Comparison of clinical outcomes of trifocal intraocular lens (AT LISA, Eyecryl SERT trifocal) versus extended depth of focus intraocular lens (Eyhanse, Eyecryl SERT EDOF)

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Purpose: To compare four different types of intraocular lenses (IOLs), namely, AT LISA, Eyecryl SERT trifocal, Eyhanse, Eyecryl SERT extended depth of focus (EDOF) with respect to their clinical outcomes.

Methods: This is a retrospective comparative study in which patients who underwent surgery and one of the four types of IOL were implanted. Postoperative evaluation was recorded at one month, postoperatively. The monocular uncorrected distance visual acuity (UDVA) and corrected distance visual acuity (CDVA) (6 m), uncorrected intermediate visual acuity (UIVA) (60 cm), distance-corrected intermediate visual acuity (CIVA), uncorrected near visual acuity (UNVA) (40 cm), and corrected near visual acuity (CNVA) were assessed postoperatively on post operative day 30, for all four IOL groups. Defocus curve and contrast sensitivity were also compared.

Results: With regards to UDVA and CDVA, P value was not statistically significant. (P = 0.534 and 0.421, respectively). EDOF group of IOLs had statistically significant better UIVA and CIVA than trifocal IOL group. (P < 0.001, 0.012, <0.001) and EDOF group had statistically significant worse P value pertaining to UNVA and CNVA (P < 0.001, 0.070, <0.001, 0.190). Pertaining to contrast sensitivity, EDOF group had better contrast sensitivity than Trifocal IOL group (P < 0.001).

Conclusion: All four IOLs compared in this study had good comparable distant visual acuity. Near visual acuity was better with AT LISA and Eyecryl SERT trifocal IOL while intermediate vision was better with Eyhanse and Eyecryl SERT EDOF IOL. Contrast sensitivity was better in EDOF IOLs than in both trifocal IOLs.

Key words: Contrast sensitivity, defocus curve, EDOF IOL, trifocal IOL

Presbyopia is an unavoidable ailment that affects the aging population. Close to one billion people worldwide are affected by this condition.\[1,2\]

Ever since intraocular lens (IOL) was invented, a lot of research has been done to rectifying the loss of accommodation, and various types of IOLs have been introduced for the same, namely, bifocal, trifocal IOL, and extended depth of focus (EDOF) IOL. According to optical principles, multifocal IOLs can be divided into diffractive and refractive IOLs. All diffractive model IOLs and most of the refractive models are rotationally symmetric while some of the refractive models are rotationally asymmetric.\[3\] IOLs can be either bifocal or trifocal according to the number of measurable foci.\[4,5\]

We have come a long way from monofocal IOLs. Bifocal IOLs came first but intermediate vision was not good with these IOLs and with increase in patient demand for quality of vision, spectacle independence and with widespread usage of computers and tablets, trifocal IOLs were invented which helped in intermediate vision as well. But major drawbacks with these IOLs were glare and halos. Hence EDOF IOLs were introduced. The halo effect, which occurs due to the overlapping of near and far images, is eliminated with EDOF IOLs. However, near vision was not as good with EDOF IOL compared with trifocal IOLs.

With the evolving technology and optical research, multiple and newer designs of trifocal and EDOF IOLs are being introduced. And with the introduction of newer IOLs, clinical studies are necessary to evaluate the efficiency of these IOLs. These studies are helpful in assisting the outcomes of each IOL and also helps in deciding the type of IOL according to the needs of the patient.

Aim

The purpose of this study was to compare the clinical outcomes of four IOLs namely AT LISA, Eyecryl SERT trifocal, Eyhanse, Eyecryl SERT EDOF.

Methods

This was a retrospective comparative study where we collected data of patients after implantation of non-toric IOL (correcting presbyopia) at Uma Eye clinic, Chennai, India. The study was performed in compliance with good clinical practices and consistent with the tenets of the Declaration of Helsinki, including International Harmonization Guidelines, after obtaining ethics committee approval.

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Inclusion criteria were expected postoperative astigmatism of ≤1.00 diopters (D), and age 40 years or older.

Exclusion criteria were previous ocular surgery, corneal astigmatism >2.00 D, ocular pathology or corneal abnormalities, an endothelial cell count below 2,000 cells/mm², relevant concomitant ophthalmologic diseases, such as pseudo-exfoliation, glaucoma, traumatic cataract, age-related macular degeneration, macular disease, diabetic retinopathy, and other comorbidities that could affect capsular bag stability (e.g., Marfan syndrome), systemic disease with potential impact on visual outcome.

Preoperative examination
All patients underwent a thorough ocular examination preoperatively, including subjective refraction, slit-lamp anterior segment evaluation, and fundus evaluation under pupil dilation. The IOL power calculation was done using axial length, corneal power, and anterior chamber depth values obtained with IOLMaster 700 optical biometer (software version 7.1, Carl Zeiss AG, Jena, Germany). Emmetropia was the target refraction in all cases.

The surgical interventions were all executed under topical anesthesia by one experienced surgeon. Patients underwent either phacoemulsification with manual capsulorhexis or Femto LASIK–assisted cataract surgery according to their preference.

Outcome measures
Postoperatively, the patients were followed up regularly and values for our study were recorded at one-month postoperative period.

Visual acuity and refraction
The monocular uncorrected (UDVA) and corrected (CDVA) distance visual acuity (6 m), uncorrected intermediate visual acuity (UIVA) (60 cm), distance-corrected intermediate visual acuity (CIVA), uncorrected near visual acuity (UNVA) (40 cm), and distance-corrected near visual acuity (CNVA) were assessed postoperatively on postoperative day 30 for all four IOL groups.

Defocus curves
Monocular distance-corrected defocus curve testing was performed from 4.0 D to +1.5 D in 0.5 D increments under photopic lighting conditions. The measurement was performed with varying Early Treatment Diabetic Retinopathy Study (ETDRS) charts at 6 m to avoid the learning effect. First, negative lenses were added in 0.5 D incremental steps. Then, positive lenses were used to test visual acuity at the corresponding defocus level.

Contrast sensitivity
Contrast sensitivity was measured using modulation transfer function derived from iTrace ray tracing wavefront aberrometer.

Patients were also assessed for photopic phenomenon, namely, glare and halos. It was a subjective assessment.

Intraocular lenses
AT LISA Trifocal 839MP IOL (Carl Zeiss AG, Jena, Germany) is a hydrophilic acrylic (25%) IOL with hydrophobic surface properties with aspheric optics. It’s a diffractive IOL with near add value of about +3.33 D and intermediate add value of about +1.66 D.

Eyecryl SERT TRHYF600 (Biotech Healthcare Group, Luzern, Switzerland) is a trifocal hydrophobic acrylic foldable, diffractive IOL with aspheric optics with near add value of about +3.50 D and intermediate add value of about +1.85 D.

The TECNIS Eyhance IOL (Johnson and Johnson vision, Santa Ana, USA) model ICBOO is a hydrophobic acrylic lens with a spherical posterior surface and aspheric anterior surface with optic diameter of about 6 mm with a continuous change in power from the periphery to the center of the lens, creating a unique anterior surface that improves intermediate vision.

Eyecryl SERT model PLHFD6 (Biotech Healthcare Group, Luzern, Switzerland) is a hydrophobic acrylic foldable biconvex IOL with aspheric anterior surface and achromatic posterior diffractive surface to improve extended depth of foci that improves intermediate vision.

Statistical analysis was done using SPSS software. Comparison between the four IOL groups was performed using Pearson Chi-squared test. A P value of less than 0.05 was considered to be statistically significant.

Results
The study included 120 eyes of 115 patients. AT LISA was implanted in 30 eyes, Eyecryl SERT trifocal in 30, Eyhance in 30, and Eyecryl SERT EDOF in 30 eyes. Conventional surgery was done for 107 patients with a manual capsulorhexis while 13 patients underwent femto LASIK–assisted cataract surgery. There were no intraoperative or postoperative complications. All the patients were followed up with regularly. And one month follow-up values were recorded.

Table 1 shows preoperative values and other general parameters in different IOL groups.

Table 2 shows distant, intermediate, and near visual acuity recorded after one month post surgery. Comparing all four groups with regards to UDVA and CDVA, P value was not statistically significant (P = 0.534 and 0.421, respectively). EDOF group of IOLs had statistically significant better UIVA and CIVA than trifocal IOL group [P-value given in Table 2]. And EDOF group had statistically significant worse P value pertaining to UNVA and CNVA. Figs 1-3 represents cumulative data of uncorrected distance, intermediate and near visual acuity in all four IOL groups.

Table 3 shows contrast sensitivity values recorded with all four IOLs. Coming to contrast sensitivity, there was a statistically significant difference between EDOF group and trifocal group, with the EDOF group having better contrast sensitivity than the trifocal group [P-value as mentioned in Table 3].

In our study, we can see the incidence of glare and halos to be much higher in the trifocal group than the EDOF group as shown in Fig: 4: 43% and 47% in AT LISA and Eyecryl SERT trifocal, 11% and 9% in Eyhance IOL and Eyecryl SERT EDOF IOL, respectively. A point to be noted is that two of our patients (one from the Eyhance group and one from the AT LISA group) had dysphotopsia which was not taken into account.

Discussion
Even since the invention of multifocal IOLs, we can not only correct distance vision, we can also provide complete
| Table 1: Comparison of Pre-operative parameters between four Intraocular Lens groups |
|-----------------------------------------------|
| Parameters                                      | AT LISA | Eyecryl SERT trifocal | Eyhance | Eyecryl SERT EDOF | P     |
| Eyes (n)                                       | 30      | 30                    | 30      | 30                |
| Sex (M/F)                                      | 16/14   | 19/11                 | 20/10   | 19/11             | 0.007 |
| Age                                           | 58.41±8.88 | 63.51±7.94            | 59.23±8.17 | 61.72±8.43       | 0.04  |
| Surgery (manual/femto)                        | 28/2    | 26/4                  | 27/3    | 26/4              |
| Sphere                                        | 0.18±2.65 | −1.24±4.17            | −0.88±3.17 | 1.41±2.98        | <0.001|
| Cylinder                                      | −0.56 G 0.45 | −0.64±0.40           | −0.65±0.65 | −0.55±0.41       | 0.052 |
| UDVA                                           | 0.65±0.40 | 0.69±0.50             | 0.47±0.36 | 0.58±0.35        | 0.163 |
| CDVA                                          | 0.21±0.26 | 0.18±0.21             | 0.33±0.23 | 0.22±0.16        | 0.062 |
| K1                                             | 44.28±2.23 | 44.76±1.67             | 45.79±3.65 | 46.92±4.23       | 0.186 |
| K2                                             | 43.50±3.30 | 43.34±2.45             | 43.69±3.25 | 44.81±2.23       | 0.054 |
| AL                                             | 23.72±1.11 | 24.20±1.77             | 24.30±1.87 | 23.47±0.97       | 0.021 |
| ACD                                            | 3.27±0.42 | 3.34±0.37             | 3.29±0.50 | 3.08±0.36        | 0.002 |
| IOL                                            | 21.50±3.50 | 20.50±3.00             | 22.50±4.00 | 22.00±2.50       | 0.268 |

| Table 2: Comparison of Post-operative visual outcomes in logMAR (logarithm of the minimum angle of resolution) value between four Intraocular Lens groups at the end of one month |
|-----------------------------------------------|
| Parameters                                      | AT LISA | Eyecryl SERT trifocal | Eyhance | Eyecryl SERT EDOF | P     |
| UDVA                                           | 0.023±0.13 | 0.24±0.10             | 0.02±0.12 | 0.04±0.09        | 0.534 |
| CDVA                                          | 0.006±0.07 | 0.07±0.02             | 0.01±0.01 | 0.01±0.01        | P=0.421|
| UIVA                                          | 0.016±0.12 | 0.20±0.11             | 0.02±0.11 | 0.03±0.08        | <0.002|
| CIVA                                          | 0.005±0.02 | 0.001±0.01            | 0.01±0.01 | 0.01±0.01        | P<0.001|
| UNVA                                          | 0.068±0.13 | 0.71±0.15             | 0.07±0.04 | 0.09±0.03        | <0.001|
| CNVA                                          | 0.003±0.01 | 0.004±0.02            | 0.02±0.01 | 0.01±0.01        | P<0.001|

| Table 3: Comparison of contrast sensitivity values between four Intraocular Lens groups |
|-----------------------------------------------|
| Parameter                                      | AT LISA | Eyecryl SERT trifocal | Eyhance | Eyecryl SERT EDOF | P     |
| Contrast Sensitivity (Mean ± SD)               | 0.376±0.173 | 0.365±0.137            | 0.518±0.161 | 0.573±0.275      | P<0.001|

A-B: 0.185  A-C: 0.043  A-D: 0.005  B-C: 0.071  B-D: 0.284  C-D: 0.100
<0.002  P<0.001  A-B: 0.004  A-C: <0.001  A-D: 0.012  B-C: 1.000  B-D: <0.001  C-D: 0.1
<0.001  P<0.001  A-B: 1.000  A-C: <0.001  A-D: 0.070  B-C: <0.001  B-D: 0.190  C-D: <0.001
0.231  0.012  0.001  0.002  0.348  0.034  0.189
spectacle independence to the patients. The selection of each IOL for different patients depends upon their lifestyle, work requirements, and daily activities. As there are multiple IOLs available on the market, ophthalmologists should have a thorough knowledge about every IOL so that the right type of IOL can be provided to the patient. Hence, comparative studies are necessary to provide proper information about these IOLs so that the patients can be educated properly.\[5–10\]

In this study, we compared four IOL models: Two of them were trifocal non-toric IOLs and the other two were extended depth of foci (EDOF) models. Coming to the comparison of preoperative characteristics, \(P\) value was not statistically significant which allows for a meaningful comparison between the four IOL groups. Coming to CDVA and UDVA, all four IOL groups provided good CDVA and UDVA. On comparison between each IOL, there was no statically significant difference except for between AT LISA and Eyecryl SERT EDOF \([P\)-value provided in Table 2]. There was statistically significant difference between the trifocal group and the EDOF group with regards to UIVA and CIVA \((P < 0.002\) and \(P < 0.001\), respectively). As expected, UNVA and CNVA were statistically significantly better with AT LISA and Eyecryl SERT trifocal than Eyhance and Eyecryl SERT EDOF \((P < 0.001)\). This is in concordance with a study conducted by Mencucci \textit{et al}.\[6\] Other studies which were in concordance with our study includes Ruiz-Mesa \textit{et al}.\[11,12\]

Coming to the defocus curve, all four IOLs had quite a good visual acuity with LogMAR values of about 0.4 or better, from \(-2.5\) D to 0.0 D. This implies that all the four IOLs have good range of vision. On deeper analysis there was no significant difference in distant visual acuity between all four IOLs. Both AT LISA and Eyecryl SERT trifocal IOLs had a drop with intermediate vision and again a peak at \(-2.50\)D while Eyhance IOL and Eyecryl SERT EDOF IOL had significantly better visual acuity from 1 m to 50 cm, as shown in Fig. 5.

Coming to contrast sensitivity, statistical analysis showed both Eyhance and Eyecryl SERT EDOF IOL had better contrast sensitivity than AT LISA and Eyecryl SERT trifocal IOL \([P\)-value as shown in Table 3] which was comparable to the study done by Jing Liu \textit{et al}\.\[13\] Another study done by Gunderson \textit{et al}\.\[14\] had contradictory results where both trifocal and EDOF IOLs had similar contrast sensitivity values.

With regards to optical phenomenon, as shown in Fig. 4, percentage of glare and halos were more with both the trifocal IOLs than EDOF IOLs. This is similar to the study conducted by Zhong \textit{et al}\.\[15\] Even though there was higher incidence of glare and halos in trifocal IOLs, it was not considered bothersome in most cases. However, this is a subjective evaluation, hence proper objective evaluation cannot be done.

There are certain limitations to the study. Only a limited number of patients were included in the study, and there was lack of randomization as well, which in turn can affect
generalized ability of findings. In addition, this was a retrospective study and patient satisfaction was not taken into account. And also, we compared non-tori IOLs; hence residual astigmatism could have hindered the actual visual outcome.

**Conclusion**

In conclusion, all four IOLs compared in this study had good comparable distance visual acuity. Near visual acuity was better with AT LISA and Eyecryl SERT trifocal IOL, while intermediate visual acuity was better with Eyhance and Eyecryl SERT EDOF IOL. Hence, EDOF IOLs would facilitate patients whose profession is based out of computers. And both trifocal IOLs seems to be a good option for patients demanding distant, intermediate, and near vision. Quality of vision seem to be similar in all four IOLs even though contrast sensitivity was better in EDOF IOLs than in both trifocal IOLs. Further studies are required with a larger sample size and randomization for more unbiased results.

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**Conflicts of interest**

There are no conflicts of interest.

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