Comparative evaluation of modified crater (endonucleation) chop and conventional crater chop techniques during phacoemulsification of hard nuclear cataracts: A randomized study

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Purpose: To compare the clinical outcomes of endonucleation chop (EC) versus conventional crater (CC) chop techniques in phacoemulsification of hard nuclear cataracts. Methods: In this Prospective, longitudinal, randomized controlled study with double-blinding. Hundred consecutive eyes with uncomplicated cataracts (nuclear grades 3 and 4) were equally divided into Group A (EC) and Group B (CC). Intraoperative effective phacoemulsification time (EPT) and balanced salt solution (BSS) volume used was noted. Postoperative central corneal thickness (CCT), endothelial cell density (ECD), uncorrected Visual Acuity (UCVA), best-corrected visual acuity (BCVA), and IOP were recorded at days 1, 7, 30, and 90 postoperatively. The Chi-square test (categorical data), Mann–Whitney U test, and t-tests for other parameters were done. Results: The mean EPT in Groups A and B were 6.6 and 14.25 s, respectively (P < 0.001). The BSS volume used was 105.9 and 221.7 mL, respectively (P < 0.001). At 3 months, the ECD loss was 4.35 and 8.6%, respectively (P = 0.025). The first-day CCT was significantly increased in Group B but was the same in both groups at 3 months. A significant improvement in BCVA was noted in both groups. This new technique significantly reduces EPT, the BSS used, and ECD loss. Conclusion: Compared with the CC chop technique, the EC technique for phacoemulsification of hard nuclear cataracts conserved phacoemulsification energy and minimized exposure to the intraocular irrigating solution, provided a significant reduction in corneal endothelial damage, and led to faster visual rehabilitation.

Key words: Conventional crater chop, effective phacoemulsification time, endothelial cell density

Phacoemulsification is the most common surgical technique for cataract removal as it provides good vision with minimal complications.[1,2] The density and the thickness of the crystalline lens tend to increase with age. The central core of the lens, i.e., the nucleus undergoes hardening with age (nuclear sclerosis). The lens proteins (crystallins) undergo chemical changes and aggregate into high molecular weight proteins.[3]

Phacoemulsification of very hard cataracts is a challenge to the surgeon because of the difficulty in breaking the nucleus, and then, separating the broken nucleus from the adjacent epinucleus. The phacoemulsification time and energy required increase with an increase in the nuclear hardness and density. The crater and chop technique is one of the most frequently used techniques of nucleofractis in phacoemulsification for hard cataracts.[4] However, a significant amount of ultrasonic energy is released inside the anterior chamber to make the crater. There is no clear guideline as to how deep or wide the crater must be to make chopping easier. Complications like endothelial cell loss, corneal edema, anterior capsule tears, and posterior capsule ruptures are more common in phacoemulsification in hard cataracts.[5,7]

A simple modification of the CC chop (henceforth called the EC) is a new technique where the central core of the nucleus is disengaged from the epinuclear shell by giving multiple small peripheral chops. Hong Kyun Kim described a similar technique in 2009 but there was a slight difference in making the initial chops.[8] It was not followed up with any study comparing it to other accepted procedures. This study was undertaken once the surgeon gained sufficient confidence in the repeatability of this procedure. Reducing the potential for injury to the corneal endothelial cells helps shorten the recovery period and improves visual outcomes.[9,10] The main cause of endothelial cell loss in cataract surgery is the use of ultrasound energy. The effective phacoemulsification time (EPT) and endothelial cell loss (ECL) can be conveniently studied to establish the superiority and safety of one technique over the other.

Xinyi Chen et al.[11] compared the outcomes between femtosecond laser-assisted cataract surgery and conventional phacoemulsification cataract surgery in patients with...
hard nuclear cataracts and found that the EPT, absolute phacoemulsification time, and mean ultrasound power were lower in the femtosecond group. The ECD in the conventional group was also lower than the femtosecond group. A similar model was adopted for this study.

**Methods**

This single-center interventional study was performed with the approval of the Institutional Ethics Committee and as per the tenets of the Declaration of Helsinki. Written informed consent was obtained from all the patients after giving them a full explanation of the procedure and study.

Patients with uncomplicated hard nuclear cataracts were recruited for the study.

Preoperatively, each cataract was graded in accordance with the Emery-Little classification\(^1\)\(^2\) using a BQ 900 slit-lamp (Haag-Streit AG). According to the grading of the coloration of the lens,\(^3\)\(^4\) patients with cataract nucleus graded 3 or 4 were included.

**Patient evaluation**

Preoperatively, the medical histories of all patients were recorded. Comprehensive evaluations were performed, including BCVA, slit-lamp examination, Goldmann Applanation tonometry, ECD, and central corneal thickness (CCT) by specular microscopy (Topcon SP-3000P), dilated fundoscopy, and optical biometry [Zeiss Optical Biometer - IOLMaster 500]. Conventional manual keratometry and ultrasonic A-scan were done where the optical biometer failed to give an accurate assessment.

Patients with preoperative endothelial cell density (ECD) less than 2000 cells/mm\(^2\), poorly diluted pupils (<5.0 mm), Morgagnian cataract, cataract with subluxation, recent or old uveitis, intraoperative complications compromising vision (posterior capsular rent, subluxation, nucleus drop), Fuchs endothelial dystrophy, glaucoma, history of intraocular surgery, or laser were excluded from the study. Subsequently, consecutive 100 eyes were included in the study. These were randomized (lottery method, by operator) into two groups. Group A: EC technique and Group B: CC chop technique. The surgeon was not involved in assigning the groups. Every eye in the two groups underwent phacoemulsification surgery (Laureate by Alcon) through a clear corneal 2.2 mm temporal incision.

**Surgical technique**

The eye to be operated was fully dilated with tropicamide (0.8%) and phenylephrine (5%) combination drops which were instilled three times at 5 min intervals. Topical anesthesis was achieved using proparacaine (0.5%) eye drops by instilling one drop three times at 5 min intervals. This was augmented with 0.2 mL of intracameral 1% lignocaine through a 1.1 mm side-port incision. The aqueous in the anterior chamber was replaced with 1.4% sodium hyaluronate. A clear corneal temporal incision was made with a 2.2 mm clear corneal keratome. Trypan blue dye (0.06%) was used to stain the anterior capsule if the fundal glow was inadequate. A 5 mm continuous curvilinear anterior capsulorhexis was performed with Inamura microincision forceps. After cortical cleavage hydrodissection, nucleus rotation was ensured. The chamber was then filled with a cohesive viscoelastic (Viscoat\(^5\)). The anterior chamber irrigating fluid used was BSS by Alcon\(^6\).

**CC chop:** The central core was sculpted using the following parameters—US linear power 40–75% (as per nucleus core hardness), pulsed phaco (50% duty cycle, 60 ppm), AFR 20 mL/min, and vacuum 80 mmHg. After most of the central core was removed, the settings were changed to direct chop; US linear power preset 65%, pulsed phaco (30% duty cycle, 60 ppm), AFR 35 mmHg (fixed), and vacuum 360 mmHg (fixed). The peripheral rim was cracked with the direct chop maneuver and the pieces were emulsified. The anterior chamber was periodically filled with Viscoat\(^5\) to protect the corneal endothelium.

EC: The US parameters were kept the same as the direct chop described above. The nucleus was engaged in the mid-periphery and a small peripheral chop with minimal lateral separation was done. The end-point of this separation was when a small circumference of the central nucleus core became visibly separate. After the nucleus rotation, these small chops were repeated all-around 360° of the nucleus. These cracks were not extending throughout the posterior plate. They were given just enough to separate the central nucleus core. After 8–12 of such chops (depending on the nucleus volume and density), the phaco needle was embedded in the central core which was then disengaged from the peripheral shell. This ‘endonucleus’ was mechanically crushed between the chopper and the phaco needle and was then emulsified. The peripheral partial cracks were then extended through the posterior plate of the nucleus and the pieces emulsified [Video Clip 1]. Viscoat\(^5\) was injected periodically for endothelial protection.

After cortical aspiration, the anterior chamber was filled with 1.4% sodium hyaluronate. This was followed by the implantation of a posterior chamber aspheric, monofocal, hydrophobic foldable intraocular lens. The residual viscoelastic was removed with an irrigation-aspiration cannula. The wound was sealed with stromal hydration after injecting 0.1 mL moxifloxacin (Vigamox\(^5\)) in the anterior chamber. All the surgeries were performed by the same experienced surgeon using this standard protocol. All the measurements were taken by the same observer and the conditions were kept consistent for all the operated eyes.

The only difference in the two groups was the chopping technique used for the disassembly of the nucleus and the rest of the procedure remained the same. Intraoperative complications, if any, were noted. However, significant complications (posterior capsule rupture, zonular dehiscence) led to the exclusion of the eyes from the study.

The EPT was calculated by multiplying the ultrasound time (UST) in seconds with \([\text{AP} \times 100] \) where AP 3 = Average phacoemulsification time in foot-switch position 3. The bottle height varied from 65 to 80 cm. The BSS volume used was noted. Any operative complications were noted.

Postoperatively, every patient was prescribed topical antibiotic (moxifloxacin 0.5%) which was stopped after 1 week and topical steroid (prednisolone acetate 1% qid) which was tapered over 6 weeks.

**Postoperative follow-up**

Every subject was followed up postoperatively on days 1, 7, 30, and 90. Besides routine evaluation, the following parameters...
were recorded for every subject at each visit: UCVA and BCVA (logMAR), IOP, ECD, and CCT. The complications, if any, were noted.

All measurements were taken by the same operator, and the conditions were kept consistent for all operated eyes.

**Statistical analysis**

The sample size was determined based on a power calculation (alpha error 0.05 and power 80%) using standard deviations obtained in the former study. At least 35 eyes per group were required to be included in the analysis to achieve sufficient power in the statistical calculations.

The statistical analysis was performed with the SPSS, version 21, for Windows statistical software package (SPSS inc., Chicago, IL, USA). The categorical data were presented as numbers (percent) and were compared among the groups using the Chi-square test. The quantitative data were presented as mean and standard deviation and were compared by the Student’s t-test. Probability (P-value) was considered to be significant if less than 0.05.

**Results**

A total of 50 eyes were operated on in Group A (EC) and 51 eyes were operated on in Group B (CC chop). One eye in Group B had zonular dialysis during the surgery and so was excluded from the study. Thus, 50 eyes were evaluated in each group.

No significant complications occurred in the EC group. One subject in the CC chop group had intraoperative miosis which did not respond to intracameral epinephrine, but was included in the study since the surgery was completed uneventfully.

Table 1 shows the comparison of demographic data between the two groups. There were no significant differences in age and sex between the two groups. In addition, there was no statistically significant difference in the preoperative UCVA, BCVA, IOP, ECD, and CCT between the two groups.

Table 2 shows the comparison of the intraoperative parameters, i.e., the EPT and volume of the BSS used between the two groups. Both the mean EPT and the mean BSS for Group A were found to be significantly less than that of Group B in our study.

Table 3 shows the ECD values for both groups over time. Postoperatively, although the mean ECD decreased in both groups, Group A had significantly higher ECD values than Group B at every postoperative visit. The ECL between the preoperative levels and 3rd month of postoperative follow-up was between 4.1 and 4.6% for Group A and 8.4 and 8.8% for Group B.

Table 4 shows the CCT changes over time. A significant increase in the CCT was observed postoperatively in both groups (more in Group B), which was consistent with our ECD results. The comparison between the mean CCT values of the two groups was found to be statistically insignificant at each postoperative visit except at day 1 post-op where Group A had a significantly less corneal thickness increase. However, the CCT values in both groups returned close to the baseline level at the end of 3 months.

Fig. 1 shows the BCVA changes over time. Preoperatively, the mean BCVA (logMAR) was 1.25 ± 0.47 in Group A and 1.26 ± 0.44 in Group B (P = 0.903). Preoperatively, the mean UCVA (logMAR) was 1.34 ± 0.43 in Group A and 1.33 ± 0.41 in Group B (P = 0.924).

Compared with the preoperative levels, the mean UCVA and BCVA improved after the surgery for both the groups at each postoperative visit. The comparison between the mean UCVA and BCVA between the two groups was not statistically significant throughout the follow-up except for the first postoperative day visit wherein the EC group had a significantly better mean UCVA and BCVA than the CC chop group (P < 0.001 and <0.001 for the mean UCVA and BCVA, respectively, at postoperative day 1).

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**Table 1: Comparison of demographic characteristics between the two groups**

| Parameter                  | Group A (EC) | Group B (CC chop) | P   |
|----------------------------|--------------|-------------------|-----|
| Mean age (y)±SD            | 66.32±8.32   | 65.96±9.17        | 0.837|
| Female, n (%)              | 16 (32)      | 18 (36)           | 0.833|
| Male, n (%)                | 34 (68)      | 32 (64)           | 0.833|

**Table 2: Comparison of intraoperative parameters, i.e., EPT and BSS between the two groups**

| Parameter                  | Group A (EC) | Group B (CC chop) | P   |
|----------------------------|--------------|-------------------|-----|
| Mean EPT (s)±SD            | 105.9±34.87  | 14.25±4.93        | <0.001*|
| Mean BSS (mL)±SD           | 221.7±64.77  | 121.7±54.93       | <0.001*|

EPT - Effective phacoemulsification time; BSS - Balanced salt solution

**Table 3: Mean ECD (cells/mm²) changes over time**

|                  | Group A (EC) | Group B (CC chop) | P   |
|------------------|--------------|-------------------|-----|
| Preoperative     | 2615±247     | 2680±246          | 0.189|
| Postoperative d  | 2343±243     | 2228±224          | 0.015*|
| Postoperative day 7 | 2338±242     | 2227±224          | 0.019*|
| Postoperative day 30 | 2335±244     | 2225±224          | 0.021*|
| Postoperative day 90 | 2331±243     | 2225±224          | 0.025*|

ECD - Endothelial cell density

**Table 4: Mean CCT (microns) changes over time**

|                  | Group A (EC) | Group B (CC chop) | P   |
|------------------|--------------|-------------------|-----|
| Preoperative     | 501.02±16.49 | 497.74±16.81      | 0.353|
| Postoperative day 1 | 515.64±21.73 | 522.84±13.34      | 0.048*|
| Postoperative day 7 | 507.82±17.60 | 513.16±13.16      | 0.088|
| Postoperative day 30 | 504.88±15.89 | 507.76±13.76      | 0.335|
| Postoperative day 90 | 503.26±16.03 | 503.78±12.90      | 0.858|

CCT - Central corneal thickness
Discussion

Successful division and emulsification of a hard nucleus is a challenge for the surgeon, but at the same time can be rewarding for the patient. Still, the rate of vision-threatening complications is more in the phacoemulsification of hard cataracts.\[^{15}\]

The various modalities for dealing with the dense brown nuclei have been described in detail in the review article by Foster et al.\[^{15}\]

The efficacy and safety of any nucleus disassembly technique can be assessed and compared using many criteria. The EPT gives the total ultrasonic energy delivered inside the eye and represents the number of seconds that are equivalent of 100% longitudinal power delivered. The volume of the balanced salt solution (BSS) also indirectly reflects the duration that the phacoemulsification needle remains inside the eye. The ECD represents the true summation of intraocular insult during surgery and its assessment is the key to the comparison between various techniques. However, all other confounding factors should be kept as constant as possible except for the variable under study. The CCT also gives indirect evidence of the corneal insult during the surgery and is usually increased immediately postoperatively. The time it takes for it to regain its preoperative level is also suggestive of the extent of the damage. The ultimate goal of cataract surgery is visual restoration. The best-corrected visual acuity (BCVA) is also studied to compare the efficacy of various methods of cataract surgery.

This study compared the clinical outcomes after the phacoemulsification surgery of hard nuclear cataracts with the EC technique and the CC chop technique of nucleofractis with these parameters pre- and postoperatively. All the procedures were performed by the same experienced surgeon on a single machine (Laureate by Alcon\(^\text{®}\)) and on patients with similar grades of nucleus hardness. Both the groups were age- and sex-matched and care was taken to ensure strict inclusion and exclusion criteria with randomization to minimize bias and confounding factors.

Regarding intraoperative parameters, both the EPT and volume of BSS used were significantly less for the EC technique. These indirectly indicated lesser intraocular insult. The use of modified chopping techniques and also femtosecond laser for hard cataracts significantly reduce the EPT, absolute phacoemulsification time, the volume of BSS used, and mean ultrasound power compared with conventional surgery, as reported by Elnaby EA et al.\[^{16}\]\ and Hatch et al.\[^{17}\]\ respectively. As the fibers are laid on the lens over time, the nucleus becomes harder. The radial suture plane of these lenses, which is made of fiber adhesions, tends to have a strongly adhesive quality around the posterior epinucleus, forming a dense posterior nuclear plate.\[^{18}\]\ Therefore, it becomes more difficult to use conventional techniques to complete the nuclear division of a hard cataract. As per the steps of the EC technique already explained in methodology, it provides three advantages. First, the incomplete peripheral chops can be easily completed under direct visualization. Second, adequate space is created in the bag for the separation of these segments. Lastly, these smaller peripheral fragments easily prolapse into the center of the capsular bag and true endocapsular phacoemulsification can be achieved.

In this study, the ECD decreased in both groups after the surgery. Group A (endonucleation chop) had significantly higher ECD values than the CC chop group at every postoperative visit indicating that the use of this technique of nucleofractis in phacoemulsification can prevent a certain amount of endothelial cell damage and ocular trauma leading to quicker recovery. The corneal endothelium plays an important role in maintaining corneal transparency and normal thickness.\[^{19}\]\ The phacoemulsification time and energy are the most significant factors influencing endothelial cell damage.\[^{9,20}\]\ Many new techniques have been used to reduce the EPT and the required phacoemulsification energy, which can reduce corneal endothelial injury. Mencucci et al.\[^{21}\]\ found that the ECL in standard phacoemulsification surgery is approximately 4–25%; however, the mean rate of ECL is greater in the eyes with hard nuclei and can be as high as 42% at the final follow-up.\[^{22}\]\ Thus, ECL is particularly problematic in the eyes with a cataract with a hard nucleus. However, it is important to note that the use of the modified crater chop technique of nucleofractis in phacoemulsification can prevent a certain amount of endothelial cell damage which results in less trauma and quicker recovery.

A significant increase in CCT was observed postoperatively in both the groups (more in Group B), which was consistent with our ECD results but a comparison between the mean CCT values of the two groups was found to be statistically insignificant at each postoperative visit except at day 1 post-op. The thickening of the central cornea always accompanies ECL.\[^{21}\]\ A significantly more postoperative increase in CCT at day 1 in Group B suggests more severe corneal swelling. This is most likely to be related to the longer EPT, a larger volume of BSS, and greater ECL. With postoperative topical steroids, however, this recovers and the final CCT becomes similar in the groups. Xinyi Chen et al.\[^{21}\]\ reported that femtosecond laser-assisted cataract surgery can lessen the degree of corneal edema soon after surgery and shorten the recovery time.

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**Figure 1**: BCVA changes over time

March 2022 Upadhyay, et al.: Endonucleation chop Vs conventional crater chop in phacoemulsification
The comparison between the mean IOP values of the two groups was found to be statistically insignificant at each postoperative visit.

In this study, all patients had improved UCVA and BCVA postoperatively. Group A had a significantly better vision on day 1 post-op. This correlates well with the observation of an increased degree of corneal edema on the first postoperative day in the eyes operated by the CC chop technique.

This study was limited by small sample size in hard nuclear cataracts. Nevertheless, the findings have meaningful clinical relevance to support the efficiency and safety of the modified crater chop technique of phacoemulsification in these cataracts. An objective, accurate, and reproducible lens evaluation system is required for a detailed clinical study of cataracts. Optical photography offers less variability and is more objective than other methods.[24–27] The Anterior Segment Analysis System, based on the Scheimpflug imaging principle, can be used for the detection and quantitative assessment of nuclear cataract lens density more accurately.[28]

Conclusion

This EC technique of nucleus fractis in phacoemulsification surgery permits uneventful successful endocapsular phacoemulsification of significantly hard cataracts. The EPT and volume of BSS used are significantly reduced leading to quicker recovery and minimal trauma to the ocular structures during surgery.

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Conflicts of interest

There are no conflicts of interest.

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