µ.

**Average cell size,** the maximum and minimum cell area gives the range of variation in cell size. It was measured in µm2.
**Coefficient of Variation,** the maximum and minimum cell area gives the range of variation in cell size.

**Detail of surgery;** cataract surgeries were preferably Extra Capsular Cataract Extraction With Posterior Chamber Intra Ocular Lens (ECCE with PCIOL) implantation except in few cases which required Anterior Chamber Intra Ocular Lens (ACIOL) implantation or simple Extra Capsular Cataract Extraction(ECCE).the surgeries were performed by the consultants as well as residents in the department.

**Intra-operative complications** were noted like descemets tear, vitreous loss, PC rent and hyphema etc.

**Investigations** like, Applanation, Tonometry, Keratometry, Biometry, Pachymetry, Syring, Urine Sugar and USG-B scan also done.

## RESULTS AND OBSERVATION

**Profile of eyes included in the study**

**(A) Preoperative visual status (Table 1).**

All the patients who were operated for cataract had best correct preoperative visual acuity of ≤ 6/60 in the operated eye. Out of these 301(65.9%) had visual acuity of PL + to ≤ 1/60, 92 (20.1%) had visual acuity ≥ 1/60 to < 3/60 and 64 (14.0%) had visual acuity ≥ 3/60to < 6/60.

**Table 1. Visual acuity in operated eye preoperatively**

| Best corrected visual acuity | No. of eyes(%)(n=457) |
|---|---|
| ≥6/18 | 0(0.0) |
| ≥6/60 - <6/18 | 0(0.0) |
| ≥3/60 - <6/60 | 64(14.0) |
| ≥1/60 - <3/60 | 92(20.1) |
| ≥PL+ - <1/60 | 301(65.9) |

**(B) Lens status (Table 2),** in the study evaluation of lens status on slit lamp biomicroscopy 68 (14.9%) had “hard cataract” (Dense Brown Nuclear Cataract) where as 184(40.2%) had “soft cataract” (Cortical and Posterior Subcapsular Cataract).in 205(44.9%) eyes morphology of lens showed mixed cataract.

**Table 2. Lens status of eyes included in study**

| Lens status | No. of Eyes (%) |
|---|---|
| posterior sub capsular cataract | 134(29.3) |
| Nuclear cataract | 68(14.9) |
| Cortical Cataract | 50(10.9) |
| Mixed Cataract | 205(44.9) |
| Total | 457(100.0) |

**(c) Intra ocular pressure (IOP) profile (Table 3),** On Applanation tonometry maximum Intra Ocular Pressure (IOP) recorded in the operated eyes was 20 mm Hg and minimum was 8 mm Hg. On statistical analysis IOP was found to be normally distributed and there was no significant difference in the mean Intra Ocular Pressure between operated and fellow eyes.

**Table 3. Profile of Intra Ocular Pressure (IOP)**

| IOP (mm Hg) | Operated eyes No. (%) | Fellow eyes No. (%) |
|---|---|---|
| ≤ 8 | 8(01.7) | 8(01.70 |
| 09 – 10 | 63(13.8) | 68(14.9) |
| 11 – 12 | 89(19.5) | 94(20.6) |
| 13 – 14 | 133(29.1) | 132(28.9) |
| 15 – 16 | 121(26.5) | 108(23.6) |
| 17 – 18 | 22(04.8) | 28(06.1) |
| 19 – 20 | 21(04.6) | 19(04.2) |
| Total | 457(100) | 457(100) |

**(D) Distribution of Axial Length (Table 4)** On A-Scan Biometry maximum axial length recorded in the operated eyes was 24.9 mm and minimum was 21.8 mm. On statistical analysis axial length as found to be normally distributed and there was no significant difference in the mean axial length between operated and fellow eyes.

**Table 4. Distribution of axial Length**

| Axial length (mm) | Operated Eyes No. (%) | Fellow eyes No. (%) |
|---|---|---|
| 21.5 - 22.0 | 52(11.4) | 50(10.9) |
| 22.1 - 22.5 | 68(14.9) | 62(13.6) |
| 22.6 - 23.0 | 78(17.1) | 76(16.6) |
| 23.1 - 23.5 | 88(19.3) | 90(19.7) |
| 23.6 - 24.0 | 68(14.9) | 74(16.2) |
| 24.1 - 24.5 | 59(12.9) | 63(13.8) |
| 24.6 - 25.0 | 44(9.5) | 42(09.2) |
| Total | 457(100.0) | 457(100.0) |

**(E) Type of Cataract Surgery (Table 5),** Out of 457 eyes included in the study Extra Capsular Cataract Extraction with Posterior Chamber Intra-Ocular Lens Implantation (ECCE with PCIOL) was done in 422 (92.3%) eyes. Anterior Chamber Intraocular Lens Implantation (ACIOL) was done in 26 (5.7%) eyes and in 9 (2%) eyes with myopia and / or subluxated lens Extra Capsular Cataract Extractions (ECCE) was done without IOL implantation.

**Table 5. Profile of Cataract Surgery**

| Surgery | Total No. of surgeries (%) |
|---|---|
| ECCE | 9(2) |
| ECCE with PC IOL | 422(92.3) |
| ACIOL | 26(5.7) |

**(F) Intra-Operative Complication (Table 6),** Out of the 457 eyes operated for cataract 60 (13.1%) eyes had intra-operative complications like descemets tear, vitreous loss, posterior capsule rent and nyphema. While the rest 397 (86.9%) eyes had no intra operative complication.

**Table 6. Frequency of Intra operative complications**

| Intra operative Complication | NO. of Eyes (%) |
|---|---|
| Present | 60(13.1) |
| Absent | 397(86.9) |
| Total | 457(100) |

**(G) Surgical Experience (Table 7),** Out of the 457 eyes included in the study in which cataract surgery was performed, 327 (71.6%) eyes operations were performed by faculty members with sufficient surgical experience, while 130 (28.4%) operations were performed by residents in training under supervision.

**Table 7. Distribution of eyes with Surgeon**

| Surgeon | No. of eyes (%) |
|---|---|
| Resident | 130(28.4) |
| Consultant | 327(71.6) |
| Total | 457(100) |

higher cell loss (17.6%). A hard cataract doubled the risk of severe (>/ 15% cell loss). Hayashi *et al* (1996) reported that firmness of nucleus was significant risk factor for endothelial injury. Sugar *et al* (1978) found that the postoperative endothelial cell loss was more with increasing age and increasing nuclear density but these differences were not of statistical significant. Ishikawa *et al* (2002) reported that advanced nuclear cataract was a significant risk factor for postoperative reduced endothelial cell density ($p < 0.001$).

**(2) Type of Cataract Surgery:** In the present study postoperatively mean ECD was found to decrease in all the type of cataract surgery.

**Table 8. Preoperative lens Status and Corneal changes on specular microscopy. Mention**

| Endothelial variables | | Hard cataract (mean±SD) (n=68) | Soft cataract (Mean±SD) (n=389) | p Value |
|---|---|---|---|---|
| ECD | Pre Operative | 2407.9+423.7 | 2406.6+44.4 | |
| (Cell/mm$^2$ ) | Post Operative | 2061.5+512.1 | 2039.8+508.5 | |
| | Difference | 346.4+400.2 | 365.3+459.4 | 0.75 |
| H (%) | Pre Operative | 29.8+8.1 | 30.7+9.3 | |
| | Post Operative | 25.9+9.6 | 25.5+9.9 | |
| | Difference | 3.8+10.9 | 5.3+11.8 | 0.33 |
| Avg. Cell Size (μm$^2$) | Pre Operative | 428.7+95.6 | 429.3+93.0 | |
| | Post Operative | 521.0+201.7 | 521.1+169.0 | |
| | Difference | -92.3+157.9 | -91.9+144.6 | 0.98 |
| CV | Pre Operative | 23.5+6.6 | 23.4+5.7 | |
| | Post Operative | 26.3+8.4 | 25.8+7.3 | |
| | Difference | 2.8+10.0 | -2.3+9 | 0.00002 |
| CCT (μ) | Pre Operative | 487.9+34.1 | 492.6+33.6 | |
| | Post Operative | 484.7+42.7 | 476.9+40.8 | |
| | Difference | 3.3+33.4 | 15.7+33.4 | 0.004 |

## DISCUSSION

### Factors Affecting Specular Microscopic Changes in Corneal Endothelium in Relation To Cataract Surgery

**(1) Preoperative Lens Status:** In the present study decrease in mean central corneal Endothelial Cell Density in eyes with hard nuclear cataract was 346.4 ± 400.2 cells/mm$^2$ as compared to decrease in central corneal Endothelial Cell Density in eyes with soft cortical cataract (365.3 ± 459.4 cells/mm$^2$) (Table 29). Difference in preoperative and postoperative ECD between hard and soft cataract was statistically not significant ($p = 0.75$) (Table 29). Hexagonality change in eyes with hard nuclear cataract was 3.8 ± 10.9% where as Hexagonality change in eyes with soft cortical cataract was 5.3 ± 11.8%. Difference in preoperative and postoperative Hexagonality between hard and soft cataract was statistically not significant ($p = 0.33$) (Table 29). Both hard nuclear cataracts and soft cataract showed increase in Average Cell Size (ACS) in all the age groups.

The change in mean ACS between hard nuclear (92.3 ± 157.9) and soft cortical (91.9 ± 144.6) cataract was not significant (p value = 0.98) (Table 29). Difference in increase in mean ACS between hard nuclear (92.3 ± 157.9) and soft cortical (91.9 ± 144.6) cataract was not significant (p value = 0.98). Mean Coefficient of variation (CV) increased both in hard (2.8 ± 10) and soft (2.3 ± 9) cataract. This difference was significant. (p value < 0.05) CV refleot polymegathism which was significantly more in hard cataract in our patients. Bourne *et al* (2004) noted that patients with hard cataract had significantly

Patients undergoing ACIOL implantation showed decrease in mean ECD of 494.8 ± 515.6 cells/mm$^2$. Those with PCIOL implantation showed decrease in mean ECD of 356.7 ± 444.6 cells/mm$^2$. Least decrease in ECD was seen after ECCE (cell loss of 249.3 ± 522.9 cells/mm$^2$). Statistical analysis showed that this difference was not significant (p value = 0.24) (Table 30). Patients undergoing ACIOL implantation showed decrease in mean Hexagonality of 5.7 ± 10.8%. Those with PCIOL implantation showed decrease in mean Hexagonality of 5.1 ± 11.8%. Least decrease in Hexagonality was seen after ECCE (2.8 ± 11.7%). Statistical analysis showed that this difference was not significant (p value = 0.81).ACS also increased in all 3 types of cataract surgery. Maximum increase in ACS was seen in ACIOL patient (131.5 ± 222.6 μ m$^2$). Least increase in ACS was seen in patients undergoing ECCE (67.4 ± 141.2 μ m$^2$). CV showed similar changes in all B types of surgery. ECCE showed difference in preoperative and postoperative CV of 3.3 ± 7.8, PCIOL showed difference of 2.3 ± 9.1 & ACIOL showed difference of 4.5 ± 9.8 which was found to be not significant (p value = 0.47).

Specular pachymetry revealed that CCT increased following all types of cataract surgery. Sugar *at al.,* (1977) confirmed the finding that intraocular lens implantation causes significantly greater endothelial damage than cataract extraction alone. Katz *et al* suggested that the direct trauma is the most significant factor to the endothelium at the time of surgery, showing that contact between the surface of an OIL and corneal endothelium instantaneously damages cells (81).Cheng *et al* (1977) in a study of operated patients ranging from age group 55-84, reported that mean endothelial cell loss in eyes with intraocular implants was more (41.3%) as compared to intracapsular cataract extraction (21.4%) (23). Diaz-Valle *et al* (1998) evaluated postoperative endothelial cell damage in various type of cataract surgery: griup-I phacoemulsification, group2-planned ECCE with continuous curvilinear capsulorrhexis and group3-ECCE with letter-box capsulotomy. Endothelial response was not statistically significantly different among the surgical techniques, although endothelial damage was lower in group3 (26).

In a study by Bourne *et al* (2004) no significant difference was found in overall corneal endothelial cell loss between the two operative techniques i.e. modern Phacoemulsification surgery and extra capsular extraction. Schultz *et al* found that at one week after ECCE significant cell loss was restricted to the areas of incision. They also reported stabilization of cell density after ECCE by 3 months. Bourne *et al* (1994) found postoperative loss of endothelial cells at the rate of 2.5% per eyes after 1st year of cataract surgery when preoperative cell density was 2200 cells/mm$^2$. Sugar *et al* (1977) confirmed the finding that intraocular lens implantation causes significantly greater endothelial damage than cataract extraction alone. kata *et al* (1977) suggested that the direct trauma is the most significant factor to the endothelium at the time of surgery, showing that contact between the surface of an IOL and corneal endothelium instantaneously damages cells (81).

Cheng *et al* (1977) in a study of operated patients ranging from age group 55-84, reported that mean endothelial cell loss in eyes with intraocular implants was more (41.3%) as compared to intracapsular cataract extraction (21.4%) (23). Diaz-Valle *et al* (1998) evaluated postoperative endothelial cell damage in various type of cataract surgery: group1-phacoemulsification, group2-planned ECCE with continuous curvilinear capsulorrhexis and group3-ECCE with letter-box capsulotomy. Endothelial response was not statistically significantly different among the surgical techniques, although endothelial damage was lower in group 3 (26). Sugar *et al,* (1977) confirmed the finding that intraocular lens implantation causes significantly greater endothelial damage than cataract extraction alone. Katz *et al* suggested that the direct trauma is the most significant factor to the endothelium at the time of surgery, showing that contact between the surface of an IOL and corneal endothelium instantaneously damages cells (81). Cheng *et al.* (1977) in study of operated patients ranging from age group 55-84, reported that mean endothelial cell loss in eyes with intraocular implants was more (41.3%) as compared to intracapsular cataract extraction (21.4%) (23). Diaz-Valle *et al* (1998) evaluated postoperative endothelial cell damage in various types of cataract surgery: group1-phacoemulsification, group2-planned ECCE with continuous curvilinear capsulorrhexis and group3-ECCE with letter-box capsulotomy.

Endothelial response was not statistically significantly different among the surgical techniques, although endothelial damage was lower in group3 (26). In the study by Galin *et al.* (1979), the endothelial cell density was found to decrease by 25 to 30% in eyes with implants and 10 to 15% in non implanted eyes no change in Hexagonality was noted postoperatively. Rao *et al* (1987) found long term changes in corneal endothelium following IOL implantation and found a decline in endothelial cell density following both IOL implantation and simple cataract extraction. Sugar *et al.* (1978) found that IOL implantation causes significantly greater endothelial damage than cataract extraction alone. They found direct correlation between manipulation of the cornea and cell loss.In a study by Bourne *et al.* (2004) no significant difference was found in overall corneal endothelial cell loss between the two operative techniques i.e. modern Phacoemulsification surgery and extra capsular extraction. Schultz *et al* found that at one week after ECCE significant cell loss was restricted to the areas of incision.

They also reported stabilization of cell density after ECCE by 3 months. Early specular microscopic data supported the conclusion that lens implantation procedure is more traumatic to the endothelium than is an uneventful, cataract extraction without lens implantation. Implanting an anterior chamber lens appeared to be more traumatic than implanting a posterior chamber lens. Ravalico *et al.* (1997) studied corneal endothelium postoperatively and conclude that the functional endothelial failure occurred in the early period after ECCE, while phacoemulsification seemed to minimize postoperative functional damage to the endothelium.

**(3) Intraoperative Complications:** In the present study patients who had intraoperative complications during surgery had more cell loss as compared to those without any complications. Difference in preoperative and postoperative mean ECD in eyes with intraoperative complications was 473.8±431.9cells/mm$^2$, while in eyes without complications the difference in preoperative and postoperative mean ECD was 345.7 ± 451.6 cells/mm$^2$. This showed that intraoperative complications caused significant decrease in mean ECD (p value = 0.04). Intraoperative complications also caused more decrease in postoperative mean hexagonality (7.1 ± 10.8%). Eyes without complications showed change in hexagonality of (4.8 ± 11.8%). Statistically the difference was not significant (p value = 0.16). More increase in ACS was seen in eyes which suffered intraoperative complications (104.9 ± 182.5 μ m$^2$) as compared to eyes without intraoperative complications (90.0 ± 140.4 μ m$^2$).

This increase in ACS was also not found to be statistically significant (p value = 0.46). Change in CV (3.6 ± 9) was seen in eyes who had intraoperative complications and difference of CV in eyes who had no complications was 2.2 ± 9.1. The difference was not significant (p value = 0.27) showing that intraoperative complication did not significantly change the postoperative polymegathism. In eyes suffering from intraoperative complication there was a difference of mean CCT of 10.6 ± 36.7 μ and in eyes which did not have operative complications, the difference of mean CCT was 14.4 ± 33.2 μ which was not statistically significant (p value = 0.42). The difference in percentage cell loss following intraoperative complication was not significant (p value < 0.27).

Average postoperative ECD in eyes without intraoperative complication was 2401.5 cell / mm$^2$ and percentage cell loss was 14.5%. Average postoperative ECD in eyes with intraoperative complications was 1968.0 cell / mm$^2$ showing a cell loss of 19.4%. Bourne *et al.* (2004) reported that ntraoperative complications were found to be significant associated with increased cell loss. (% cell loss equal to 11.5%), Complications of surgery such as capsule rupture & vitreous loss carried a 2.6 times risk of severe (>/15%) cell loss at one year. Abbott *et al.* (1979) found that the patients who maintained an intact hylaoid face showed a 10% cell loss compared with the 26% cell loss in the eyes with the ruptured vitreous face ($p < 0.1$). Abbott *et al.* (1979) found that the patients who maintained an intact hylaoid face showed a 10% cell loss compared with the 26% cell loss in the eyes with the ruptured vitreous face ($p < 0.1$).

**(4) Surgical Experience:** In the present study majority 327 (71.6%) of the surgeries were performed by experienced surgeons. Salient comparative analysis of specular changes revealed that mean ECD difference in eyes operated by consultants was 285.6 ± 421.9 cells / $mm^2$ and mean ECD in eyes operated by residents was 556.5 ± 464.2 cells / $mm^2$. This difference was highly significant (p value < 0.0001). Residents surgeries also showed significant decrease in hexagonality (7.4 ± 12%) as compared to consultant surgery which revealed decrease in hexagonality of 4.1 ± 11.5%. This was statistically significant (p value = 0.006). Patients operated by residents also showed increase in mean ACS with the difference being 142.8 ± 1616 $\mu m^2$. Patients operated by consultants also showed small increase in average cell size.

The difference was statistically highly significant (p value < 0.0001). Residents surgeries showed increase in CV of 4.0 ± 8.6 while eyes operated by surgeon showed increase in CV of only 1.8 ± 9.3. Difference in CV was statistically significant (p value = 0.02) indicating that in eyes operated by residents there was more polymegathism postoperatively. CCT also showed change in corneal thickness postoperatively but the difference in CCT in eyes operated by residents and consultants was not statistically significant (p value = 0.23). Percentage cell loss calculated by proportional analysis showed that resident surgery caused much more cell loss of 25.3% as compared to cell loss of 12.4% occurring in eyes operated by consultants. Irvien *et al.* (1978) concluded that altering the surgical technique so as to minimize touch the corneal endothelium could, considerably reduce endothelial damage. Taylor *et al* (1983) concluded that the postoperative endothelial cell loss more with iris supported IOLs, eyes with guttata or chronic glaucoma or previous surgery and was also affected by the skill of surgery. Sugar *et al*. (1978) found that increase in endothelial cell loss after cataract surgery was pronounced with increased endothelial trauma during surgery. Presently available implants of both anterior and posterior chamber design, the availability of viscoelastic material, improved model microsurgical technique and increasingly high levels of surgical training and skill have reduced the surgical risk.

## REFERENCE


Bourne, R.R.A, Minassian, D.C., Dart, J. K.D., Rosen, P, Kaushal, S. and Wingate, N. 2004. Efeect of cataract surgery on the corneal endothelium. *Ophthalmology*; 111:679-685.

Bourne, W.M., Nelsen, L.R. and Hodge, D.O., 1994. Continued endothelial cell loss ten year after lens implantation. *Ophthalmology*;101:1014-1023.

Cheng, H., Sturrock, G.D., Rubinstein, B. and Bulpitt, 1977. Endothelial cell loss and corneal thickness after intra capsular extraction and iris clip lens implantation:A randomized controlled trial (interm report) *Br J Ophthalmol*. 61:785-790.

Diaz-Valle, D., Sanchez, J.M., Castillo, A., Sayagues, O. and Moriche, M., 1998. Endothelial damage with cataract surgery techniques. *J cataract Refract surg*; 24(7):951-955.

Galin, M.A., Lin, L.L., Fetherolf, E., Obstbaum, and sugar, A. 1979. Time analysis of corneal endothelial cell density aftaer cataract extraction . *AM.J. Ophthalmol*. 88:93-96.

Irvine, La, Kartz R.P. and O'Donnell, J.J. 1978. Endothelial damage with phacoemulsification and intra ocular lens implantation. *Arch ophthamol*. 96:1023-1026.

Ishikawa, A. 2002. Risk factors for reduced corneal endothelial cell density before cataract surgery. *J Cataract Refract Surg*; 28(11):1982-1992.

Ravalico, G., Tognetto, D., Palomba, M.A., Lovisato, A. and Baccara, F. 1997. Corneal Endothelial function after extracapsular cataract extraction and phacoemulsigication. *J cataract refracts surg*: 23(7):967-968.

Sugar, A. and Fetherolf, E.C., 1977. Endothelial cell loss from intra ocular lens insertion. *Am.J.Ophthalmol*; 85:394-399


*******