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Original Article

CONTRAST SENSITIVITY AND HIGH ORDER ABERRATIONS AFTER FEMTOSECOND LASIK AND IMPLANTABLE COLLAMER LENSES IN CORRECTION OF HIGH MYOPIA

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Abstract
Purpose: *To compare visual quality (UCVA, BCVA, and contrast sensitivity) and optical quality (High order aberrations) of Femtosecond assisted LASIK and implantable collamer lens implantation in correction of high myopia.* ***Methods***: *This study was non-randomized comparative prospective consecutive interventional study. It included 31 eyes with high myopia (≥ -6 Ds) of 21 patients attended to the outpatient ophthalmic clinic of Sohag university hospitals from the period from Jan.2016 to Jan.2017. The patients were divided into two groups depending on: Degree of myopia, corneal thickness and corneal tomography. Group A (14 eyes) of 12 patients were subjected to implantable collamer lenses implantation and Group B (17 eyes) of 9 patients were subjected to femtosecond assisted LASIK.* ***Results***: *Postoperative data in both groups was, in Group A (ICL group) showed UCVA was (0.188±0.123) and UCVA of Group B (Femtosecond assisted LASIK) was (0.105±0.06) with (p-value <0.133). BCVA of Group one (ICL) was (0.171±0.114) and that of Group two was (0.105±0.04) with (p-value <0.174). Spherical error in Group A was (0.321± 0,590) and that of Group B (-0.75±0.31) postoperative with (p-value <0.001*). Cylindrical error was (-0.392±0.318) and Group two was (-0.750±0.204) with (p-value <0.00*). Spherical equivalent in Group A was (-0.00±0.433) and that of Group B was (-1.12±0.748) with (p-value <0.004*). Contrast sensitivity of Group A was (132.57±39.99) and that of Group B (102.857±23.688), with (p-value <0.075). There wasn't significant difference in RMS Group A (0.770±0.21) and that of Group B (1.15±0.53) with (p-value <0.22). There was significant difference in mean values of spherical aberrations of Group A (-0.13±0.9123), Group B (0.781±0.406) with (p-value <0.001*) , coma of Group A (0.131±0.0649), Group B (0.4600±0.2075) with (p-value <0.011*) and trefoil high order aberrations of Group A (-0.151±0.09), Group B (0.282±0.11) with (p-value <0.03* .* ***Conclusion***: *Both implantable collamer lens and femtosecond assisted LASIK proved good visual quality regarding visual acuity and contrast sensitivity in photopic conditions. For optical quality both induced high order aberrations which were more in Femtosecond assisted group.*

Keywords: *High myopia, Femtosecond, Excimer laser, Implantable collamer lens, contrast sensitivity, High order aberrations,*

1. Introduction
Phakic intraocular lenses (PIOLs) are an alternative treatment for ametropia correction among various refractive ranges. Fast visual recovery, high efficacy, pred-

ictability and stability of visual quality, preservation of accommodation, and reversibility are several advantages that have been attributed to PIOL implantation [1,2]. The Visian Implantable Collamer Lens (ICL; STAAR Surgical Co, Monrovia, California) is approved by the United States Food and Drug Administration (FDA). The lens material, trade-named Collamer, is a hydrophilic collagen-polymer combination with water content of 34% and a refractive index of 1.45 [1]. Femtosecond (FS) laser is an infrared laser with a wavelength of 1053nm. It works by producing photodisruption or photoionization of the optically transparent tissue such as the cornea [3]. Application of FS results in production of a rapidly expanding cloud of free electrons and ionized molecules. The acoustic shock wave generated results in disruption of the treated tissue [4]. FS laser has pulse duration in the femtosecond range (10-15 second). Reducing the pulse duration reduces the amount of collateral tissue damage makes FS laser safe to be used in corneal surgeries [5,6]. Flap creation using (FS), the suction ring is centered over the pupil and suction is applied once the proper centration of the ring has been ensured. The docking procedure is then initiated while keeping the suction ring parallel to the eye. Once the laser's computer has confirmed centration, the surgeon administers the FS laser treatment. Each pulse of the laser generates free electrons and ionized molecules leading to formation of microscopic gas bubbles dissipating into surrounding tissue. Multiple pulses are applied next to each other to create a cleavage plane and ultimately the LASIK flap. Suction is then released. A spatula is carefully passed across the flap starting at the hinge and sweeping inferiorly to lift the flap for Excimer laser ablation [4,7-9]. Contrast sensitivity provides additional information on the aspect of visual performance [10]. The amount of contrast a person needs to see a target is called contrast threshold. The detection threshold for a target is the lowest contrast threshold. Contrast sensitivity is simply the reci-procal of threshold. Thus, persons with low thresholds are said to have high sensitivity, and those with high thresholds have low sensitivity [11,12]. Contrast sens-itivity VS visual acuity, patients with normal visual acuity (VA) may complain of poor vision if CS is reduced. VA is a measurement of spatial resolution (ability to discern minimal stimulus size) when contrast is high and constant. Methods to measure contrast sensitivity, traditionally contrast sensitivity has been measured using electronically generated targets which are expensive, difficult to set up and calibrate, and often use time consuming psychometric methods. Therefore, they are unsuited to clinical practice. Over the last decade, a number of rapid and relatively inexpensive chart-based tests have been introduced with the aim of making contrast sensitivity a clinically viable technique [13]. There are numerous higher-order aberrations, third and fourth-order Zernike terms are coma, trefoil and spherical aberration which are of clinical interest. A perfect lens focuses rays to a point on the Optical axis [14]. In Spherical aberration peripheral rays are focused more tightly than central rays and the focus shifts anteriorly causing night (dim light) myopia which is commonly increased after myopic LASIK and surface ablation and resulting in halos around point images. In brighter conditions, the pupil constricts, blocking the more peripheral rays and minimizing the effect of spherical aberration. The increase in overall wave aberration with pupil size increases the second power of the pupil radius. This is due to the fact that most wave aberration is due to 2nd order aberrations, which have a square radius dependency [15]. The effect of spherical aberration increases as the fourth power of the pupil diameter. Doubling pupil diameter increases spherical aberration 16 times [16]. Thus, a small change in pupil size can cause a significant change in refraction. This should be considered in patients who have fluctuating vision despite well-healed corneas following keratorefractive surgery. Coma is the distortion in image formation occurring when a bundle of light rays enters an optical system not parallel to the optic axis. Coma results in off-axis point sources such as stars appearing distorted, with a comet-like tail [14]. The acuity test is effective for assessing normal human eyes; it is often inadequate in the clinical diagnosis of eyes with abnormal vision. First, when an eye cannot see 20/20 with the best correction lenses, the acuity test cannot specify the optical defects such as the high order aberrations. Second, if an eye can see 20/20 or better, the acuity test cannot account for visual symptoms such as ghost images and halos [17].

2. Methods

Twenty one individuals (14 eyes) subjected to implantable collamer lens implantation surgery and (17 eyes) subjected to femtosecond assisted Lasik surgery, aged 27-33 years who attended to the outpatient ophthalmic clinic of Sohag university hospitals from the period from Jan. 2016 to Jan. 2017.Group one (ICL) had Spherical refractive errors mean value (-9.65±1.359) with astigmatism (-1.07± 0.313). The patients had clear intraocular media and no known ocular pathology. Group two (Femto second assisted Lasik) had Spherical refractive errors mean value (-9.73±1.159) with astigmatism (-2.00± 1.302). The patients had clear intraocular media and no known ocular pathology. Contrast sensitivity was measured pre and postoperative in both groups with BCVA, as all of our patients in this study were have UCVA less than 20/20. CS assessment was measured using Cambridge low-contrast grating test (Clement Clarke, London, UK) at spatial frequency of 4 cpd, equal to acuity of 20/150. Each eye was first tested separately followed by binocular assessment. The test included 12 pairs of plates with luminance of 150 cd/m^2. The series of plate pairs were presented in descending cont-rast, and a forced choice procedures was used four times for each eye. The observer was told to choose whether the top or bottom plate contained the grating. The test score was determined by adding the number of pages for which an error occurred. CS was determined using a conversion table. High order aberrations were evaluated by Scheimpflug-placido topographer using the corneal map analysis system (Sirus CSO, Florence, Italy) on all eyes before and after surgeries. The tenets of the declaration of Helsinki were followed. Informed consent was obtained from each participant after verbal and written explanations of the nature and possible consequences of the study were provided. The study protocol received institutional review board approval.

3. Intraocular Lens

The Visian ICL is a plate-haptic single-piece intraocular lens, which is a flexible. It can be folded and implanted in the posterior chamber via a 2.8-3.2 mm corneal incision. It has a high degree of biocompatibility, good permeability of gases and metabolites, and good absorption of ultraviolet radiation. The ICL design has been modified many times in the past. In this study, the phakic IOL patients were ICL V4c lens designs. The ICL V4c is a 6.00 mm wide lens and comes in four sizes (12.1, 12.6, 13.2 and 13.7 mm in length). Its optic zone diameter is 4.9-5.8 mm, with a spherical power range of -0.50 to -18.00 DS and a cylindrical power range of +0.50 to +6.00 DC. ICL power calculations were performed by the manufacturer (STAAR Surgical) using a modified vertex formula. The variables in the formula included preoperative manifest spherical and cycloplegic refractions, keratometric power, central corneal thickness and central ACD (ACD, Pentacam, measured from the corneal endothelium to the anterior lens). The size (length) of the implanted ICL was determined based on the patient's WTW and ACD. For the ICL V4c, the sizes (lengths) of 12.1, 12.6, 13.2 and 13.7 mm were equal to the ICL V4 sizes (lengths) of 11.5, 12.0, 12.5 and 13.0 mm, respectively [18].

3.1. *Femtosecond LASIK in high myopia*

One of the concerns in the application of LASIK for highly myopic patients is the risk of post-LASIK ectasia 41.42 which is believed to be reduced using femt-osecond laser (femto-LASIK) and the ability of creation of smaller flap thickness. Less higher order aberrations (HOAs) are induced with femto-LASIK compared to the conventional approach [19]. Although concerns are not resolved completely, especially in cases with larger pupil diameters [20], results in terms of contrast sensitivity, especially in high spatial frequencies, are better with femto-LASIK compared to the conventional method [21, 22].

3.2. *Statistical analysis*

Statistical analysis was performed using SPSS version 16 (IBM, USA). An independent samples t-test was used to compare mean values of measured parameters. Pearson's correlation coefficient was used to evaluate the correlation between quantitative variables.

4. Results

Preoperative data in both groups was, in Group one (ICL group) showed UCVA was (1.891±0.255) and UCVA of Group two (Femtosecond assisted LASIK) was (1.69±0.13) with (p-value <0.087). BCVA of Group one (ICL) was (0.491±0.318) and that of Group two was (0.335±0.162) with (p-value <0.318). Spherical error in Group one was (-9.65± 1.359) and that of Group two (-9.73± 1.159) with (p-value <0.902). Group one cylindrical error was (-1.07± 0.313) and Group two was (-2.00±1.302) with (p-value <0.165). Spherical equiv-alent in Group one was (-10.00±0.972) and that of Group two was (-10.73± 0.920) with (p-value <0.936). Contrast sensitivity of Group one was (68.857± 37.38) and that of Group two (40.571± 26.89), with (p-value <0.165). There was significant difference in mean values of spherical aberration of Group one (0.0943± 0.090), Group two (0.127±0.128) with (p-value <0.002**) and coma high order aberrations of Group one (0.111±0.0362), Group two (0.167±0.048), with (p-value <0.038*) which were higher in group two (Femto second assisted Lasik). Postoperative data in both groups was, in Group one (ICL group) showed UCVA was (0.188±0.123) and UCVA of Group two (Femtosecond assisted LASIK) was (0.105± 0.06) with (p-value <0.133). BCVA of Group one (ICL) was (0.171±0.114) and that of Group two was (0.105±0.04) with (p-value <0.174). Spherical error in Group one was (0.321±0,590) and that of Group two (-0.75±0.31) postoperative with (p-value <0.001*). Cylindrical error was (-0.392±0.318) and Group two was (-0.750± 0.204) with (p-value <0.00*).Spherical equivalent in Group one was (-0.00±0.433) and that of Group two was (-1.12± 0.748) with (p-value <0.004*). Contrast sensitivity of Group one was (132.57±39.99) and that of Group two (102.857±23.688), with (p-value <0.075). There wasn't significant difference in RMS Group one (0.770±0.21) and that of Group two (1.15±0.53) with (p-value <0.22). There was significant difference in mean values of spherical aberrations of Group one (-0.13±0.9123), Group two (0.781±0.406) with (p-value <0.001*), coma of Group one (0.131± 0.0649), Group two (0.4600±0.2075) with (p-value <0.011*) and trefoil high order aberrations of Group one (-0.151±0.09), Group two (0.282±0.11) with (p-value <0.03*). In the study, contrast sensitivity correlated to high order aberrations. Contrast sensitivity was moderately negative correlated to RMS postoperative in group B (p-value<0.018*). Contrast sensitivity was moderately negative correlated to spherical aberration postoperative in group B (p-value<0.014*).

Table (1) Group A is ICL group; group B is Femto-Lasik group pre-operative data.

	Group A (ICL) (n=14)	Group B (Femto-Lasik) (n=17)	P-value
UCVA	1.891(±0.255)	1.69(±0.13)	**0.087**
BCVA	0.4918(±0.318)	0.335(±0.1625)	**0.318**
Spherical error	-9.65(±1.359)	-9.73(±1.159)	**0.902**
Cylindrical error	-1.071(±0.313)	-2.00(± 1.302)	**0.165**
Spherical equivalent	-10.00(±0.972)	-10.73(±0.920)	**0.936**
Average K	43.627(±0.973)	42.870(±0.444)	**0.085**
RMS	0.215(±0.996)	0.300(±0.073)	**0.073**
Spherical aberrations	0.0943(±0.090)	0.127(±0.128)	**0.002****
Coma	0.111(±0.0362)	0.167(±0.048)	**0.038***
Trefoil	0.087(±0.02)	0.137(±0.068)	**0.173**
Contrast sensitivity	**68.8571(±47.38)**	**40.571(±26.893)**	**0.165**

Table (2) Group A is ICL group; group B is Femto-Lasik group post operative data

	Group A(ICL) (n=14)	Group B (Femto-Lasik) (n=17)	P-value
UCVA	1.891(±0.255)	1.69(±0.13)	**0.087**
BCVA	0.4918(±0.318)	0.335(±0.1625)	**0.318**
Spherical error	-9.65(±1.359)	-9.73(±1.159)	**0.902**
Cylindrical error	-1.071(±0.313)	-2.00(± 1.302)	**0.165**
Spherical equivalent	-10.00(±0.972)	-10.73(±0.920)	**0.936**
RMS	0.215(±0.996)	0.300(±0.073)	**0.073**
Spherical aberrations	0.0943(±0.090)	0.127(±0.128)	**0.002****
Coma	0.111(±0.0362)	0.167(±0.048)	**0.038***
Trefoil	0.087(±0.02)	0.137(±0.068)	**0.173**
Contrast sensitivity	**68.8571(±47.38)**	**40.571(±26.893)**	**0.165**

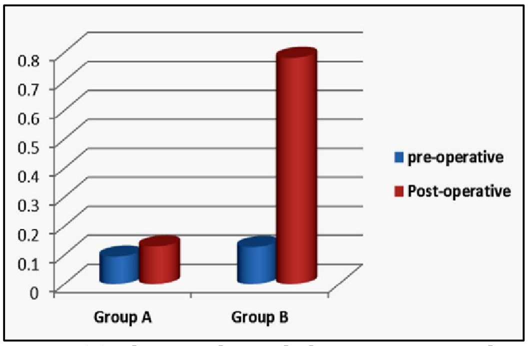

Figure (1) Shows spherical aberrations in study groups

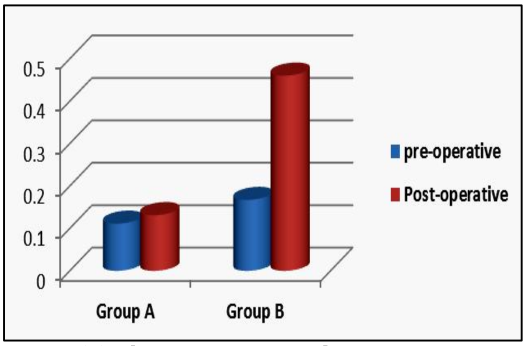

Figure (2) Shows coma in study groups

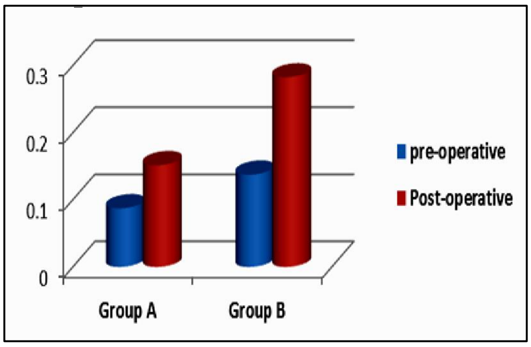

Figure (3) Shows trefoil in study groups

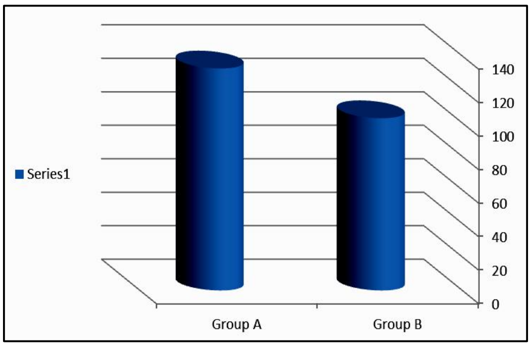

Figure (4) Contrast sensitivity in both groups

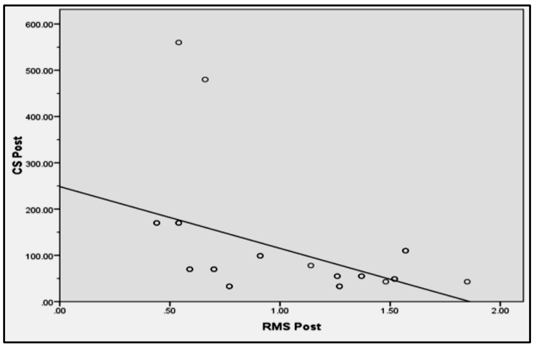

Figure (5) Shows correlation between contrast sensitivity and RMS in group B

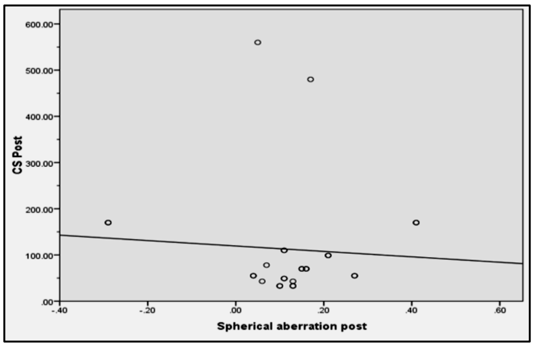

Figure (6) Shows correlation between contrast sensitivity and spherical aberrations in group B

5. Discussion

The aim of this study was to evaluate the visual outcomes of femtosecond LASIK in comparison with implantable collamer lenses for correction of high myopia regarding visual acuity, high order aberrations and contrast sensitivity. The patients were divided into two groups. The group A was subjected to implantable collamer lenses implantation and the s group B subjected to femtosecond assisted LASIK. Excimer laser surgeries proved effectiveness for myopia correction, but they have complications such as myopic regression and ectasia which were reported in eyes with high myopia [23,24]. Correction of high myopia is associated with increased HOAs [25]. It is proved that Phakic IOL implantation has predictability in correction of high myopia [26,27]. Implantation of PIOL can induce complications such as cataract, lens dislocation and elevation of intraocular pressure. Therefore, assessing visual and outcomes of PIOL is helpful when selecting the more appropriate, safe, stable and effective procedure to correct high myopia, especially when the patients have an overlapping range of both procedures [28]. Visual quality of both groups showed significant improvement of UCVA, BCVA with insignificant difference on comparing both groups. Both groups showed high safety and efficacy indices as there weren't significant changes in postoperative UCVA and BCVA. Follow up period extended for one year and showed significant difference in Spherical error, cylindrical error and spherical equivalent. Spherical equivalent of ICL group mean value was (0.0000±0.433) and that of the Femtosecond assisted group (-1.12±0.748) with ($p<0.004^*$) this data is consistent with Cari perez-vives et al [29]. The above mentioned changes of spherical equivalent of manifest refraction equal or more than (1.00D) in an interval of 6 months is known as stability. The study showed better stability for ICL implantation than that of Femtosecond assisted LASIK for the same refractive error range. There wasn't significant difference in contrast sensitivity for both groups postoperative for photopic vision (well-lit room).This finding is supported by other studies as by Chandhrasri & Knorz [30]. We didn't measure CS in mesopic condition as our used CS test (Cambridge low contrast test) depends on measures in well-lit room with application of BCVA. Optical quality showed increased spherical aberration, coma and trefoil like HOAs significantly postoperative in Femtosecond assisted group than that of the ICL group. These results are consistent with that of Ferial M. Al-Zeriad and Uchechukwu L. Osuagwu who studied induced HOAs after LASIK performed with wave front-guided intralase femtosecond laser in moderate to high astigmatism [31]. Both groups showed high efficacy and safety, but group A (ICL) showed more stability during the follow up period than group B (Femtosecond Lasik). These finding were consistent with that of Chen et, al. who studied contralateral eye comparison of the long-term visual quality and stability between implantable collamer lens and laser refractive surgery for myopia. Their study conducted on 52 eyes of 26 high-myopia anisometropia patients who were suitable for surgical treatment. In each patient, the higher-myopia eye was implanted with ICL and the lower-myopia eye was treated with LRS. The patients were followed for 3 years [32]. Group B postoperative showed that RMS and spherical aberration had significant negative moderate correlation to contrast sensitivity, which is strongly matched to the HOA changes found postoperative in the femtosecond assisted LASIK group [33]. These findings were consistent with Youn Shin Joo who compared changes in ocular higher order aberrations (HOAs) after Visian Implantable Collamer Lens implantation and wave front-guided laser epithelial keratomileusis to correct high myopia. His study included 30 eyes (18 patients) that underwent ICL implantation (ICL group) and 33 eyes (18 patients) who are followed for 3 months after surgery. He studied contrast sensitivity both in photopic and mesopic conditions; whereas this study evaluated only contrast sensitivity in photopic condition. In summary both ICL implantation and femtosecond LASIK provided good visual quality regarding visual acuity and contrast sensitivity in photopic conditions. For optical quality both groups showed changes of HOAs which was more in femtosecond LASIK assisted group. ICL implantation had better visual and optical quality for high myopic patients.

6. Conclusion

Both implantable collamer lens and Femtosecond assisted LASIK proved good visual quality regarding visual acuity and contrast sensitivity in photopic conditions. For optical quality both induced high order aberrations which were more in Femtosecond assisted group. ICL implantation had better visual and optical quality for high myopic patients

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