Preliminary clinical study of LenSx femtosecond laser-assisted limbal relaxing incision on correction of high myopia with low to moderate astigmatism in posterior implantable collamer lens implantation

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Abstract

Background

To evaluate the safety, efficacy, and predictability of the LenSx femtosecond laser-assisted limbal relaxing incision (LRI) for correction of high myopia with low to moderate corneal astigmatism (-0.75 to -1.50D) in implantable collamer lens implantation (ICL).

Methods

This prospective clinical control study included 56 eyes from 46 patients. They were divided into an ICL group with ICL implantation (14 patients,16 eyes); a TICL group with toric ICL implantation (17 patients, 23 eyes); and a LenSx + ICL group with a LenSx femtosecond laser-assisted LRI and an ICL implantation (15 patients, 17 eyes). The visual acuity, astigmatism correction ability and visual quality were measured before and 1, 3, and 6 months after surgery.

Results

The postoperative visual acuity of the 3 groups were higher than the preoperative visual acuity ($P < 0.01$), and the improvements in the LenSx + ICL group and the TICL group were greater than those in the ICL group ($P < 0.01$). The LenSx + ICL and TICL groups had less residual astigmatism and higher astigmatism correction index (CI) than the ICL group ($P < 0.01$). There was no significant difference in the three groups of total high order aberrations (HOAs) before and after surgery ($P > 0.05$).

Conclusion

LenSx femtosecond laser-assisted LRI combined with ICL implantation can effectively correct low to moderate corneal astigmatism in high myopia. Compared with TICL implantation, it can achieve similar clinical effects in the short term.

Trial registration

This article has been retrospectively registered at the Chinese Clinical Trial Registry in 10 June 2019. (NO: ChiCTR1900023743).

Background

In recent years, implantable collamer lens (ICL) implantation has become the mainstream of intraocular refractive surgery due to its effectiveness, safety and predictability. Ophthalmologists often meet patients with high myopia combined with astigmatism of -1.50D or less in clinical work. For such patients, there are usually two solutions. One way is to correct the astigmatism with a TICL implantation. However, the lens may rotate in the ciliary sulcus which will cause the decrease of astigmatism correction or even create a new astigmatism [1]. Besides this, the patients have to wait a relatively long time for surgery. The other way is a simple ICL implantation without astigmatism correcting, but long-term follow-up has shown that patients with uncorrected astigmatism often fail to achieve the best corrected visual acuity, accompanied by a decline in visual quality, especially in contrast sensitivity and night vision. Some scholars have attempted to make limbal relaxing incisions (LRIs) on the cornea to correct the astigmatism and achieved certain results [2, 3]. However, it is difficult to accurately control the length, position and depth of the manual incision, and inappropriate location may cause difficulty for the surgeon [4].

In 2009, femtosecond laser-assisted cataract surgery (FLACS) was invented. In addition to controlling the femtosecond laser for corneal incision, lens capsule release, and lens nucleus fragmentation, some scholars have tried to resolve corneal astigmatism with the help of femtosecond laser-assisted LRIs and achieved ideal results [5–8]. So we think about whether we can apply the FLACS technique to ICL implantation surgery, and use the femtosecond laser to make LRIs to correct the low to moderate corneal astigmatism before ICL implantation. This can avoid the shortcomings of the manual incision, and prevent the problem in TICL implantation. We innovatively combined femtosecond laser-assisted corneal LRIs with traditional ICL implantation to correct low to moderate astigmatism and to verify the safety, efficacy, and predictability of this method.

Methods

From January 2019 to May 2019, 46 patients amomg 18–44 years old with high myopia among − 6.00D to -14.75D and low to moderate astigmatism among − 0.75D to -1.50D were recruited from the Chongqing Aier-Mega Eye Hospital (Chongqing, China). According to the principles of random selection and voluntary participation, the patients were divided into 3 groups, including 16 eyes of 14 patients in the ICL group, 23 eyes of 17 patients in the TICL group, and 17 eyes of 15 patients in the LenSx + ICL group. There were no statistically significant differences among the 3 groups before operation (Table 1). The inclusion criteria for the three groups were as follows: stable refractive error (≤ 0.50D change of refractive error in the past 2 years), anterior chamber depth (ACD) of 2.80 mm or more, and an endothelial cell density greater than 2000 cells/mm^2.

Table 1
Preoperative data of patients

parameter	ICL Group	TICL Group	LenSx + ICL Group	P value
Age (years)	26.06 ± 5.98	25.00 ± 7.37	25.12 ± 5.92	0.864
Number of eyes	16	23	17	-
spherical refraction(D)	−8.46 ± 1.65	−8.78 ± 0.89	−8.58 ± 1.18	0.601
Cylindrical refraction(D)	−1.09 ± 0.20	−1.20 ± 0.19	−1.19 ± 0.18	0.187
Note:There was no statistical difference among the three groups before operation.				

The uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), residual astigmatism, and correction index (CI) were collected before and 1, 3, and 6 months after surgery. The iTrace analyzer measured and recorded the total high-order aberrations (HOAs) and modulation transfer function (MTF) value to observe the astigmatism correction and visual quality of the patients after surgery. Vector analysis was performed, utilizing the Alpins vector method with ASSORT software (ASSORT Pty; Cheltenham, Victoria, Australia) to show the magnitude and directionality of the residual astigmatism.

This study was approved by the medical ethics committee of Chongqing Aier Eye Hospital [batch number: 2019(IRB010)], and all patients signed the informed consent documentation. This study adhered to the tenets of the Declaration of Helsinki.

Surgical Technique

Levofloxacin eye drops (Clopbitone, Japan Tower Corporation), a slit lamp inspector (Topcon SL-1E, Topcon, Japan), Scheimpflug tomography (Pentacam, Oculus Optikgerate GmbH), a comprehensive refractometer (Topcon, Japan), an iTrace Visual Function Analyzer (Collin, Tracy, USA), LenSx femtosecond laser (Alcon Surgical, Inc.).

According to the conventional ICL implantation method, all patients dropped Levofloxacin before operation (4 times each day, 3 days in total). For the TICL group and the LenSx + ICL group, the astigmatism axis was marked on the eye 1 hour before the surgery while the patient was in a sitting position at the slit lamp. In the ICL group, after surface anesthesia, the surgeon made a 3 mm main incision at the scleral limbus, then slowly implanted the lens into the anterior chamber and used a special hook to adjust the lens into the ciliary sulcus under the iris to ensure a centered position of the ICL. The postoperative eye was treated with a special ointment and covered well. In the TICL group, the surgeon simply rotated the lens according to the astigmatism axis provided by the STAAR company after implantation. In the LenSx + ICL group, astigmatism axis locations was determined by using an online software (Abbott Medical Optics, USA; available at http://www.lricalculator.com). Individual surgeon's surgically induced astigmatism was considered as 0.5D(Fig. 1). Then the surgeon marked the astigmatism axis on the patient's eye. The computer automatically calculated the position, depth, and arc length of the limbal relaxing incision according to the vector calculator. The depth of the limbal relaxing incision (the setting depth is 85% of the corneal thickness) was measured under the guidance of an anterior optical coherence tomography segment. The laser was started, and the vacuum was released after the laser operation was over. The vacuum ring was then removed, the patient was moved to a conventional operating table, and the remaining steps were completed according to the conventional ICL surgery procedure.

All the operations were performed by an experienced surgeon without any complications.

Statistical Analysis

All statistical analyses were performed using SPSS (version 19; SPSS Inc). Figures were drawn using GraphPad Prism (version 8; GraphPad Software). Data are presented as mean ± standard deviation. Student's t-test was used for normally distributed data, and the Mann-Whitney test was used for non-normally distributed data. One-way ANOVA was used to analyze the differences among the 3 groups of different operative methods, and LSD was used to perform additional multiple comparison tests. $P < 0.05$ was considered statistically significant.

Results

Surgical Complications

The postoperative follow-up found that in the LenSx + ICL group, there was only a short arc-length relaxing incision left under the cornea after the surgery (Fig. 2). There was no bleeding or infiltration of the incision, the tightness was good, and no complications (such as infection or poor healing of the incision) occurred.

Visual Acuity

The UDVA and CDVA before and after surgery in each group were showed in the Table 2. Figure 3 shows that the UDVA in the 3 groups 1, 3, and 6 months after surgery were higher than the CDVA before operation, and the differences were all statistically significant ($P < 0.01$).

Table 2
The UDVA and CDVA before and after surgery in each group

parameter		Pre-CDVA (LogMAR)	Post-CDVA (LogMAR)	Post-UDVA (LogMAR)	Post-UDVA minus Pre-CDVA (LogMAR)
1 month	LenSx + ICL Group	0.094 ± 0.083	−0.035 ± 0.049	−0.029 ± 0.059	−0.124 ± 0.097
	TICL Group	0.039 ± 0.058	−0.083 ± 0.058	−0.122 ± 0.042	−0.161 ± 0.084
	ICL Group	0.050 ± 0.063	−0.019 ± 0.054	0.063 ± 0.057	−0.044 ± 0.063
	P Value	P = 0.048	/	P < 0.0001	P = 0.0072
3 month	LenSx + ICL Group	0.094 ± 0.083	−0.071 ± 0.047	−0.024 ± 0.044	−0.118 ± 0.073
	TICL Group	0.039 ± 0.058	−0.091 ± 0.060	−0.083 ± 0.072	−0.122 ± 0.052
	ICL Group	0.050 ± 0.063	−0.038 ± 0.050	0.006 ± 0.057	−0.044 ± 0.073
	P Value	P = 0.048	/	P < 0.0001	P = 0.0018
6 month	LenSx + ICL Group	0.094 ± 0.083	−0.071 ± 0.047	−0.024 ± 0.044	−0.118 ± 0.073
	TICL Group	0.039 ± 0.058	−0.078 ± 0.052	−0.083 ± 0.065	−0.122 ± 0.060
	ICL Group	0.050 ± 0.063	−0.025 ± 0.051	−0.006 ± 0.057	−0.056 ± 0.063
	P Value	P = 0.048	/	P = 0.0002	P = 0.0078

Note:logMAR = logarithm of the minimum angle of resolution,CDVA = corrected distance visual acuity,UDVA = uncorrected distance visual acuity,Pre-=preoperative,Post-=postoperative,Means ± SD,the P values in the table shows the comparison among the three groups.

The improvements between postoperative UDVA and preoperative CDVA were compared between each group (Fig. 4). The improvements in the LenSx + ICL group and the TICL group were higher than those in the ICL group at 1, 3, and 6 months after surgery ($P < 0.05$). Further comparison was made between the improvement of the LenSx + ICL group and the TICL group. At 1, 3, and 6 months after surgery, the mean improvements in the TICL group were higher than those in the LenSx + ICL group, but there was no statistically significant difference between the two groups ($P > 0.05$).

We further compared the CDVA before and after surgery in the 3 groups (Fig. 5). At 1, 3, and 6 months after operation, the CDVA were improved compared with those before surgery, and the differences were statistically significant ($P < 0.05$).

Residual Astigmatism and CI

Residual astigmatism was shown using the astigmatism double-angle plot of the Alpins vector analysis method (Fig. 6–7). Compared with the ICL group, the LenSx + ICL group and the TICL group had smaller residual astigmatism at 1, 3, and 6 months after operation, and the differences were statistically significant ($P < 0.01$). Further comparison was made between the LenSx + ICL group and the TICL group, and the residual astigmatism of the LenSx + ICL group was slightly lower than that of the TICL group at 1 month after surgery, whereas that of the TICL group was lower than that of the LenSx + ICL group at 3 and 6 months after surgery; however, these differences were not statistically significant ($P > 0.05$).Table 3 and Fig. 8 showed the CI (CI = |SIA|/|TIA|) values for the 3 groups at 1, 3, and 6 months after operation. Among these, the LenSx + ICL group and the TICL group had higher CI than the ICL group, and the differences were statistically significant ($P < 0.01$). However, there was no statistically significant difference between the LenSx + ICL group and the TICL group after surgery ($P > 0.05$).

Table 3
CI in three groups after surgery

	LenSx + ICL group	TICL group	ICL group	P value
1 month	0.65 ± 0.16	0.65 ± 0.12	0.25 ± 0.17	P > 0.99,P < 0.001
3 month	0.61 ± 0.18	0.67 ± 0.12	0.23 ± 0.15	P = 0.38,P < 0.001
6 month	0.58 ± 0.16	0.68 ± 0.12	0.14 ± 0.15	P = 0.10,P < 0.001

Note:The front P value in the column is the pairwise comparison result of LenSx + ICL group and TICL group,the latter one is the comparison of LenSx + ICL group and TICL group respectively with ICL group,Means ± SD

The Total HOAs and MTF Values

None of the total HOAs in the 3 groups before or 1, 3, or 6 months after surgery showed statistically significant differences ($P > 0.05$) (Table 4 and Fig. 9).

Table 4
The total HOAs in three groups before and after surgery

Groups	parameter	Pre-	Post−1m	Post−3m	Post−6m	P value
LenSx + ICL group	3mm	0.180 ± 0.059	0.190 ± 0.066	0.186 ± 0.055	0.179 ± 0.066	0.9489
	5mm	0.415 ± 0.190	0.388 ± 0.130	0.398 ± 0.130	0.411 ± 0.130	0.9503
TICL group	3mm	0.154 ± 0.093	0.140 ± 0.080	0.138 ± 0.058	0.141 ± 0.063	0.8879
	5mm	0.359 ± 0.181	0.371 ± 0.173	0.354 ± 0.152	0.349 ± 0.144	0.9689
ICL group	3mm	0.238 ± 0.143	0.242 ± 0.112	0.248 ± 0.123	0.228 ± 0.117	0.9714
	5mm	0.478 ± 0.190	0.506 ± 0.173	0.499 ± 0.124	0.484 ± 0.095	0.9477

Note:Pre-=preoperative,Post-=postoperative,Means ± SD

Table 5 and Fig. 10 show that there were no statistically significant differences in the MTF values among the 3 groups before the operation at pupil diameters of 3 mm or 5 mm ($P = 0.7812$, $P = 0.8544$). The comparison among the 3 groups after surgery showed that the MTF values of the TICL group were always slightly higher than those of the LenSx + ICL group, but the difference was not statistically significant ($P > 0.05$). The MTF values in the TICL group were always higher than those of the ICL group, and the differences were statistically significant ($P < 0.01$). Except for the condition of a 3 mm-diameter pupil at 6 months after surgery, the MTF values in the LenSx + ICL group were always better than those in the ICL group, whether at 1, 3, or 6 months after the operation ($P < 0.05$).

Table 5
The MTF value among three groups

parameter		LenSx + ICL group	TICL group	ICL group	P value
Pre-	3mm	0.268 ± 0.073	0.282 ± 0.096	0.263 ± 0.073	0.7812
	5mm	0.210 ± 0.046	0.220 ± 0.079	0.213 ± 0.047	0.8544
Post−1m	3mm	0.357 ± 0.069	0.374 ± 0.091	0.264 ± 0.073	0.0034
	5mm	0.276 ± 0.037	0.287 ± 0.090	0.213 ± 0.059	0.0050
Post−3m	3mm	0.365 ± 0.087	0.391 ± 0.083	0.290 ± 0.080	0.0019
	5mm	0.274 ± 0.083	0.295 ± 0.059	0.217 ± 0.052	0.0025
Post−6m	3mm	0.359 ± 0.081	0.381 ± 0.072	0.305 ± 0.078	0.0124
	5mm	0.261 ± 0.087	0.284 ± 0.066	0.203 ± 0.036	0.0020
Note:Pre-=preoperative,Post-=postoperative,Means ± SD					

Discussion

Astigmatism is one of the common types of refractive error in the eye. Previous studies have reported that nearly 80% of individuals with refractive errors have astigmatism of varying degrees, and about 25% of individuals have astigmatism greater than − 1.00D [9]. Astigmatism over − 0.75D can cause diplopia, blurred vision, and photophobia [10]. STARR company launched TICL implantation for astigmatism correction, however, the lens may rotate in the ciliary sulcus after implantation, which may lead to a decrease in astigmatism correction or create a new astigmatism. Patel C [11] showed that an axial deviation of 10 degrees in TICL can only correct 2/3 of the estimated astigmatism, and an deviation of 30 degrees has no correction effect at all. If the deviation exceeds 30 degrees, there will be symptoms such as diplopia, dazzle, and decreased visual acuity, which have a significant impact on patients [12–14]. Some scholars have tried to make LRIs to solve the corneal low to moderate astigmatism in ICL implantation [15]. However, the traditional LRIs are performed manually, it is difficult to achieve accurate length, position, and depth of the incision, which often makes the astigmatism correction effect unpredictable [4]. In cataract surgeries, some scholars have tried to solve corneal astigmatism with the help of femtosecond laser-assisted LRIs and achieved ideal results. This study compares the traditional ICL implantation, TICL implantation, and femtosecond laser-assisted LRIs with ICL implantation to assess the safety, efficacy, and predictability of this new approach to treating astigmatism, and we hope to propose a new treatment for the correction of low to moderate astigmatism in ICL surgery.

This study found that the UDVA of the 3 groups were improved compared with the preoperative CDVA. It showed that all 3 studied methods can improve the visual acuity in a certain way. Further comparison of the improvements between postoperative UDVA and preoperative CDVA showed that compared with the

ICL group, both the LenSx + ICL group and the TICL group had better visual improvement, and the LenSx + ICL group achieved similar corrected visual acuity to that of the TICL group.

Compared with the ICL group, the residual astigmatism was smaller in the LenSx + ICL group and the TICL group after surgery, which means that the LenSx + ICL group and the TICL group experienced better astigmatism correction than the ICL group. Although the residual astigmatism between the LenSx + ICL group and the TICL group displayed some differences, these were not statistically significant. To make further comparisons about the astigmatism correction capabilities of the 3 methods, CI values were introduced. CI = 1 means that the expected astigmatism was completely corrected, CI < 1 indicates under correction, and CI > 1 indicates over correction. These CI values were less than 1 in all 3 groups, indicating that all 3 groups were under corrected after surgery. Among these, the LenSx + ICL group and the TICL group had higher CI values than the ICL group, and just like the residual astigmatism, there were no statistically significant differences between the LenSx + ICL group and the TICL group. We found that the CI values in the LenSx + ICL group became smaller, just as the residual astigmatism values became higher. It is considered that during long-term corneal incision healing in the LenSx + ICL group, the diopter of the astigmatism is increased, which indicates astigmatism regression and thus may result in a slight decrease in visual acuity and visual quality. This is consistent with the research by Tetikoğlu [16], which found that the healing process of surgical incision directly affects the corneal astigmatism and thus affects the change in corneal aberration.This also suggests us that we can further explore the problem of astigmatism regression caused by corneal incision healing, and adjust the nomogram so as to obtain a more stable and longer-term astigmatism correction effect.In recent years, refractive surgeons have aimed not only to improve the visual acuity of the patient but also to improve the patients' visual quality through a series of personalized operations. Myopia and astigmatism are low-order aberrations (LOAs) and cannot truly reflect the visual quality of patients. Therefore, we collected and studied the HOAs of 3 methods to analyze the visual quality of postoperative patients. We used the iTrace visual quality analyzer to analyze the patients' visual quality before and after surgery. The iTrace analyzer uses optical path tracing technology, and the visual quality of the patient can be simulated by computer software. The iTrace analyzer can convert the point spread function to a Fourier transformation to obtain the MTF curve. At present, many scholars [17] use iTrace analyzer to compare the visual quality of patients between femtosecond laser-assisted cataract surgery and traditional phacoemulsification surgery. In this study, the researchers selected 2 major indicators of visual quality: total HOAs and MTF value. Lower HOAs and higher MTF values indicated better visual quality. This study collected patients' total HOAs and MTF values with a pupil diameter of 3 mm and 5 mm before and after surgery. The total HOAs in the 3 groups before and 1, 3, and 6 months after surgery displayed no statistically significant differences, indicating that no new HOAs were introduced, regardless of the method used. This is consistent with some earlier research, including that of Zhou Xingtao et al., [18] who used the OQAS objective visual quality analysis system to compare the visu al quality of wavefront aberration-guided LASIK surgery and ICL implantation and concluded that the ICL implantation introduced no new aberrations and achieved better visual quality than the LASIK operation. In another long-term comparative observation of 3 years, Zhou Xingtao et al. [19] also found that compared with traditional refractive surgery, ICL implantation offers more stable visual acuity and smaller aberrations. This study found that the MTF values of the TICL group were always slightly higher than those of the LenSx + ICL group; however, the differences were not statistically significant. In comparison to the ICL group, the LenSx + ICL and TICL groups had higher MTF values, except for the comparison between the LenSx + ICL and the ICL group under the 3 mm-diameter pupil in 6 months after the surgery. The results show that, compared with the ICL implantation, the visual acuity obtained in the LenSx + ICL group was obviously superior, and the visual quality of the patients was better. In addition, the LenSx + ICL group achieved a similar effect compared with that of TICL implantation.

Postoperative follow-up found that in the LenSx + ICL group, only a short arc-length incision was left under the cornea after the surgery. There was no bleeding or infiltration of the incision, and the postoperative tightness was good. There were no complications, such as infection and poor healing of the incision. Masket et al.[7] also showed that femtosecond laser-assisted corneal incisions are much neater and tighter than manual corneal incisions. Studies by Chung SH et al. [20] also showed that femtosecond laser-assisted cataract phacoemulsification surgery yields good watertightness and neatness in the corneal incision. Traditional manual corneal incisions are relatively poorly sealed, and this inevitably results in edema of the surrounding tissues during the post-operative period, causing an increase in high-order aberrations after surgery. In addition, the postoperative CDVA in all 3 groups were better than the preoperative CDVA, and the differences were statistically significant. This shows that whether the traditional ICL implantation or the femtosecond assisted ICL implantation was used, there was no loss in CDVA, which reflects the safety of the surgery and suggests that for some patients with amblyopia, this surgical method can correct visual acuity to a degree that is unobtainable with ordinary frame glasses, thus improving patient quality of life.

Conclusion

In summary, this study provides a new method to resolve high myopia combined with low to moderate astigmatism to a certain extent, and it preliminarily verifies the safety, efficacy, and predictability of this method of astigmatism correction. Femtosecond laser-assisted LRI combined with ICL implantation may be an alternative because of time constraints in the TICL lens. In addition, it is probable that the femtosecond parameters (such as incision depth and arc length) can be further optimized to obtain stable, long-term astigmatism correction. However, due to ethical considerations, this study did not set up a manual LRI combined with an ICL implantation group, and the number of patients included were limited. We plan to compare the manual LRI and the femtosecond LRI in the next step. Therefore, a larger samples and a longer follow-up time are needed to further verify the surgical effects.

Abbreviations

LRI
laser-assisted limbal relaxing incision
ICL

implantable collamer lens
TICL
toric implantable collamer lens
UDVA
uncorrected distance visual acuity
CDVA
corrected distance visual acuity
CI
correction index
HOAs
total high order aberrations
MTF
modulation transfer function
HOAs
High-order aberrations.

Declarations

Ethics approval and consent to participate

This study was approved by the medical ethics committee of Chongqing Aier Eye Hospital [batch number: 2019(IRB010)], and all patients signed the informed consent documentation. This study adhered to the tenets of the Declaration of Helsinki.

Consent for publication

Not applicable

Availability of data and materials

Available upon request from the first author: Dr. Miaomiao Zhu.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

YLP and MMZ involved in design the study and preparation of the manuscript; MMZ and ZXZ participated in the collection and analysis of the data; XLL participated in technical support. All authors review and approval of the final manuscript.

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CONSORT guidelines

This study adhered to CONSORT guidelines and included a completed CONSORT checklist.

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Figures

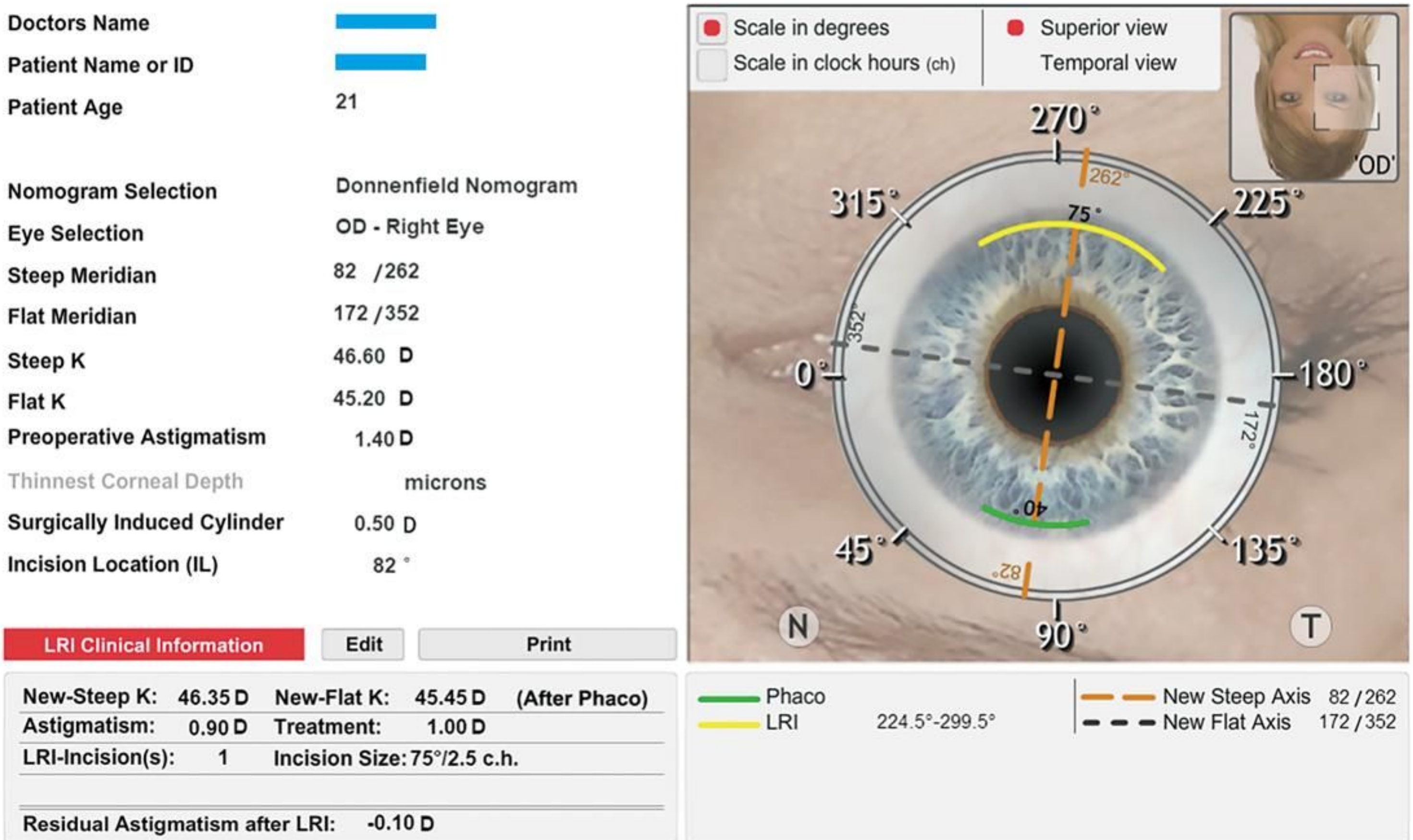

Figure 1

Example of LRI surgical planning (https://www.lricalculator.com)

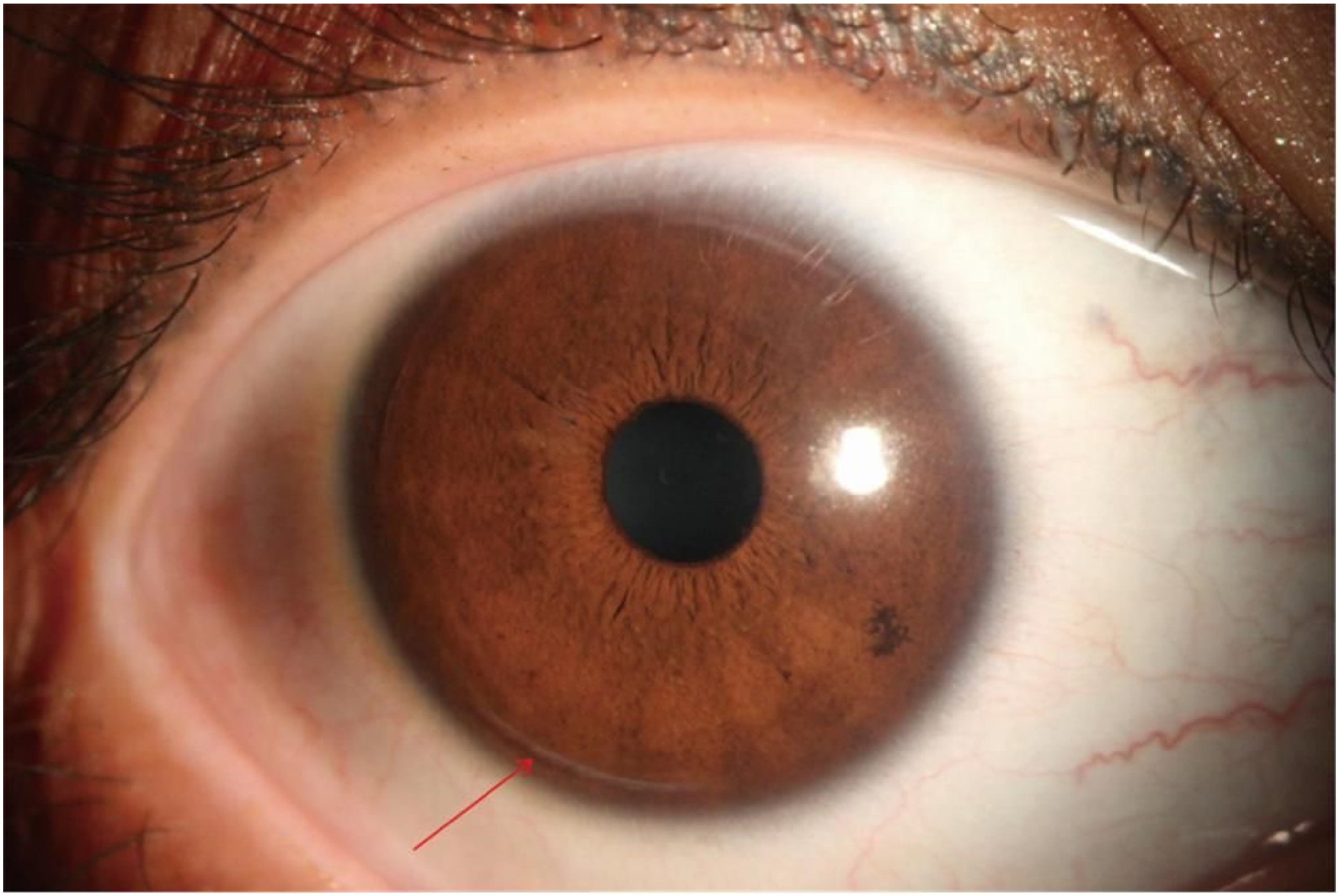

Figure 2

The location of the cornea limbal relaxing incision in the LenSx+ICL group after surgery. (the red arrow in the figure shows the location of limbal relaxing incision)

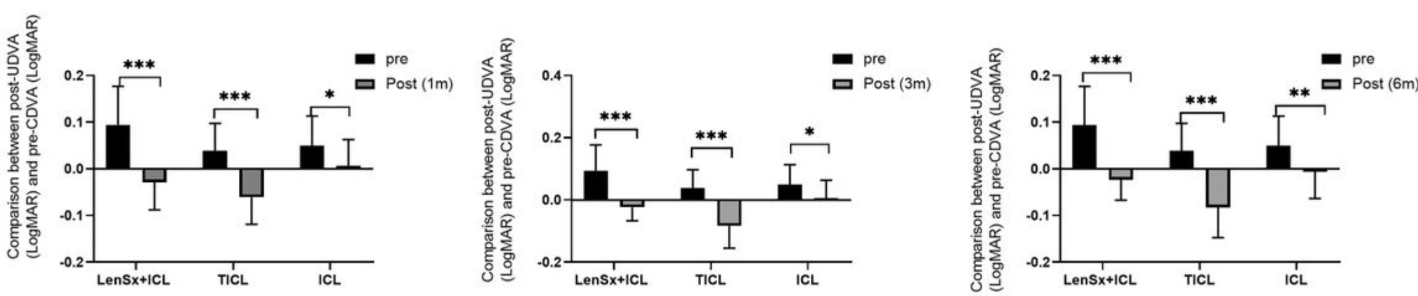

Figure 3

The postoperative LogMAR UDVA and preoperative LogMAR CDVA in three groups after surgery at 1, 3 and 6 months. (The results are expressed as the means ± SD, * means P<0.05, ** means P<0.01, *** means P<0.001)

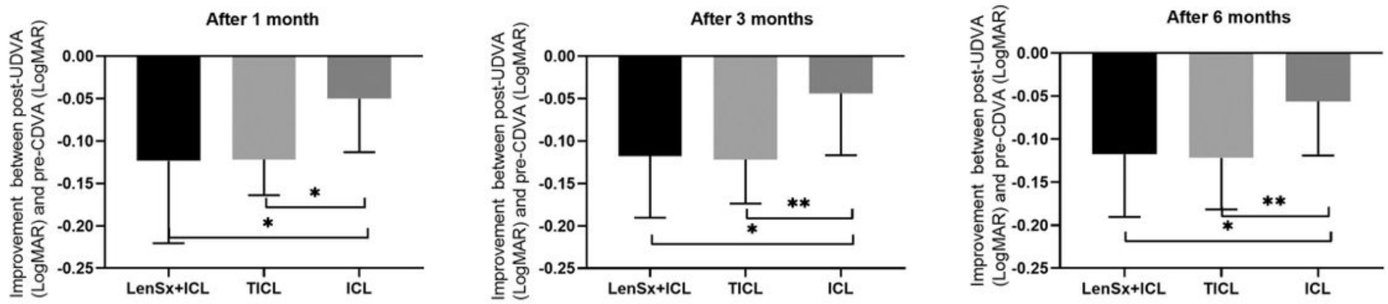

Figure 4

The improvement between postoperative LogMAR UDVA and preoperative LogMAR CDVA in three groups. (The results are expressed as the means ± SD, * means P<0.05, ** means P<0.01)

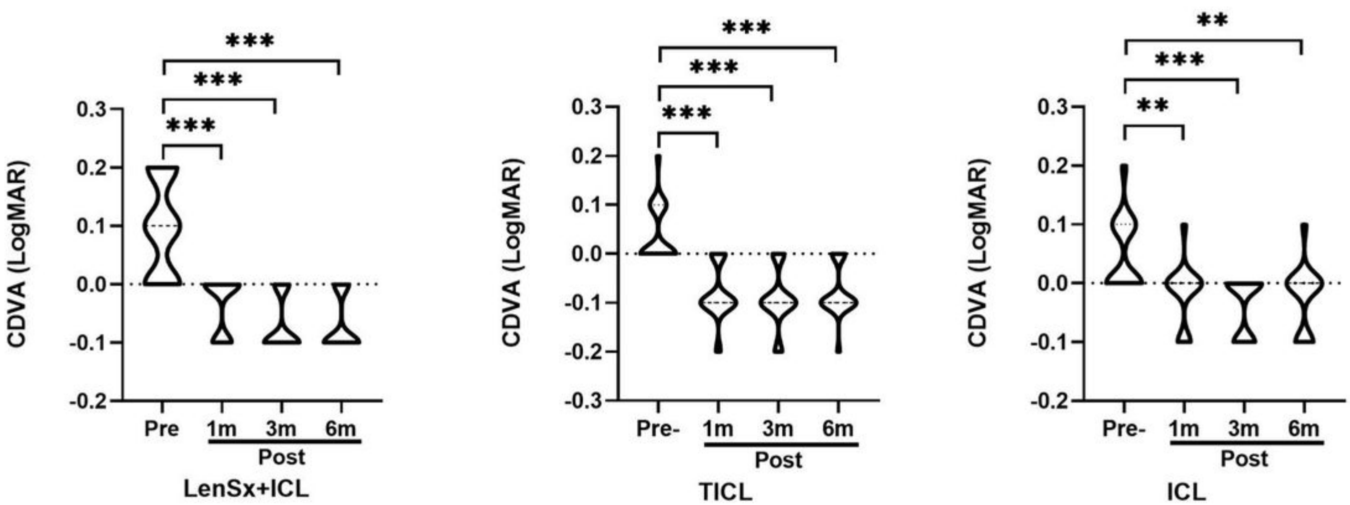

Figure 5

The LogMAR CDVA before and after surgery at 1, 3 and 6 months in three groups. (The results are expressed as the means ± SD, ** means P<0.01, *** means P<0.001)

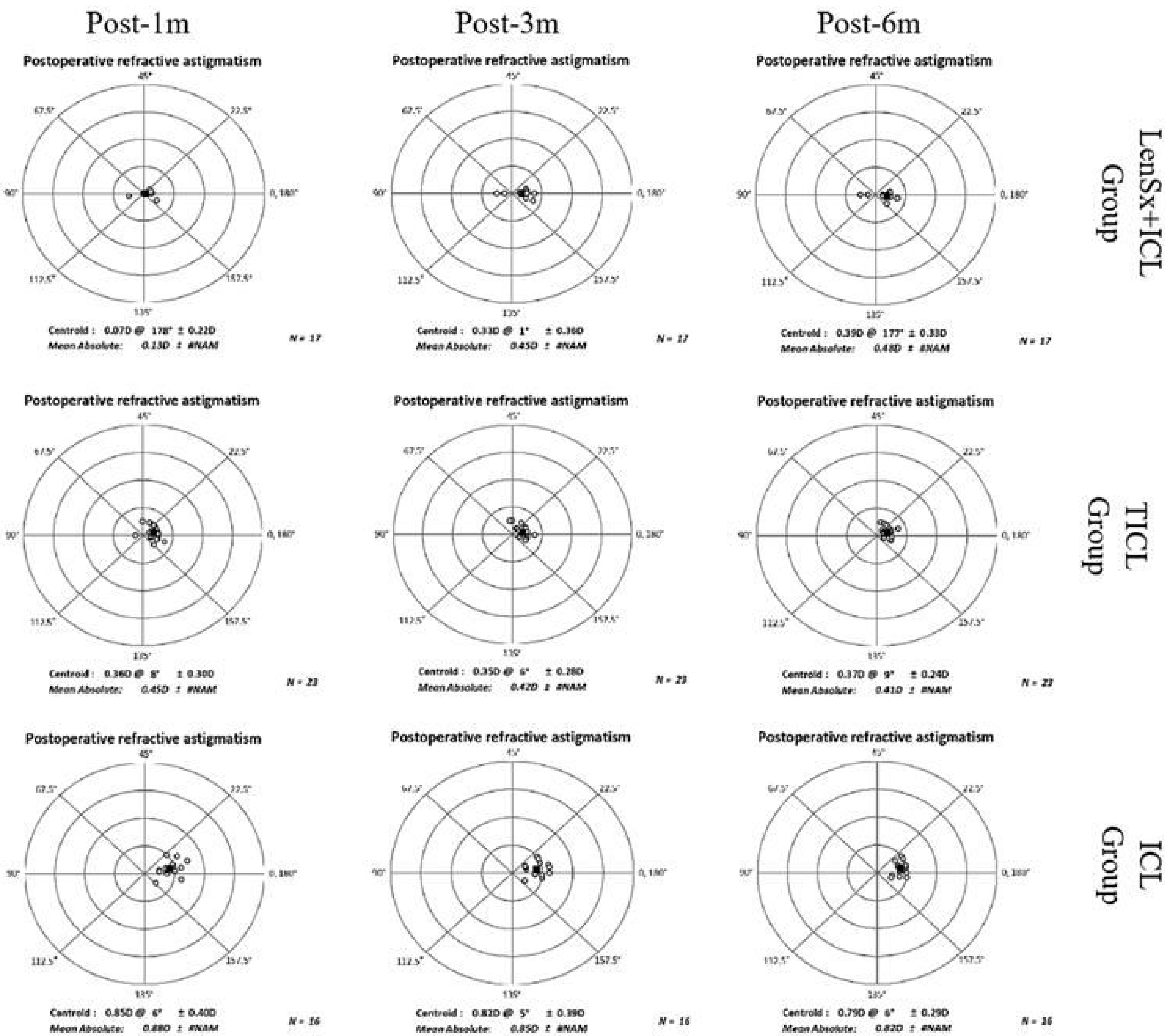

Figure 6

Double-angle plot vector analysis of postoperative residual astigmatism distribution in three groups at 1, 3 and 6 months. (The figure shows the LenSx+ICL group, TICL group and ICL group respectively, each ring = 1.00 D.)

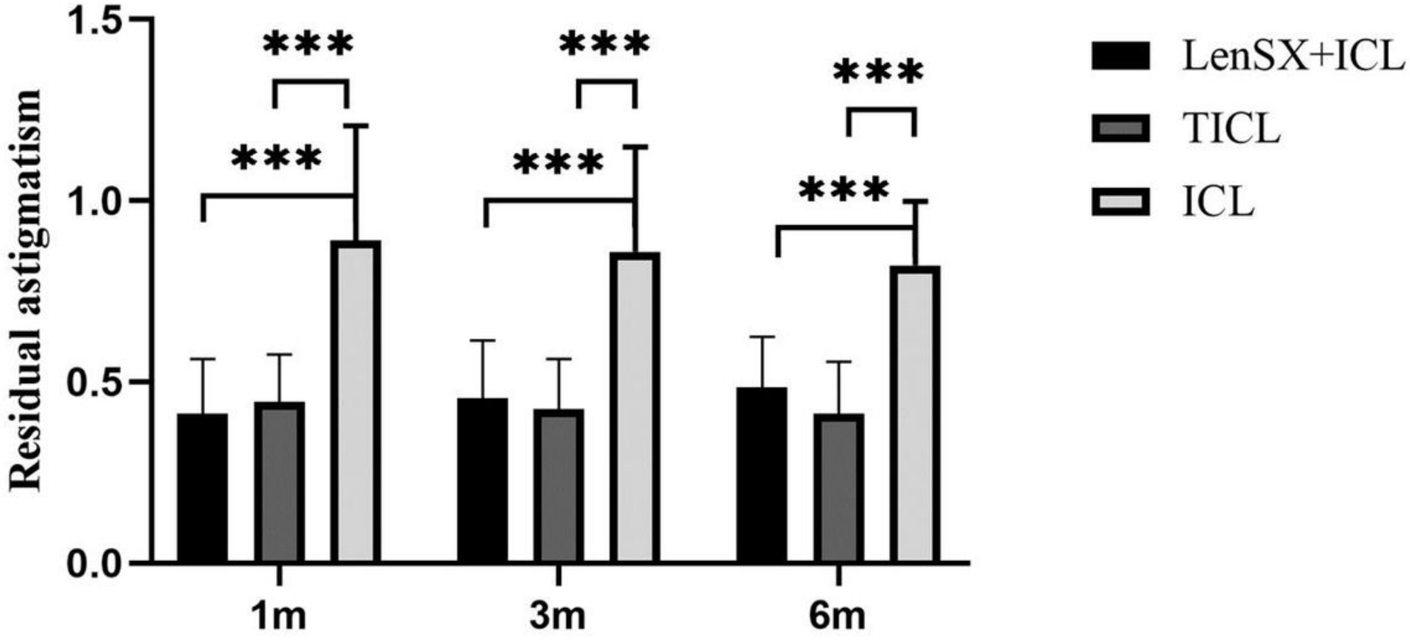

Figure 7

The comparison of postoperative residual astigmatism in three groups at 1, 3 and 6 months.(The results are expressed as the means ± SD, *** means P<0.001)

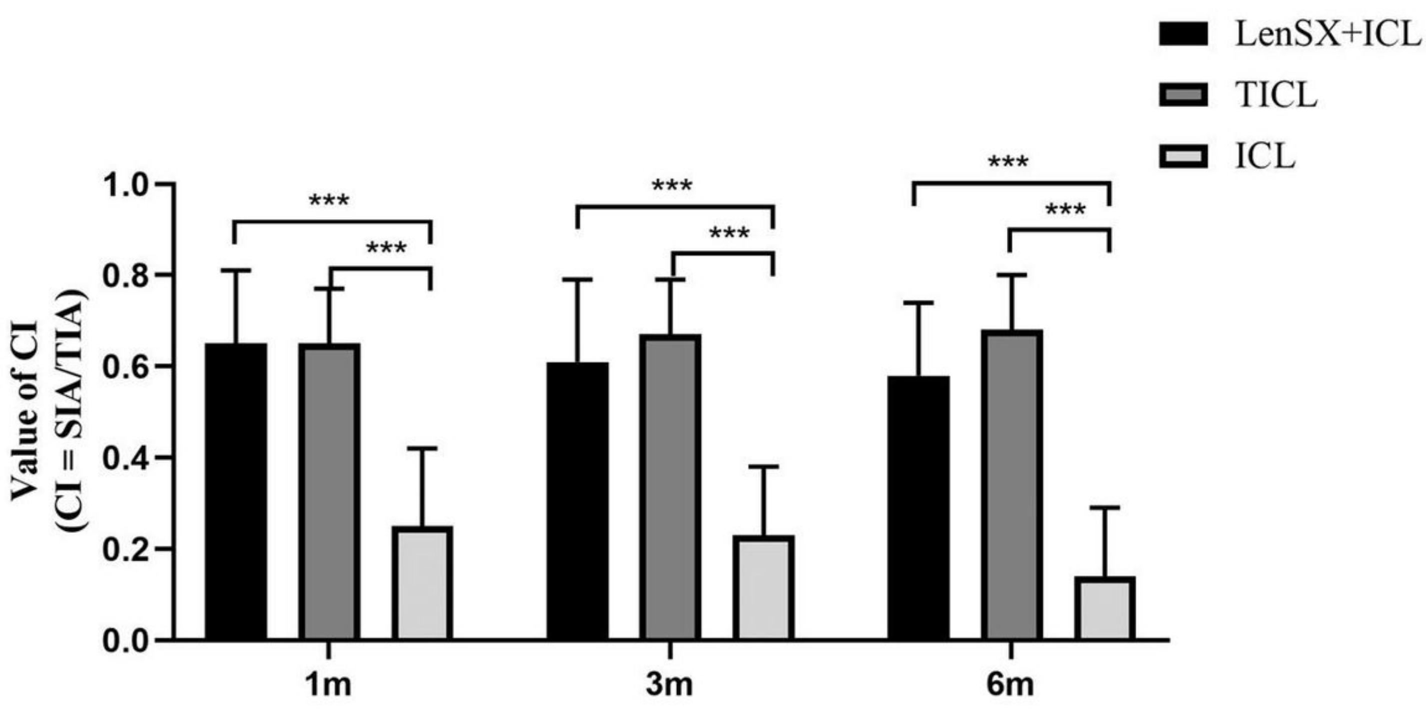

Figure 8

The comparison in astigmatism correction index among the three groups after surgery at 1, 3 and 6 months (The results are expressed as the means ± SD, *** means P<0.001)

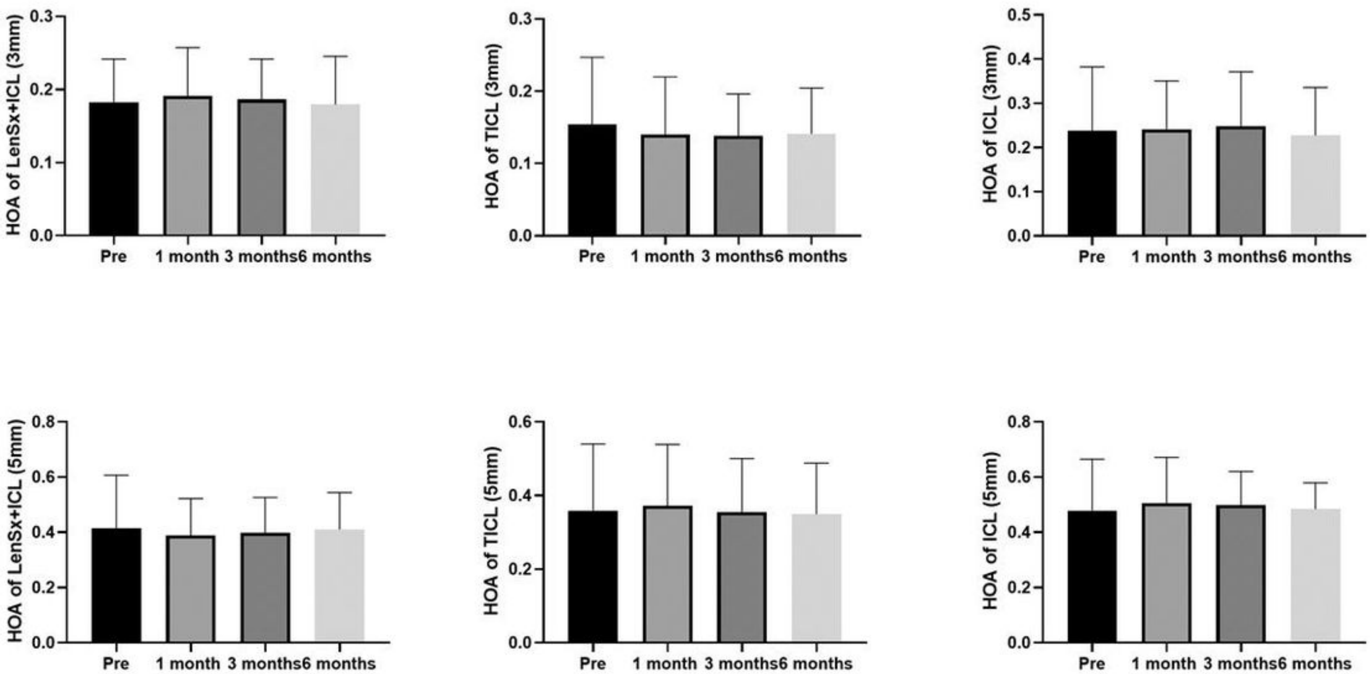

Figure 9

The total high order aberrations in the three groups before and after surgery at 1, 3 and 6 months. (The results are expressed as the means ± SD.)

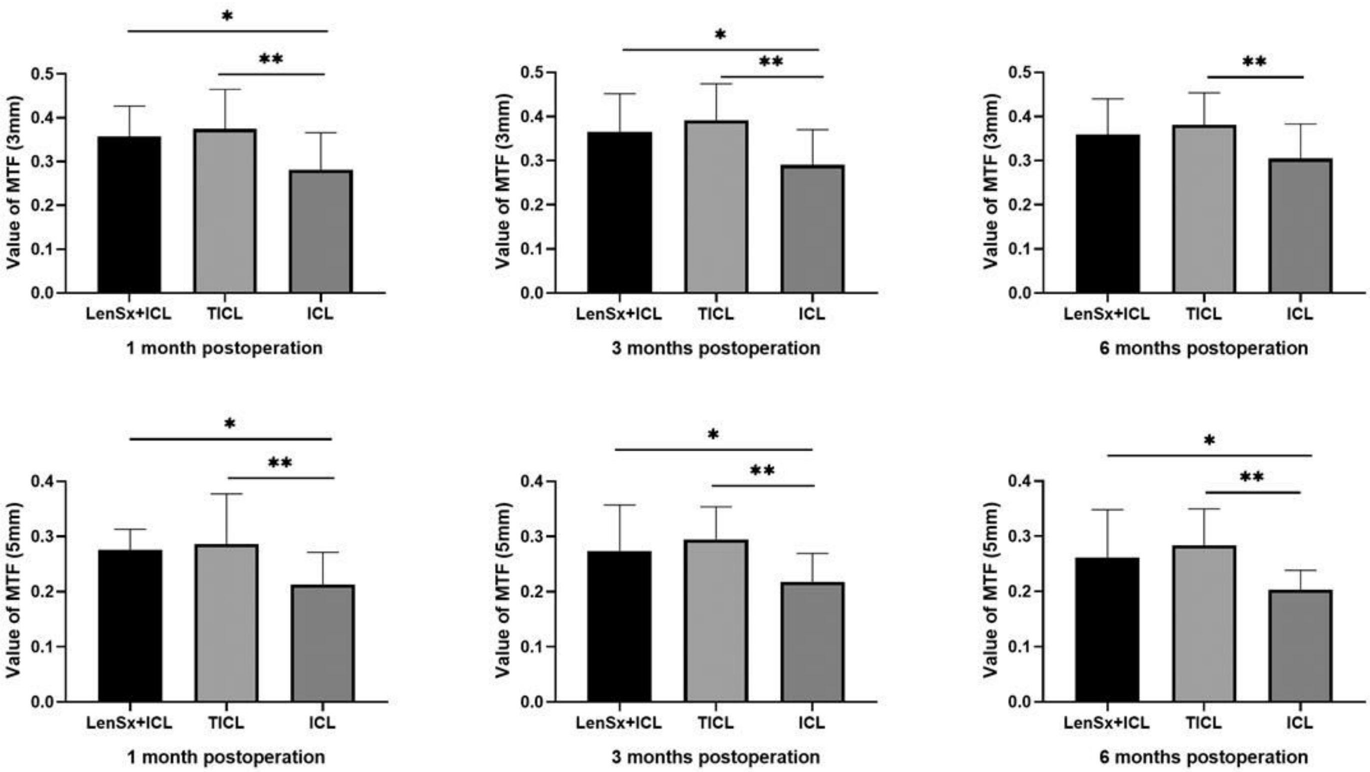

Figure 10

The comparison of modulation transfer function values among three groups after surgery at 1, 3 and 6 months at pupil diameters of 3mm and 5mm. (The results are expressed as the means ± SD, * means P<0.05, ** means P<0.01)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- statement.docx
- CONSORT2010Checklist.doc