Refractive and Visual Outcomes of Surgical Treatments for High Myopia

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ABSTRACT

Objective: To present the refractive and visual outcomes of refractive surgical treatment options in high myopia.

Methods: This was a retrospective review of patients diagnosed with high myopia (manifest refractive spherical equivalent [MRSE] ≥-6.00D) who underwent one of the following procedures: laser-in-situ keratomileusis (LASIK), photorefractive keratectomy (PRK), phakic IOL implantation with the Staar Implantable Collamer Lens (ICL), or Alcon Cachet Phakic IOL. Eyes with best corrected distance vision of less than 20/30 due to amblyopia or other eye pathologies were excluded.

Results: This study evaluated 145 eyes of 77 patients: 86 eyes underwent LASIK, 37 eyes PRK, 16 eyes implanted with the ICL, and 6 eyes with Cachet lens. Preoperatively, the mean MRSE was -7.44D, -7.71D, -9.82D, and -12.08D for the LASIK, PRK, ICL, and Cachet groups respectively. At 1 year postoperatively, the mean MRSE was -0.22D, +0.23D, -0.40D, and -0.28D, respectively. The mean uncorrected distance vision (UDVA) at 1 year follow-up was 20/20 in the LASIK and PRK groups, 20/25 in the ICL and 20/30 in the Cachet, while the best corrected distance vision (BDVA) was 20/20 in all groups. An increase in spherical aberration (SA) and total higher-order aberration (HOA) was observed in LASIK (SA p=0.00; HOA p=0.00) and PRK (SA p=0.00; HOA p=0.00) but not in the ICL (SA p=0.11; HOA p=0.69) and Cachet (SA p=0.95; HOA p=0.25) groups.

Conclusion: The four refractive treatment options were effective at reducing the myopic refractive error and achieving good uncorrected distance vision. Laser refractive treatments caused an increase in spherical and higher order aberrations not seen in the phakic IOL treatments.

Key words: Laser-in-situ Keratomileusis (LASIK), Photorefractive Keratectomy (PRK), Implantable Collamer Lens (ICL), Acrysof Cachet Phakic IOL, High Myopia

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Uncorrected refractive errors are the main cause of visual impairment worldwide. In Asia, there appears to be a trend towards an increase in the prevalence of high myopia (over -6.0 D). Taiwan population studies showed the prevalence of high myopia to be as much as 18% among young men and 24% among young women[1]. In Singapore, approximately 10% of adults have high myopia compared to less than 2% in most Western populations[2]. Unfortunately, the prevalence of high myopia in the Philippines is not fully recognized since there is no national registry for this condition.

Treatment for myopic eyes have been well established with the advent of various surgical modalities, the most popular of which are laser-in-situ keratomileusis (LASIK) and photorefractive keratectomy (PRK). Choosing the appropriate treatment modality for low to moderate myopia is easy given the proven efficacy, stability, and safety of LASIK and PRK.[3-6] However, for high myopic treatments, because of the large amount of corneal tissue to be removed, LASIK may predispose patients to corneal ectasia[7], PRK may induce scar formation, and corneal refractive surgery, in general, may cause regression and induction of higher-order aberrations which eventually affect visual outcome and quality of vision.

With the advent of newer technologies and the development of more biocompatible materials, intraocular lens (IOL) insertion, particularly phakic IOL implantation, is gaining popularity in the field of refractive surgery. Implantation of phakic IOLs is a reversible procedure that can correct spherical refractive errors and astigmatism while preserving both corneal tissue as well as the natural lens.

The Visian Implantable Collamer Lens (ICL, Staar Surgical) is a plate-haptic posterior chamber implant that is inserted behind the iris and in front of the natural crystalline lens. The sulcus location keeps it away from the corneal endothelium decreasing the risk of corneal decompensation. Once inserted, the Visian ICL is hardly visible to the naked eye because of its location behind the iris.[8]

The Acrysof Cachet (Alcon Laboratories Inc., Fort Worth, TX) is an angle-supported phakic IOL designed for implantation into the anterior chamber angle. Since it is placed in front of the iris, it reduces the risks associated with elevated eye pressures and cataract development commonly associated with implantable contact lenses placed behind the iris.[9]

Reports on older models of phakic IOLs have shown these lenses to be associated with long-term endothelial cell loss and cataract formation. However, newer designs and materials make it an attractive method for refractive correction since it allows preservation of accommodation and the normal physiologic corneal contour and thickness.[9,10]

The choice of refractive treatment depends on many criteria, such as the degree of myopia, corneal thickness, anterior chamber depth, angle structure, as well as a number of individual factors. The surgeon must be aware of the inclusion and exclusion criteria as well as the risks and benefits associated with each of the various alternatives. We are presenting our experience and reporting the refractive and visual outcomes of high myopia patients who underwent refractive correction in our institution.

METHODS

The data of all patients diagnosed with high myopia with or without astigmatism (manifest refractive spherical equivalent (MRSE) of ≥-6.0 D), who underwent laser refractive surgery (LASIK or PRK) during the period of January 2009 to August 2012 and implantation of a phakic IOL (Acrysof Cachet IOL or Staar Visian Implantable Collamer Lens) from the period of January 2010 to August 2012 with a minimum followup of 1 month were retrospectively reviewed. Uncorrected and best corrected distance vision, manifest refraction, spherical aberration, and higher-order aberration were analyzed per treatment group.

Pre-operative Screening

Patients were instructed to discontinue soft contact lenses for one week or rigid contact lenses for three weeks prior to screening. All patients had a detailed ocular examination, including uncorrected (UDVA) and best-corrected distance visual acuity (BDVA), topography, aberrometry, pupillometry, pachymetry, specular microscopy, intraocular pressure (IOP) measurement, Schirmer's test, slit lamp examination to rule out lenticular opacity, and cycloplegic refraction. A dilated examination was,

likewise, performed to detect any retinal lesion or optic nerve pathology.

Patients found to have eye pathologies in the cornea, lens, optic nerve, or retina were disqualified from any refractive procedure. Patients with amblyopia defined as BDVA of less than 20/30 were still allowed to undergo refractive surgery but their data were excluded from analysis in this study.

Treatment Selection

During counselling by the surgeon, patients were informed of the screening results and a treatment plan was discussed. The Zyoptix Treatment Planner (Technolas Perfect Vision, Munich, Germany) was utilized to compute the excimer laser ablation depth and residual corneal bed thickness under a 120um corneal flap. If the estimated residual bed thickness was higher than 280um, LASIK was the recommended procedure. If the bed thickness was less than 280um, PRK was allowed if the residual total corneal thickness with the epithelium on was at least 360um (300um residual bed and 60um epithelium). For the phakic IOL option, if the patient had astigmatism greater than 1.0D, a toric ICL was advised as long as the anterior chamber depth (ACD) measurement from the Orbscan II (Technolas Perfect Vision, Munich, Germany) was greater than 2.8mm. If the patient had less than 1.0D of astigmatism, a Cachet lens was considered if the ACD from the IOLMaster (Carl Zeiss AG, Germany) was at least 3.2mm, the endothelial cell count was greater than 2,800 cells/ mm^2, and the myopic spherical error was between -6.0 to -16.0D since the Cachet had only these IOL powers available. Otherwise, a non-toric ICL was selected.

Whether patients fit the criteria for either LASIK or PRK, the phakic IOL option was discussed for the high myopes and the patient was asked to choose which procedure they prefer after a complete and thorough explanation of the advantages, disadvantages, risks, benefits, and alternatives of each procedure. An informed consent was secured prior to surgery. LASIK was found to be the first choice of most patients if they qualified. All surgeries were performed by one surgeon (RTA).

Surgical Techniques

LASIK

A 120um superior hinged flap was created using a femtosecond laser (520F, Technolas, Munich, Germany) or an XP microkeratome (Technolas, Munich, Germany). Wavefront-guided ablation was performed using 217Z100 excimer laser (Technolas, Munich, Germany). Iris registration and an active eye tracker were used to ensure centration, cyclotorsion compensation, and accurate ablation. The optical zone size was 6.5-6.8 mm. After ablation, the flaps were floated into place and dried.

PRK

A 6.0 semi-sharp optical zone marker was used to create a groove in the corneal epithelium. Several drops of diluted ethyl alcohol (20%) was instilled inside a 7.0 mm optical zone marker that served as a well. After 30 seconds, the alcohol was removed with a sponge and the epithelium was peeled to a diameter of 6.5mm using a microhoe. Wavefront-guided excimer laser ablation was performed using the 217Z100 excimer laser (Technolas, Munich, Germany). A circular sponge soaked in Mitomycin C 0.02% was placed over the ablated area for 30 seconds after the laser procedure and washed off with 30cc of balanced salt solution. A bandage contact lens was placed on each treated eye which was removed at the one week follow-up.

ICL Phakic IOL Implantation

A few days before ICL implantation, patients underwent yag laser iridotomies to prevent pupillary block glaucoma and postoperative IOP rise. On the day of surgery, eyes were instilled with 1 drop of tropicamide-phenylephrine solution (SanMyd, Santen, Osaka, Japan) for 3 times until the pupils were fully dilated. For toric lens implantation, on the slit lamp, ink marks were placed at 3:00, 6:00 and 9:00 position for orientation. After sedation, a toric marker was used to mark the axis for alignment of the lens. Paracentesis incisions were created at 12:00 or 6:00 and non-preserved lidocaine and hydroxypropyl methylcellulose viscoelastic solution (Ocucoat, Bausch and Lomb, Aliso Viejo, CA, USA) were injected into the anterior chamber. A 3.2mm temporal clear corneal incision was made and the ICL was implanted into the anterior chamber. The corner footplates were tucked under the iris on top of the crystalline lens one by one using a modified spatula. The ICL toric marks were aligned to the axis reference marks made on the limbus. Viscoelastic solution was flushed out of the anterior chamber using balanced salt solution after which intracameral diluted carbachol (Miostat, Alcon

Laboratories, Fort Worth, Texas, USA) was injected to constrict the pupil.

Cachet Phakic IOL Implantation

Prior to surgery, eyes were instilled with 1 drop of pilocarpine 2% every 10 minutes for a total of 3 times before the procedure to constrict the pupils. After sedation, paracentesis incisions were made at 12:00 or 6:00 through which non-preserved lidocaine and sodium hyaluronate viscoelastic solution (Provisc, Alcon Laboratories, Fort Worth, Texas, USA) were injected into the anterior chamber. A 2.6mm temporal clear corneal incision was made and the Cachet was gradually inserted into the anterior chamber above the iris. The viscoelastic was removed via continuous irrigation of balanced salt solution using a 21G cannula.

Postoperative Course

Postoperative medications for each procedure included topical levofloxacin (Oftaquix, Santen, Osaka, Japan), prednisolone acetate 0.1% (Pred Forte, Allergan, Irvine, CA, USA) and ketorolac (Acular, Allergan, Irvine, CA, USA) four times daily until the bottles were consumed. For phakic IOL implantations, brimonidine (Alphagan, Allergan, Irvine, CA, USA) was added at a dose of 1 drop twice a day for two weeks. Artificial tears were begun a few days after surgery.

Postoperative examinations were performed at days 1 and 7; 1, 3, 6, and 12 months and every 6 months thereafter. In all visits, manifest refraction, uncorrected and best-corrected distance visual acuity, intraocular pressure and slit lamp examinations were done. Specular microscopy was performed on phakic IOL-implanted eyes at every 6 month visit.

Outcomes

Outcomes were analyzed based on effectiveness (UDVA and MRSE achieved), predictability (percentage of eyes with MRSE ± 0.5D and 1.0D), safety (gain or loss of lines of BDVA vision), and spherical and higher-order aberration change from pre- to final postoperative visit. Visual acuities were converted to logMAR values and the means and standard deviations were back-calculated to Snellen acuity.

Statistical Analysis

Data was analyzed using SPSS for Windows statistical software (version 16.01 SPSS, Inc.). Comparison of means was by t-test for independent samples at a 95% confidence level. Differences were considered statistically significant when the p value was less than or equal to 0.05.

RESULTS

This study evaluated 145 eyes of 77 patients with high myopia who underwent refractive surgery. In this study population, 86 eyes of 47 patients underwent LASIK, 37 eyes of 19 patients underwent PRK, 16 eyes of 8 patients were implanted with ICL, and 6 eyes of 3 patients were implanted with Cachet lens. The mean age was 33.21 years ± 9.69 (SD) for all participants. One year data was available in 55 eyes of 30 patients, of which 29 eyes belonged to LASIK, 14 eyes to PRK, 8 eyes to ICL , and 4 eyes to Cachet groups (Table 1).

Table 1. Patient demographics and preoperative refractive error.

	TOTAL	LASIK	PRK	STAAR ICL	CACHET
Patients	77	47	19	8	3
Eyes (At entry)	145	86	37	16	6
Eyes (Completed 1 yr)	55	29	14	8	4
Sex					
Male	30	20	5	5	0
Female	47	27	14	3	3
Age (y) Mean ± SD	33.29±9.69	35.11±10.03	30.74±9.79	32.63±7.52	27.67±7.64
Sphere (D) Mean ± SD	-7.32±1.92	-6.98±1.12	-6.87±1.45	-8.84±2.12	-11.75±3.58
Cylinder (D) Mean ± SD	-1.24±0.99	-0.95±0.63	-1.68±1.22	-2.08±1.25	-0.80±0.41
SE (D) Mean ± SD	-7.94±1.9	-7.45±1.08	-7.71±1.34	-9.82±2.05	-12.08±3.45

ICL = Implantable Collamer Lens; LASIK = laser-in-situ keratomileusis; PRK = photorefractive keratectomy; SE = spherical equivalent

EFFICACY

Sphere

Preoperatively, the mean sphere was -6.97D in the LASIK, -6.87D in the PRK, -8.84D in the ICL, and -11.75D in the Cachet groups. At 1 year, the mean sphere improved to -0.01D in the LASIK, +0.42D in the PRK, -0.12D in the ICL, and +0.25D in the Cachet groups (Table 2).

Table 2. Mean manifest refraction spherical equivalent.

	LASIK	PRK	STAAR ICL	CACHET
Sphere (D)				
Preoperative	-6.8±1.12 (n=86)	-6.87±1.45 (n=37)	-8.84±2.12 (n=16)	-11.75±3.58 (n=6)
1 week	0.13±0.34 (n=84)	0.58±0.82 (n=12)	0.31±0.28 (n=16)	0.08±0.83 (n=6)
1 month	0.16±0.39 (n=80)	0.20±0.64 (n=35)	0.33±0.33 (n=16)	0.29±0.56 (n=6)
6 months	0.06±0.34 (n=44)	0.25±0.60 (n=23)	0.02±0.29 (n=12)	0.19±0.75 (n=4)
1 year	-0.01±0.31 (n=29)	0.43±0.66 (n=14)	-0.13±0.30 (n=8)	0.25±0.68 (n=4)
Cylinder (D)				
Preoperative	-0.95±0.63	-1.68±1.22	-2.08±1.25	-0.80±0.41
1 week	-0.45±0.39	-0.71±0.48	-0.78±0.40	-0.88±0.57
1 month	-0.54±0.32	-0.44±0.35	-0.93±0.47	-0.75±0.50
6 months	-0.49±0.32	-0.41±0.35	-0.79±0.40	-1.06±0.13
1 year	-0.44±0.27	-0.39±0.25	-0.55±0.20	-1.06±0.13
SE (D)				
Preoperative	-7.45±1.08	-7.71±1.34	-9.82±2.05	-12.08±3.45
1 week	-0.10±0.34	0.23±0.79	-0.08±0.33	-0.33±0.79
1 month	-0.11±0.39	-0.02±0.68	-0.06±0.31	-0.15±0.53
6 months	-0.19±0.35	0.04±0.54	-0.38±0.32	-0.34±0.69
1 year	-0.23±0.32	0.23±0.58	-0.40±0.33	-0.28±0.62

Cylinder

The preoperative cylinder was -0.94D in the LASIK, -1.68D in the PRK, -2.08D in the ICL, and -0.80D in the Cachet groups. At one year postoperative follow-up, mean cylinder was -0.44D in the LASIK, -0.39D in the PRK, -0.55D in the ICL and -1.06D in the Cachet groups (Table 2).

Spherical Equivalent

The mean manifest refraction spherical equivalent (MRSE) improved from -7.44D to -0.22D in the LASIK, from -7.71D to +0.23D in the PRK, from -9.82D to -0.40D in the ICL, and from -12.08D to -0.28D in the Cachet groups (Table 2).

Visual Acuity

There was a significant improvement in UDVA in all groups. At 1 year postoperatively, mean UDVA was 20/20 for LASIK and PRK, 20/25 for ICL, and 20/32 for the Cachet groups. BDVA from preoperative to 1 year postoperative visit was maintained at 20/20 in the LASIK, PRK, and ICL groups, and improved from 20/25 to 20/20 in the Cachet group (Table 3).

Table 3. Mean UDVA and BDVA. Values in logMAR (Snellen).

	LASIK	PRK	STAAR ICL	CACHET
UDVA				
Preoperative	>1.5 (20/630)	>1.5 (20/630)	>1.5 (20/630)	>1.5 (20/630)
1 week	0.063 (20/25) ±0.090	0.213 (20/32) ±0.150	0.063 (20/25) ±0.150	0.067 (20/25) ±0.080
1 month	0.035 (20/20) ±0.080	0.083 (20/25) ±0.142	0.019 (20/20) ±0.834	0.100 (20/25) ±0.110
6 months	0.034 (20/20) ±0.064	0.039 (20/20) ±0.099	0.033 (20/20) ±0.107	0.175 (20/32) ±0.096
1 year	0.028 (20/20) ±0.060	0.043 (20/20) ±0.085	0.075 (20/25) ±0.120	0.150 (20/32) ±0.057
BDVA				
Preoperative	0.041 (20/20) ±0.110	0.035 (20/20) ±0.116	0.105 (20/20) ±0.254	0.133 (20/25) ±0.082
1 week	0.024 (20/20) ±0.056	0.083 (20/25) ±0.119	0.013 (20/20) ±0.050	0.017 (20/20) ±0.041
1 month	0.003 (20/20) ±0.024	0.046 (20/20) ±0.104	0.000 (20/20) ±0.037	0.000 (20/20) ±0.089
6 months	0.005 (20/20) ±0.021	0.000 (20/20) ±0.043	-0.008 (20/20) ±0.051	0.025 (20/20) ±0.050
1 year	-0.003 (20/20) ±0.033	0.000 (20/20) ±0.000	0.013 (20/20) ±0.035	0.000 (20/20) ±0.000

PREDICTABILITY

At 1 year postoperatively, 26 out of 29 eyes (89.7%) from the LASIK group were within ± 0.5D and 28 eyes (96.6%) within ± 1.0D MRSE. For the PRK group, 10 out of 14 eyes (71.4%) were within ± 0.5D and 12 eyes (85.7%) within ± 1.0D MRSE. For the ICL, 7 out of 8 eyes (87.5%) were within ± 0.5D, and 1 eye was beyond 1.0D MRSE. For the Cachet, 2 of 4 eyes (50%) were within ± 0.5D, and 4 eyes (100%) were within ± 1.0D MRSE (Table 4).

Table 4. Achieved manifest spherical equivalent.

1 WEEK POSTOPERATIVELY		
	± 0.5 D	**± 1.0 D**
LASIK (n = 84)	88.1%	100%
PRK (n = 12)	58.3%	83.3%
STAAR ICL (n = 16)	93.8%	100%
CACHET (n = 6)	66.7%	83.3%
1 MONTH POSTOPERATIVELY		
	± 0.5 D	**± 1.0 D**
LASIK (n = 80)	82.5%	97.5%
PRK (n = 35)	65.7%	91.4%
STAAR ICL (n = 16)	93.8%	100%
CACHET (n = 6)	66.7%	100%
6 MONTHS POSTOPERATIVELY		
	± 0.5 D	**± 1.0 D**
LASIK (n = 44)	90.9%	97.7%
PRK (n = 23)	87.0%	91.3%
STAAR ICL (n = 12)	75.0%	100%
CACHET (n = 4)	50.0%	100%
1 YEAR POSTOPERATIVELY		
	± 0.5 D	**± 1.0 D**
LASIK (n = 29)	89.7%	96.6%
PRK (n = 14)	71.4%	85.7%
STAAR ICL (n = 8)	87.5%	87.5%
CACHET (n = 4)	50.0%	100%

STABILITY

No significant regression was observed in MRSE values from 1 month to 1 year. UDVA and BDVA remained stable from 1 month to 1 year (Figures 1a-c).

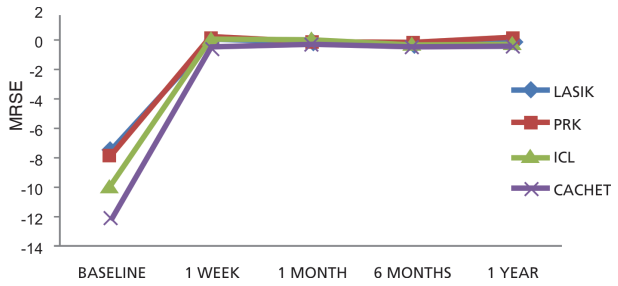

Figure 1a. Time course of MRSE after refractive surgery.

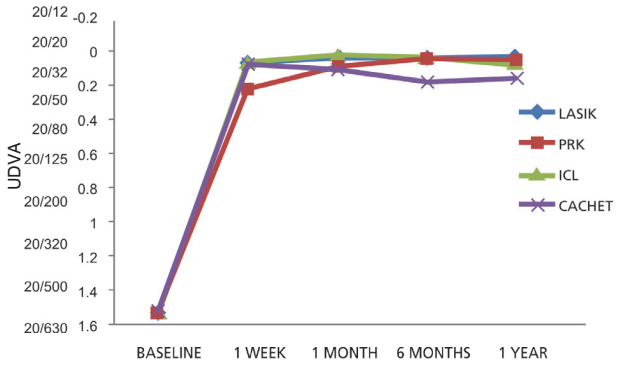

Figure 1b. Time course of UDVA after refractive surgery.

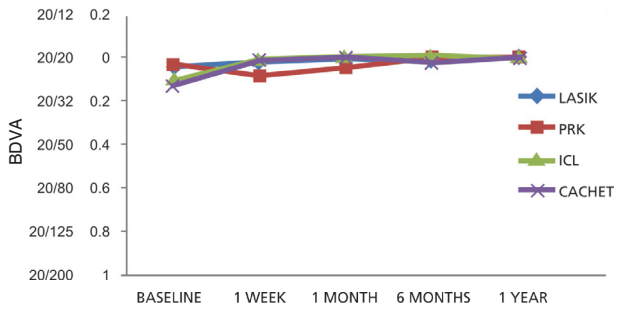

Figure 1c. Time course of BDVA after refractive surgery.

SAFETY

At 1 year postoperatively, no eye lost 2 or more lines of BDVA. One eye in the LASIK group lost 1 line of BDVA (Figure 2).

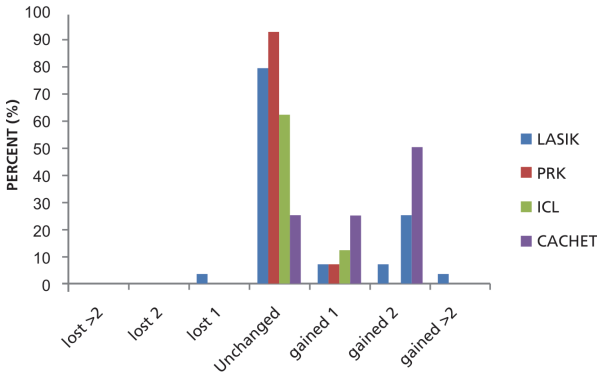

Figure 2. Postoperative changes in BDVA at 1 year.

IOP AND ENDOTHELIAL CELL COUNT

The intraocular pressure remained within normal limits in the ICL group (14.88mm Hg) and Cachet group (15.00mm Hg) at the 1 year follow up. The endothelial cell count was lower by 2% from preoperative to one year postoperatively in both the ICL (from 3001.83 to 2924.25 cells/mm^2) and the Cachet (from 3135.75 to 3049.25 cells/mm^2) groups.

ABERRATION

Spherical and total higher-order aberrations significantly increased in the LASIK (SA p=0.00, HOA p=0.00) and PRK (SA p=0.00, HOA p=0.00) groups and were unchanged in the ICL (SA p=0.11, HOA p=0.69) and Cachet (SA p=0.95, HOA p=0.25) groups (Table 5).

Table 5. Spherical and higher-order aberrations.

Spherical Aberration	preop	1 month	6 months	1 year	p value (preop vs 1 year)
LASIK	-0.174	-0.400	-0.412	-0.382	0.000
PRK	-0.155	-0.286	-0.376	-0.199	0.000
STAAR	-0.188	0.003	-0.013	0	0.110
CACHET	-0.127	-0.020	0.315	-0.013	0.950
Higher-order Aberration	preop	1 month	6 months	1 year	p value (preop vs 1 year)
LASIK	0.476	0.672	0.834	0.631	0.000
PRK	0.488	0.783	0.828	1.208	0.000
STAAR	0.760	0.435	0.535	0.643	0.690
CACHET	0.410	0.380	0.420	0.652	0.250

DISCUSSION

Performing refractive surgery on high myopes is challenging because there are many parameters and surgical options to consider which by themselves have specific criteria for usage. Patients may qualify for multiple procedures or one specific procedure only. It is important to be aware of the inclusion and exclusion criteria for best outcomes, as well as the risks and benefits of each procedure. To be viable, a treatment strategy must be effective, safe, stable, and predictable. Evaluating these parameters was how we approached our analysis of outcomes in this retrospective review. Although this study did not prospectively compare the four different treatment strategies, it presented our experience and outcomes when treating patients presenting with manifest refraction spherical equivalent of ≥-6.00 D.

Patient selection is an integral part of the decision-making, specifically which treatment to recommend and perform. In our practice, if the estimated residual bed thickness after laser ablation was at least 280um underneath a 120um corneal flap, we would recommend LASIK. If it is less than 280um, we would re-compute and if the estimated postoperative total corneal thickness was at least 360 um (60um epithelium plus 300um residual bed), then we would recommend PRK. Higher refractive errors will entail more corneal tissue removal. Therefore, there is an increasing tendency for patients with high refractive errors not to qualify for LASIK or PRK. An ICL or a Cachet phakic IOL does not depend on corneal thickness and was always discussed as an option for the high myopia patient as long as the anterior chamber depth was 2.8mm for the ICL or 3.2mm for the Cachet and the specular microscopy tests show an endothelial cell count of at least 2,800 cells/mm^2. However, the cost differential is substantial enough for patients to preferentially choose LASIK or PRK unless they were not qualified.

We evaluated the efficacy of the treatments by analyzing the achieved refractive outcomes and uncorrected distance visual acuity. Evaluating efficacy overlaps with stability since the latter demonstrated changes in vision and refraction over the follow-up period. Despite the high myopia, MRSE were near emmetropic in all treatment groups up to the final follow-up. The mean postoperative UDVA were better than 20/30 for all groups and were consistent with the achieved improvement in refractive outcome. These outcomes suggested that LASIK, PRK, ICL and Cachet IOLs were all effective in the refractive treatment of high myopia.

In terms of stability, LASIK studies have shown that visual recovery was rapid but there might be a tendency towards under correction or a myopic refraction long term due to regression.[3,4] For PRK, reports by Fazel, which evaluated the long term outcomes of PRK in high myopes (>7.0 D), have shown that regression was observed despite single or double application of mitomycin C (MMC).[11] Phakic IOLs would not be expected to have any regression effects because these treatments do not involve significant corneal wound healing. There was no significant regression observed in MRSE values in all treatment arms from 1 month to 1 year. The BDVA and UDVA were, likewise, stable in all groups until 1 year although the ICL group demonstrated a slight decrease in UDVA from 20/20 at 6 months to 20/25 at 1 year, while the Cachet decreased from 20/25 at 1 month to 20/32 at 6 months and 1 year. Perhaps a longer follow-up period and a bigger population are necessary to produce more conclusive data on stability.

The success of refractive surgery depends on how accurately and consistently we can achieve a target refraction. The 4 treatment arms showed good predictability with majority of eyes achieving an MRSE close to plano target refraction at 1 year, with only 1 eye in the LASIK, 2 in the PRK, and 1 in the ICL groups attaining an MRSE value outside ± 1.00D. All eyes in the Cachet group achieved a refractive error within ± 1.00D.

All four treatment options in our study were considered safe because best-corrected distance vision (BDVA) did not deteriorate and complications after surgery were almost none. In terms of BDVA, majority of eyes remained unchanged or gained lines of vision from their preoperative to 1 year postoperative visit. No eye lost more than 2 lines of BDVA and only 1 eye in the LASIK group lost 1 line at 1 year. The intraocular pressures for both phakic IOLs were within normal at 1 year postoperatively and only a 2% decrease in endothelial cell count was observed. There was also no incidence of cataract formation, uveitis, or glaucoma. In a study by Kohnen,[12] wherein different types of phakic IOLs were reviewed, intraocular pressure rise was not a common finding after phakic lens implantation, although eyes that displayed pigment dispersion was

kept under close observation. An endothelial cell loss of 5.2% to 5.6% at 1 year was common and was mostly attributed to intraoperative trauma. This rate of loss, which usually declines at 2 years onwards, may be due to the presence of an implanted phakic IOL or natural endothelial cell loss, which is projected to be around 0.5% annually in the normal population[12]. We performed a specular microscopy yearly and if endothelial cell loss deteriorated aggressively, patients were informed that the phakic IOL may need to be removed.

This study supported the findings that laser refractive surgery induces more total HOAs and spherical aberration than phakic IOL implantation[3,12,13]. Throughout the follow-up visits, we observed a significant increase in both spherical and total HOA values compared to preoperative for the LASIK and PRK groups, while the ICL and Cachet groups did not change significantly. The likely reason was that myopic laser refractive procedures induce a change in corneal asphericity, shifting from prolate to oblate shape of the cornea, with higher refractive errors associated with greater induction of spherical aberration and HOA.[13] The presence of spherical and HOA in post refractive surgery cases is important to surgeons since these can significantly reduce the quality of vision of patients.[14,15].

In conclusion, for highly myopic eyes, LASIK, PRK, ICL, and Cachet displayed adequate efficacy in achieving a near-plano target refraction with good UDVA of at least 20/30, as well as stability in refraction and vision over the one year follow-up. All four groups were predictable and reliable. All groups showed a good safety profile with minimal lines of BDVA lost and no intraoperative and postoperative vision-threatening complications.

One of the limitations of our study was that our subject population was small and unevenly distributed. This was the reality in a retrospective study and in a private practice setting wherein surgical volumes were the result of patient choice. We would have preferred a prospective study with a larger population which we randomly distribute among the treatment groups so we can statistically compare the effectiveness of the treatments. Quality of vision tests, such as low contrast vision and contrast sensitivity, are, likewise, recommended to demonstrate the advantages of phakic IOLs rather than being relegated as a last-resort option if patients do not qualify for a corneal laser refractive procedure.

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