CORRELATION OF VISUAL RECOVERY TIME AFTER LASER REFRACTIVE SURGERY WITH PREOPERATIVE KERATOMETRY AND ASTIGMATISM AMONG MYOPIC ASTIGMATISM PATIENTS

AHMAD NURFAHMI AKHTAR ALI, MMed (Ophthal)
DEPARTMENT OF OPHTHALMOLOGY, KULLIYYAH OF MEDICINE, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, 25200 KUANTAN, PAHANG, MALAYSIA.
drfahmiophthal@gmail.com

MD MUZIMAN SYAH MD MUSTAFA, PhD
DEPARTMENT OF OPTOMETRY AND VISUAL SCIENCE,
KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, 25200 KUANTAN, PAHANG, MALAYSIA.
syah@iium.edu.my

FADZILAH HANIM RAHIM, MBBS
DEPARTMENT OF OPHTHALMOLOGY, IIUM MEDICAL CENTRE, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, 25200 KUANTAN, PAHANG, MALAYSIA.
drfadzilahanim@gmail.com

Nadhirah Ahmad Fauzi, MBBS
DEPARTMENT OF OPHTHALMOLOGY, IIUM MEDICAL CENTRE, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, 25200 KUANTAN, PAHANG, MALAYSIA.
nadhirahfauzi@iium.edu.my

KHAIRIDZAN MOHD KAMAL, MS Ophthal (CORRESPONDING AUTHOR)
DEPARTMENT OF OPHTHALMOLOGY, KULLIYYAH OF MEDICINE, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, 25200 KUANTAN, PAHANG, MALAYSIA.
khairidzan@iium.edu.my

MOHD RADZI HILMI, PhD
DEPARTMENT OF OPTOMETRY AND VISUAL SCIENCE,
KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, 25200 KUANTAN, PAHANG, MALAYSIA.
mohdradzihilmi@iium.edu.my

ABSTRACT

Introduction: Photorefractive keratometry (PRK) and laser in situ keratomileusis (LASIK) are among the many types of laser refractive surgery available for the correction of myopic astigmatism. The outcome of the procedure can be affected by several parameters which include patient's age, optical zone diameter, epithelial hyperplasia, preoperative keratometry as well as astigmatism. **Aim:** This study aimed to determine the relationship between preoperative keratometry and astigmatism with visual recovery time after laser refractive surgery. **Methods:** Records of 174 eyes (174 patients) with myopic astigmatism who had been treated with either LASIK (71 eyes) or PRK (103 eyes) at IIUM Eye Specialist Clinic from January 2015 to June 2018, were retrospectively analyzed. Main outcome measure was the time taken for patients to achieve visual acuity (VA) 6/6 (equivalent to 0.00 LogMAR) postoperatively. Value for keratometry parameter was taken from corneal topography while astigmatism magnitude was taken from manifest refraction. Their correlation with visual recovery time was analyzed using Pearson correlation coefficient (PCC). $P < 0.05$ was considered as statistically significant. **Results:** The mean preoperative astigmatism and mean keratometry was 0.9 ±0.76D and 43.65 ±1.23D respectively. A significant but weak positive correlation between preoperative astigmatism and visual recovery time was observed (P-value = 0.013; R = 0.188), while no correlation observed for mean keratometry (P-value = 0.305; R = 0.078). **Conclusions:** Preoperative astigmatism influenced the visual recovery time post laser refractive surgery in myopic astigmatism patients, but not keratometry.

Keywords: myopic astigmatism, laser refractive surgery, manifest astigmatism, mean keratometry, visual recovery time

INTRODUCTION

The basic principle behind laser refractive surgery is that, by modifying corneal curvature, the optical power of the eye can be changed (Tuan & Chernyak, 2006). Since the last two decades, there was a dramatic advancement introduced by new technologies in the field of laser refractive surgery (Reinstein, Archer & Gobbe, 2012). Despite many types of laser refractive surgery, this study specifically focused on photorefractive keratometry (PRK) and laser in situ keratomileusis (LASIK) performed for the correction of myopic astigmatism. Although LASIK has been shown to be safe and effective for the treatment of myopia (Maldonado-Bas & Onnis, 1998), bigger outcome variability has been reported in eyes with higher degrees of myopia (Pérez-Santonja et al., 1997). Previously, many factors have been investigated to find those that possibly influenced the outcome and predictability of LASIK which include patient's age, optical zone diameter (Ditzen, Huschka & Pieger, 1998), epithelial hyperplasia (Lohmann & Güell, 1998), preoperative keratometry (K)(Pérez-Santonja et al., 1997) as well as astigmatism (Feng & Wang, 2011). Despite of these entire possible influencing factors, keratometry and astigmatism are the two parameters of interest in our study.

Keratometry is measurement of the radius of anterior corneal curvature which lies within the optical spherical zone of cornea (Hilmi et al., 2019). While in this study, K parameter is taken from corneal topography (simulated K), it can also be calculated manually (manual K). Manual K reading is the standard method of assessing corneal curvature in clinical practice. Based on study by Rah et al, (2002) no significant difference reported for the baseline keratometry readings between manual and simulated keratometry with both Dicon and Humphrey Atlas corneal topography systems (Marjorie et al., 2002). Hence, this concluded that the measurement can be used interchangeably. It is questionable whether preoperative K influences the outcome in myopic patients treated with PRK and LASIK, as findings among literatures are contradictory. Christiansen et. al reported moderately myopic eyes with flatter cornea (K =39.9D to 42.0D) were significantly associated with better visual outcome post LASIK than those with steeper cornea (K =46.0 to 47.2) (Christiansen et al., 2012). On the contrary, Mostafa (2015) and Rao et al. (2001) reported preoperative flatter cornea (K< 43.5D) tend to have greater under correction in all myopic group.

Astigmatism is known as a vector variable which has its own axis based on the orientation (Freitas et al., 2016). Ocular astigmatism regulated by manifest refraction comprises of the sum of anterior corneal astigmatism and non-anterior corneal astigmatism (Qian et al., 2015). Analysis of corneal astigmatism must be precise and complete to be accounted into a vector character (Freitas et al., 2016). The existence of refractive surgery aimed to achieve zero astigmatism or manifest astigmatism. However, there are some factors influencing manifest astigmatism including position and features of lens, differences between visual and pupillary axis, toricity of corneal surface, retina and visual perception (Qian et al., 2015).

To date, no study has analyzed the relationship between preoperative clinical characteristics with visual recovery time. Hence, in this retrospective cohort study, we aimed to analyze the correlation between preoperative parameters (keratometry, manifest astigmatism, manifest spherical equivalent and sphere) on visual recovery time which is defined as the time taken for the patient to achieve the intended visual acuity (6/6 or equivalent to 0.00 LogMAR).

MATERIALS AND METHODS

Patients' population

This is a retrospective cohort study conducted at IIUM Eye Specialist Clinic, Kuantan campus. This study included patients who underwent PRK and LASIK for the correction of compound myopic astigmatism from January 2015 to June 2018. The inclusion criteria included patients aged 18 to 50 years old, patients with compound myopic astigmatism and those who had successfully achieved 6/6 visual acuity (0.00 LogMAR) by six months' postoperative period. Those patients with ocular pathology, prior history of ocular surgery, intraoperative complications and eyes with re-treatment were excluded from the study. By using a purposive sampling, a total of 174 patients (174 eyes) were recruited to be the sample of the study. Out of these numbers, 103 eyes had undergone PRK while the remaining 71 eyes had undergone LASIK. The sample size had been calculated using Raosoft software by referring to a study done in Canada by Pop and Payette (1998) as the reference.

All study procedures were adhered to the tenets of the Declaration of Helsinki and Malaysia Personal Data Protection Act 2010. The study was approved by the International Islamic University Malaysia Research Ethical Committee (ID: IREC 2017-024).

Record review

Patients' sociodemographic including clinical characteristics of preoperative and intraoperative data were taken from patients' records. Before surgery, patients had been assessed by Visante Omni using ATLAS™ 9000 Corneal Topographer (Carl Zeiss Meditec, Jena, Germany) for corneal topography and ATLAS™ 9000 Corneal Topographer (Visante™ Carl Zeiss Meditec, Jena, Germany) for anterior segment optical coherence topography. Hence, topographic parameters (topographic patterns, steep K, flat K, mean K, astigmatism, pachymetry and posterior elevation) were documented via these procedures.

We controlled possible bias at each stage of the study by doing age-matched and choosing only one right eye as long as it is within the inclusion criteria. On the other hand, during data collection phase, double entry method had been used to minimize human error. In addition, the procedures in the refractive surgery involved the same surgeon, same machine operator and same medications were given to the patients postoperatively. 174 patients with spherical equivalent refraction from -2.25 D to -12.25 D, astigmatism less than -4.00 D and BCVA of 0.00 LogMAR were selected in this study.

Postoperative data including uncorrected distance visual acuity (UDVA) using LogMAR, intraocular pressure (IOP) and complete eyes examinations were done at one day, one week, one month, three months and six months after surgery.

Surgical procedures

All procedures were done by a single experienced surgeon. The surgical procedures were performed under topical anaesthesia; three drops of proparacaine hydrochloride 0.5% (Alcaine, Alcon-Couvreur, Puur, Belgium). In PRK, a circular corneal marker was used to define a central zone ranging from 5.50 mm to 7.0 mm centered over the pupil. A surgical sponge was used for brief application (15 seconds) of 20% alcohol, followed by immediate wiping with a wet sponge. Subsequently, the central epithelium was removed with a blunt knife (hockey stick). The formula for pupil centration was calculated using software CIPTA (Corneal interactive programmed topography ablation). Following MEL-80 G-scan flying spot excimer laser (Meditec-Aesclepion, Jena, Germany) treatment, one drop of fluorometholone acetate 0.1% (Flarex, Alcon, Texas, USA) and one drop of moxifloxacin hydrochloride ophthalmic solution 0.5% (Vigamox, Alcon, Texas, USA) were given. Bandage contact lens (Alcon: Air Optix Night & Day Aqua) were applied and removed at day four postoperatively. The postoperative treatment consisted of fluorometholone acetate 0.1% (Flarex, Alcon, Texas, USA), nepafenac ophthalmic suspension 0.1% (Nevanac, Alcon, Texas, USA), preservative-free hyaluronic acid artificial tears (Systane Ultra, Alcon, Texas, USA) and oral paracetamol or celebrex.

LASIK was performed using standard protocol. Nasal hinged lamellar flap was created with a Hansatome Microkeratome (Amadeus®; Ziemer Ophthalmic Systems AG) with thickness of 160 µm and size of 8.1 mm ring. Laser ablation was performed using the Advanced Surface Ablation, MEL 80 Carl Zeiss Meditec, creating a 6.0-6.5 mm of treatment zone**.** Following ablation, the flap was reflected back onto the treated stromal bed. The patients then received the same postoperative medications as patients who underwent PRK procedures.

Statistical analysis

All the data were imported to SPSS software (version 21.0; SPSS, Inc.) of Windows for statistical analysis. The analysis of skewness and kurtosis were performed to visualize normality of data distribution. Pearson correlation coefficient (PCC) was used to study association between preoperative clinical characteristics and visual recovery time. P-value of < 0.05 was considered as statistically significant.

RESULTS

Table 1 shows the sociodemographic characteristics of patients treated with laser refractive surgery (PRK and LASIK). The mean age of patient is 33.5 years old (SD of 7 years old) in which the value is comparable between both LASIK and PRK patients. Majority of them are female patients which comprises 54% of total patients. In both types of surgery, female patients also contribute to more than half of total patients. Besides, 94.3% of total patients are Malays which are the most dominant ethnic group who underwent treatment with both LASIK and PRK surgery. In addition, most of them (54%) have professional occupational background which contributes to 49.5% of total PRK patients and 60.6% of total LASIK patients.

Table 1. Sociodemographic features of patients treated with PRK and LASIK surgery

Sociodemographic Features		Overall		PRK		LASIK		P value
		N	%	N	%	N	%	
Age		174	33.49 (7.34)*	103	33.65 (6.81)*	71	33.25 (7.72)*	0.727
Gender	Male	80	46	46	44.7	34	47.9	0.675
	Female	94	54	57	55.3	37	52.1	
Ethnic	Malay	164	94.3	98	95.1	66	93	0.372
	Chinese	6	3.4	2	1.9	4	5.6	
	Indian	2	1.1	2	1.9	0	0	
	Others	2	1.1	1	1.0	1	1.4	
Occupation	Student	25	14.4	14	13.6	11	15.5	0.278
	Professional	94	54	51	49.5	43	60.6	
	Supporting staff	46	26.4	31	30.1	15	21.1	
	Unemployed	4	2.3	4	3.9	0	0	
	Housewife	5	2.9	3	2.9	2	2.8	

*mean (SD)

Table 2 describes the preoperative clinical characteristic including the diagnostic and intraoperative parameters of patients treated with laser refractive surgery. The median BCVA is 0.00 ± 0.1 LogMAR while the mean preoperative IOP is 15.32 ± 2.3 mmHg. Other than that, the mean for flat and steep keratometry are 43.04 ± 1.27 D and 44.27 ± 1.32 D respectively. The average manifest refraction (spherical equivalent) of the sample is 4.39, ranging from 0.38 to 12.25 while the mean preoperative cylinder (astigmatism magnitude) is 0.75 D. Meanwhile, the mean value of three intraoperative parameters which are residual stromal thickness (RST), treatment zone and ablation depth are 373.35 µm, 6.26 mm and 95.72 µm respectively.

The table also compares the preoperative clinical characteristics of patients between PRK and LASIK procedures. Preoperative BCVA gives P value of 0.00 with mean for both types of surgery is 0.00 and SD of 0.18 for PRK and 0.00 for LASIK. P value of schimmer is 0.00 with mean of 12.03 ± 9.04 and 15.23 ± 9.74 for PRK and LASIK respectively. For keratometry, P value of both steep and mean are 0.047 and 0.043.

Preoperative manifest spherical equivalent refraction is significantly higher in PRK compared to LASIK ($P < 0.001$). The value ranging from 0.75 to 7.75 (mean = 4.92 D ± 2.63 D) in PRK group while from 0.38 to 12.25 (mean = 3.53 D ± 1.73 D) in LASIK group. Meanwhile, the sphere gives the P value of 0.001 with mean for both types of surgery is 4.37 with SD of 2.54 for PRK and 3.20 with SD of 1.49 for LASIK. The mean of magnitude astigmatism for both surgeries is 0.75 with SD of 0.83 for PRK and SD of 0.69 for LASIK with P value of 0.09. Meanwhile, RST, ablation depth, mean pachymetry and treatment zone give the same P value of less than 0.00.

Table 2. Clinical characteristics of patients treated with laser refractive surgery

Clinical Characteristics	Overall		PRK (N=103)		LASIK (N=71)		P value
	Mean	SD	Mean	SD	Mean	SD	
BCVA (LogMAR)	0*	0.1**	0.00*	0.18**	0.00*	0.00**	0.00
IOP (mmHg)	15.32	2.3	15.54	2.17	15.06	2.43	0.264
Schimer (mm)	13.32	9.46	12.03	9.04	15.23	9.74	0.03
Keratometry (D)							
Flat	43.04	1.27	43.20	1.33	42.78	1.14	0.065
Steep	44.27	1.32	44.48	1.39	43.99	1.12	0.047
Mean	43.65	1.23	43.84	1.28	43.39	1.07	0.043
Spherical equivalent (D)	4.39	2.39	4.92	2.63	3.53	1.73	0.00
Astigmatism Magnitude (D)	0.75	0.75	0.75	0.83	0.75	0.69	0.09
Sphere (D)	3.92	2.24	4.37	2.54	3.20	1.49	0.001
Mean Pachymetry (µm)	538.99	29.46	532.15	31.66	549.48	22.63	0.00
RST (µm)	0.46	0.39	422.51	39.54	302.22	25.09	0.00
Treatment Zone (mm)	0.08	0.26	6.37	0.44	6.10	0.18	0.00
Ablation Depth (µm)	373.35	68.6	105.70	26.93	80.60	22.52	0.00

*Median
**IQR

Table 3 illustrates the association between preoperative clinical characteristic with the recovery time to achieve 0.00 LogMAR postoperatively. From a univariate analysis of Pearson Correlation, there are three preoperative clinical characteristics that significantly influence the recovery time but the correlations are weak. The three possible influencing factors are magnitude of manifest astigmatism (P=0.013, R=0.188), SE (P= 0.043, R= 0.153) and RST (P= 0.048, R= 0.15).

Table 3. Correlation between preoperative clinical characteristics with visual recovery time

Clinical Characteristic	P value	R
BCVA (LogMAR)	0.366	0.69
IOP (mmHg)	0.252	-0.087
Schimer (mm)	0.534	-0.047
Keratometry (D)		
Flat	0.647	0.035
Steep	0.143	0.112
Mean	0.305	0.078
Spherical equivalent (D)	0.043	0.153
Astigmatism Magnitude (D)	0.013	0.188
Sphere (D)	0.098	0.126
Mean Pachymetry (µm)	0.399	-0.064
z (4,0)	0.646	0.035
RST (µm)	0.048	0.150
Treatment Zone (mm)	0.665	-0.033
Ablation Depth (µm)	0.250	0.088

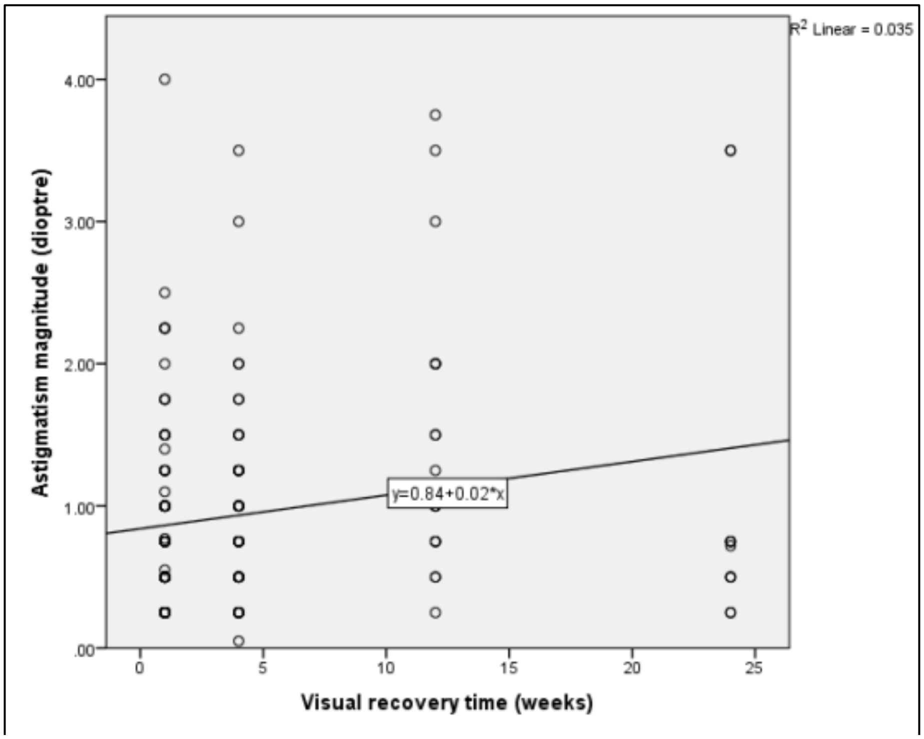

Figure 1. Correlation between astigmatism magnitude with visual recovery time

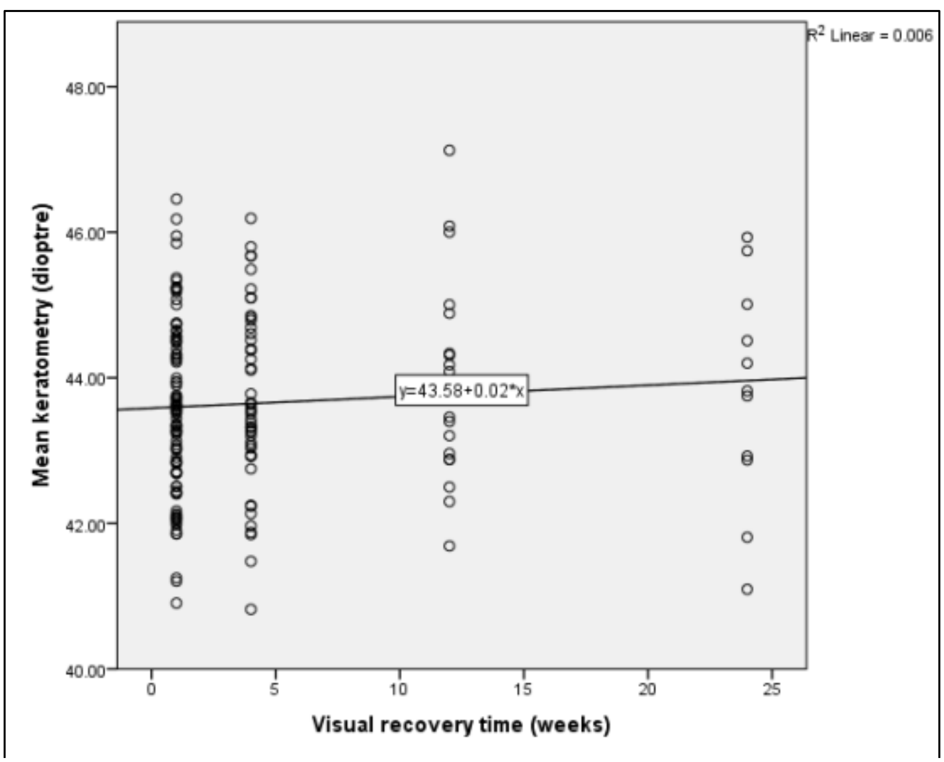

Figure 2. Correlation between mean keratometry with visual recovery time

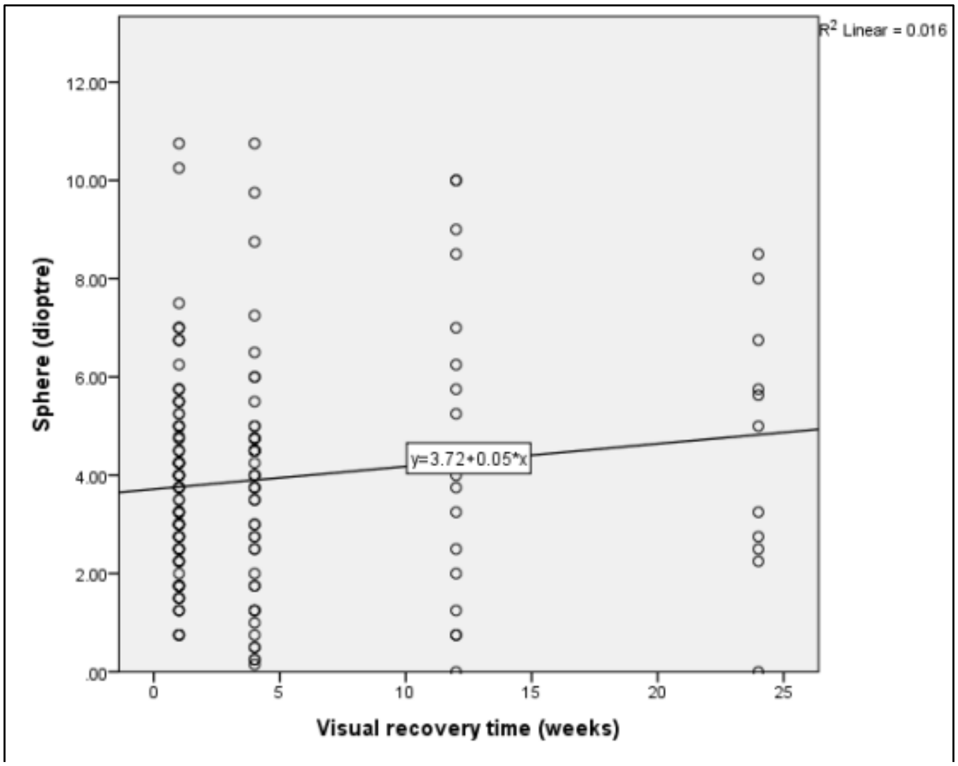

Figure 3. Correlation between sphere with visual recovery time

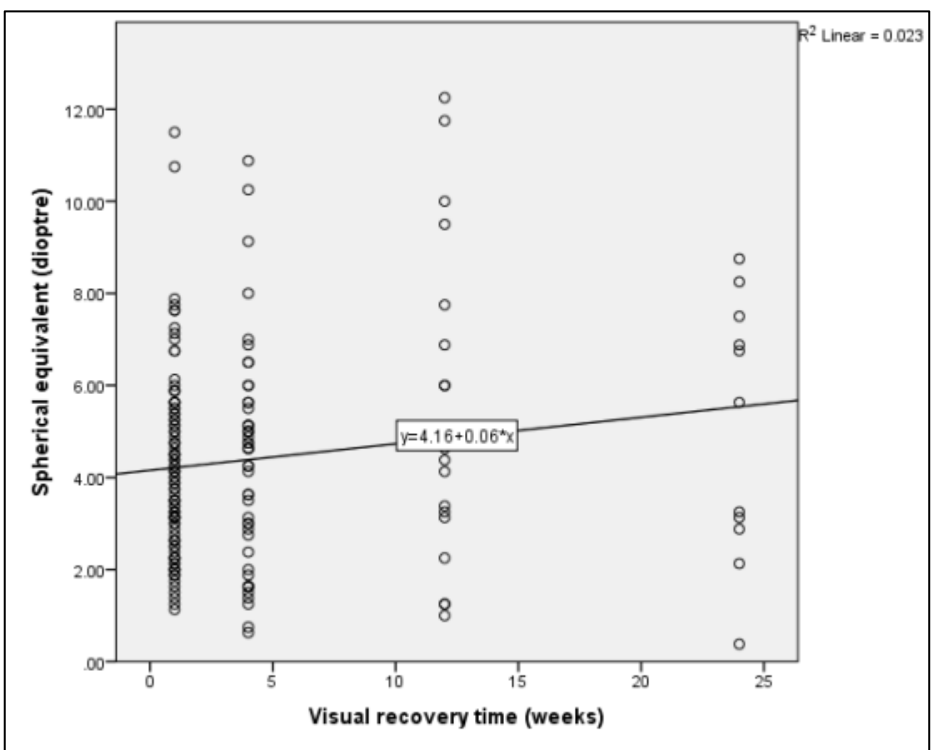

Figure 4. Correlation between spherical equivalence with visual recovery time

DISCUSSION

This retrospective cohort study was conducted at the only laser refractive centre in East Coast of Peninsular Malaysia. For both LASIK and PRK patients' population of this study, the mean age is the same, which is 33 years old. Interestingly, a study done in Korea by Lim et al., (2016) showed relatively comparable mean age of 31 and 27 years old for PRK and LASIK respectively. This similarity in the age group could represent the younger trend of patients who opted for refractive surgery in Asian countries. Our study sample size of 174 eyes became the greatest strength in this study compared to the Korean study which only recruited 62 patients. In another larger study sample (N=60 352) by UK Biobank (UKBB), they had reported patients who underwent laser refractive surgery from an older group of age ranging from 40 to 69 years old (Cumberland, Chianca & Rahi, 2015). Another European study that was conducted in Denmark (Gyldenkerne, Ivarsen & Hjortdal, 2014) had reported mean age of 37 which was also higher compared to both he current study and Lim et al., (2016). Although there is no ideal age to have laser refractive surgery, it is considerably beneficial to do it at a younger age as there are more years to be advantaged with good vision. SA Lim et al reported that there was no significant visual regression among patient in their mean age group up to 10 years postoperatively (Lim et al., 2016).

Looking at gender distribution across the studies mentioned earlier, women were the dominant group that had laser refractive surgery (Lim et al., 2016; Cumberland, Chianca & Rahi, 2015; Cumberland, Chianca & Rahi, 2015).[16–18] However, in our study, despite female being the majority, there was no statistical difference between gender and types of surgery done which was consistent with the Korean study by Lim et al., (2016).

In terms of ethnicity, our study revealed that the Malays were the majority amongst those who underwent the surgery. This is in alignment with the Malaysian ethnic composition based on 2010 Population and Housing Census of Malaysia which stated that the Malay ethnic comprises 67.4% of the total population (Department of Statistics Malaysia, 2010). The same census also reported that the majority of Malay population lives in the east coast of Malaysia, as compared to other areas in Malaysia. This finding was in keeping with the UKBB study that showed the White people as the majority who underwent laser refractive surgery in the UK as they are the dominant ethnic group that accounted for 86% of total population as stated in 2011 UK Census (Cumberland, Chianca & Rahi, 2015; White, 2011).

More than half of the subjects in our study were from professional group, which consist of health professionals, educators and managers. This portrayed that the type of occupation is closely related to monthly income of an individual, thus influencing their decision to proceed with the surgery. This was again supported by UKBB study by Cumberland et al. where they discovered that people with moderate income (£18k to £52k) and higher educational level were the majority who opted for surgery (Cumberland, Chianca & Rahi, 2015). We also recorded a small percentage of those who are unemployed and had refractive surgery which was approximately the same as previous mentioned study. Above all, our study was focusing on sociodemographic distribution in which there were lacks of study on sociodemographic distribution in Asian population. Apart from studying the clinical characteristics of our patients, we also describe their sociodemographic distributions as there is a lack of study on sociodemographic distribution of refractive laser patients in Asian population.

The mean keratometry of our patients (43.65 D) was in accordance with a study conducted in Denmark (Gyldenkerne, Ivarsen & Hjortdal, 2014) which reported mean keratometry of 43.62 D. Additionally, the mean astigmatism magnitude in this study (0.75) was similar to the result of previous study (0.79) (Lim et al., 2016). Despite that, this study found that the mean sphere (-3.92) was lower in comparison with findings acquired by previous studies. Both SA Lim et al. and Glydenkerne et al. have the mean sphere of -5.22 D and -5.43 D respectively (Lim et al., 2016; Gyldenkerne, Ivarsen & Hjortdal, 2014). Besides, these studies also reported greater value of spherical equivalent (-5.73 D and -5.43 D) in comparison with this current study (4.39 D).

To the best of our knowledge, this is the primary study that statistically analysed correlations between several preoperative parameters with time taken to achieve 0.00 LogMAR. Apart from that, this study managed to recruit exclusively included candidates that had successfully achieved 6/6 VA within six months postoperatively and this became the strength of this study. This study set six months as the cut-off time in assessing visual outcome due to a study conducted by Christiansen et. al., (2012) who had proven that after six months, the outcome (in term of spherical equivalent refraction) only changed minimally around two to five percent. Furthermore, another study reported that the refractive outcomes of 95% of PRK candidates had stabilized at six months while 99% of LASIK candidates had stabilized at one year postoperatively (Steinert et al., 1998). However, this study also showed that dropout rate had increased up to one third following one year follow up. Pérez et. al., (1997) also concluded that most patients achieved target vision at six months postoperatively. This justifies that at six months, the refractive outcome has been stabilized and perhaps the result would be almost the same if we evaluate at one year postoperatively.

This study analyses suggested that the time taken for patients to achieve 0.00 LogMAR would be prolonged if they had higher preoperative magnitude of manifest astigmatism. Even though the result had shown significant but weak positive correlation, the clinical relevance of this result would be best understood if we were able to make a comparison with other previous studies that also aimed to see correlation between preoperative astigmatism magnitude and recovery time. Unfortunately, most of the previous studies which inquired on astigmatism concentrated only on efficacy as well as surgically induced astigmatism rather than its correlation with recovery time post laser refractive surgery (Hersh et al., 1999, Arthur et al., 2016). A retrospective study by Frings et. al., (2015) was partly consistent with our finding as they were able to record that those with lower value of preoperative astigmatism (<0.9 D) have significantly lower postoperative UDVA (-0.01 ± 0.08 LogMAR) compared to those with higher astigmatism (UDVA of 0.01 ± 0.16 LogMAR). Concurrently, our sample population had recorded mean astigmatism of 0.9 D which fell under low astigmatism definition as categorized by that study. Although the author had adopted a slightly different methodology by studying the effect of topographic astigmatism rather than manifest astigmatism toward refractive outcome, an extrapolation could be made in order to make their findings comparable to this study.

There was inconsistency of postoperative outcomes as reported by Katz et al., (2014) where they found a tendency of astigmatism overcorrection, especially with low preoperative astigmatism (<0.50 D). However, their study population only concentrated on LASIK which used wavefront optimized profile rather than advanced surface ablation profile. However, their spherical equivalent and astigmatism magnitude were almost similar to this study. Furthermore, the study did not find any statistically significant difference in safety and efficacy index between different categories of preoperative astigmatism magnitude. The study also explored on axis of astigmatism where they again found no significant association between different axes of astigmatism on efficacy index. However, the latter was not an issue in this study as all subjects had with-the-rule axes of manifest astigmatism.

As far as spherical equivalent (SE) is concerned**,** this study data subsequently demonstrated higher preoperative SE results in delay of the recovery time. This was in line with previous study by Rao et. al, who reported a trend toward increased under correction in eye with high preoperative SE (-10 D to -11.9 D) (Rao et al., 2001). It is well understood that sphere and cylinder are the two components that are involved in the equation of SE (sphere + 1/2 cylinder = SE). In relation to this equation, however, when correlation towards recovery time was evaluated separately for each component of the equation, only manifest astigmatism magnitude showed a significant positive correlation, but not sphere. Regarding preoperative myopia or manifest sphere**,** high preoperative myopia was well known to be one of the risk factors for long-term regression after laser refractive surgery rather than its influence on the visual recovery time (Lim et al., 2016). With the knowledge of tissue remodelling post laser ablation, it is known that increased in SE would subsequently lead to increase in ablation depth. The type of surgery may also result to different mode of stromal tissue remodelling, where epithelial hyperplasia accompanied by new collagen formation occur in PRK, whereas, the amount of residual Bowman's membrane would influence the healing process post LASIK procedure (Fantes et al., 1990; Gris et al., 1996). All these contribute to the healing process which could be the confounding factor to our result as we analyzed both procedures as a single variable. In terms of recovery, the presence of astigmatism will prolong the recovery time as compared to simple myopia since sphere failed to show a statistically significant correlation. However, our study population had excluded simple myopic patient.

This study findings also demonstrated that there was no statistically significant correlation between preoperative keratometry and visual outcome. This is consistent with a multivariate analysis done by Young et. al., (2009) on 1659 eligible eyes, which concluded that preoperative keratometry did not influence visual outcome. However, the study analyzed the outcome for hyperopic instead of myopic LASIK. Even though their outcome was percentages of eyes that attained UDVA of 20/20 or better at 1 month follow up, this can be extrapolated as visual recovery time to make it comparable with this study.

Nevertheless, there were numerous studies that apparently showed that preoperative keratometry did have an impact on visual outcome and majority of them were in agreement that flatter preoperative keratometry yielded better end result. Christiansen et. al., (2012) reported that moderately myopic eyes with flatter cornea (K = 39.9 D to 42.0 D) had significant association with better visual outcome than those with steeper cornea (K = 46.0 to 47.2) with regard to percentages of eyes that achieved UDVA of 20/15 or better (p value = 0.001). In two other studies that focused on hyperopic LASIK, the findings are also in line with the notion that steeper K is associated with poorer outcome (Esquenazi et al., 1999; Williams, Dave & Moshirfar, 2008). Esquenazi et al., (1999) found that under correction occurred more frequent in the eyes with preoperative K > 45.0 D while a previous work had prospectively examined six months' follow-up data and recorded an increased incidence of best spectacle corrected visual acuity (BSCVA) loss with eyes that had preoperative K > 44.0 D (Williams, Dave & Moshirfar, 2008). However, the latter used limited sample size (N= 26 patients) which could influence the result reported.

Surprisingly, there were studies that had reported contradicting results. Instead of steep preoperative cornea, flatter preoperative cornea was found to have poorer postoperative visual outcome. Study by Mohamed (2015) revealed a trend toward greater under correction in patients with K < 43.5 D than those with K > 46.0 D in all myopic group which was agreed by previous works (Rao et. al., 2001; Mohamed, 2015). Even in hyperopic LASIK population also disclosed that instead of preoperative steep keratometry, flat keratometry was the one that led to greater regression and vision under correction (Ditzen, Huschka & Pieger, 1998).

Therefore, the most probable deduction for this inconsistency throughout all these studies was due to various factors of engagement with different nomograms, different speed of ablation, laser ablation patterns, degree of flap drying, and flap size differences between the groups (Williams, Dave & Moshirfar, 2008). These dissimilarities would significantly affect postoperative eye dryness and possible vision correction outcomes. A possible factor that can contribute to poor outcome was increase in eye dryness especially in those with higher preoperative K values. Dry eye was known to be a complication of LASIK and normally affects patients during the first month post operatively (Shtein, 2011). Hence, in order to control this possible confounder, this study excluded all patients with established postoperative dry eye.

Another possible explanation to support our finding on keratometry was the fact that the surgery was confined to the safety range of preoperative clinical characteristic for laser refractive surgery including keratometry parameter where the mean K in this study was equal to 43.65 D and ranging from 40.82 D to 47.12 D. Despite no correlation being observed, our study cannot draw any conclusion about keratometry that exceed the value of 47.12 D or less than 40.82 D as it is out of the range of our study.

CONCLUSIONS

Visual recovery time among those who achieved intended refractive outcome has statistically significant correlation with the degree of manifest spherical equivalent and astigmatism. Despite a positive correlation between degree of sphere and preoperative keratometry with visual recovery time, these parameters had failed to establish a statistically significant correlation.

CONFLICT OF INTEREST

All of the authors involved in our study have no affiliations with, or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) regarding subject matter discussed in this manuscript.

ACKNOWLEDGEMENT

The authors would like to express gratitude to the IIUM Research Initiative Grant Scheme for financial support (RIGS 16-129-0293). Special thanks to all staff for their precious assistance in conducting this study.

REFERENCES

1. Tuan, K-M.A & Chernyak, D. (2006) Corneal asphericity and visual function after wavefront-guided LASIK. Optom. Vis. Sci. Vol. 83, pp. 605–610.
2. Reinstein, D.Z., Archer, T.J. & Gobbe, M. (2012) The history of LASIK. J. Cataract. Refract. Surg. Vol. 28, pp. 291 – 298.
3. Maldonado-Bas, A & Onnis, R. (1998) Results of laser in situ keratomileusis in different degrees of myopia. Ophthalmology, Vol. 105, pp. 606 – 611.
4. Pérez-Santonja, J.J., Bellot, J., Claramonte, P., Ismail, M.M., Alió J.L. (1997) Laser in situ keratomileusis to correct high myopia. J. Cataract. Refract. Surg, Vol. 23, pp. 372 – 385.
5. Ditzen, K., Huschka, H. & Pieger, S. (1998) Laser in situ keratomileusis for hyperopia. J. Cataract. Refract. Surg. Vol. 24, pp. 42 – 47.
6. Lohmann, C.P & Güell, J.L. (1998) Regression after LASIK for the treatment of myopia: the role of the corneal epithelium. Semin. Ophthalmol. Vol. 13, pp. 79 – 82.
7. Feng, Y., Yu, J. & Wang, Q. (2011) Meta-Analysis of Wavefront-Guided vs. Wavefront-Optimized LASIK for Myopia. Optom. Vis. Sci, Vol. 88, pp. 1463 – 1469.
8. Hilmi, M.R., Musa, N.H., Khairidzan, M.K., Azemin, M.Z.C., Maruziki, N.N., Norazmar, N.A., Nasir, M.S. (2019). Changes In Apical Corneal Curvature In Unilateral Primary Pterygium And Normal Adults Using Simulated-K And Corneal Irregularity Measurement, International Journal Of Allied Health Sciences, Vol. 3(2), pp. 588 - 594.
9. Marjorie, R., Jackson, J., Lisa, A., Jones, J.B. (2002) Comparison of Manual Keratometry and Simulated Keratometry Readings with Corneal Topography Before and After Overnight Orthokeratology. Am. Acad. Optom.
10. Christiansen, S.M., Neuffer, M.C., Sikder, S., Semnani, R.T., & Moshirfar, M. (2012) The effect of preoperative keratometry on visual outcomes after moderate myopic LASIK. Clin. Ophthalmol, Vol. 6, pp. 459 – 464.
11. Mohamed, M.E. (2015) Effect of Flat Cornea on Visual Outcome after LASIK. J. Ophthalmol.
12. Rao, S.K., Cheng, A.C.K., Fan, D.S.P., Leung, A.T.S. & Lam, D.S.C. (2001) Effect of preoperative keratometry on refractive outcomes after laser in situ keratomileusis. J. Cataract Refract. Surg, Vol. 27, pp. 297 – 302.
13. Freitas, G.D.O. Ambrosio, R., Ramos, I., Lopes, B., Valbon, B.D.E., Botteon, C., Alve, M.R. (2016) Astigmatic Vector Analysis of Posterior Corneal Surface: A Comparison among Healthy, Forme Fruste, and Overt Keratoconic Corneas. Am. J. Ophthalmol, Vol. 167, pp. 65 – 71.
14. Qian, Y., Huang, J., Chu, R., Zhao, J., Li, M., Zhou, X., Olszewski, E., Wang, Y. (2015) Influence of intraocular astigmatism on the correction of myopic astigmatism by femtosecond laser small-incision lenticule extraction. J. Cataract Refract. Surg. Vol. 41, pp. 1057 – 1064.
15. Pop, M & Payette, Y. (2000) Photorefractive keratectomy versus laser in situ keratomileusis: A

control-matched study. Ophthalmology, Vol. 107, pp. 251 – 257.
16. Lim, S.A., Park, Y., Cheong, Y.J., Na, K.S. & Joo, C-K. (2016) Factors Affecting Long-term Myopic Regression after Laser In Situ Keratomileusis and Laser-assisted Subepithelial Keratectomy for Moderate Myopia. Korean J. Ophthalmol. Vol. 30, pp. 92 – 100.
17. Cumberland, P.M., Chianca, A & Rahi, J.S. (2015) Laser refractive surgery in the UK Biobank study: Frequency, distribution by sociodemographic factors, and general health, happiness, and social participation outcomes. J. Cataract Refract. Surg. Vol. 41, pp. 2466 – 2475.
18. Gyldenkerne, A., Ivarsen, A.R & Hjortdal, J.O. (2014) Factors affecting the decision for refractive surgery in patients with high degrees of ametropia. J. Cataract Refract. Surg. Vol. 40, pp. 1371 – 1376.
19. Population Distribution and Basic Demographic Characteristic Report 2010. Department of Statistics Malaysia (2010). Available at: https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=117&bul_id=MDMxdHZjWTk1SjFzTzNkRXYzcVZjdz09&menu_id=L0pheU43NWJwRWVSZklWdzQ4TlhUUT09. (Accessed: 6th August 2018)
20. White, E. Ethnicity and National Identity in England and Wales: 2011. Office for National Statistics (2011). Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/culturalidentity/ethnicity/articles/ethnicityandnationalidentityinenglandandwales/2012-12-11. (Accessed: 6th August 2018)
21. Steinert, R.F & Hersh, P.S. (1998) Spherical and aspherical photorefractive keratectomy and laser in-situ keratomileusis for moderate to high myopia: Two prospective, randomized clinical trials. Trans. Am. Ophthalmol. Soc, Vol. 96, pp. 197 – 227.
22. Hersh, P.S., Abbassi, R & Grp, S.P.-L.S. (1999) Surgically induced astigmatism after photorefractive keratectomy and laser in situ keratomileusis. J. Cataract Refract. Surg, Vol. 25, pp. 389 – 398.
23. Arthur, E., Sadik, A.A., Kumah, D.B., Osae, E.A., Mireku, F.A., Asiedu, F.Y., Ablordeppey, R.K. (2016) Postoperative Corneal and Surgically Induced Astigmatism following Superior Approach Manual Small Incision Cataract Surgery in Patients with Preoperative Against-the-Rule Astigmatism. J. Ophthalmol. 2016:9489036. doi: 10.1155/2016/9489036.
24. Frings, A., Richard, G., Steinberg, J., Skevas, C., Druchkiv, V., Katz, T., Linke, S.J. (2015) LASIK for spherical refractive myopia: Effect of topographic astigmatism (Ocular Residual Astigmatism, ORA) on refractive outcome. PLoS One, Vol. 10(4), pp. 1 – 9.
25. Katz, T., Frings, A., Linke, S.J., Richard, G., Druchkiv, V., Steinberg, J. (2014) Laser in situ keratomileusis for astigmatism [less than or equal to] 0.75 Diopter combined with low myopia: a retrospective data analysis. BMC Ophthalmol, Vol. 14, Doi : 10.1186/1471-2415-14-1.
26. Fantes, F.E., Hanna, K.D., Waring, G.O., Pouliquen, Y., Thompson, K.P., Savoldelli, M. (1990) Wound healing after excimer laser keratomileusis (photorefractive keratectomy) in monkeys. Arch. Ophthalmol, Vol. 108, pp. 665 – 675 (1990).
27. Gris, O., Güell, J.L & Muller, A. (1996) Keratomileusis update. J. Cataract Refract. Surg.,Vol. 22, pp. 620 – 623.
28. Young, J.J., Schallhorn, S.C., Brown, M.C & Hettinger, K.A. (2009) Effect of keratometry on visual outcomes 1 month after hyperopic LASIK. J. Refract. Surg, Vol. 25, pp. S672 – S676.
29. Esquenazi, S., Mendoza, A.M. (1999) Two-year Follow-up of Laser in situ Keratomileusis for Hyperopia. J. Cataract Refract. Surg, Vol. 15, pp. 648 – 652.
30. Williams, L.B., Dave, S.B. & Moshirfar, M. (2008) Correlation of visual outcome and patient satisfaction with preoperative keratometry after hyperopic laser in situ keratomileusis. J. Cataract Refract. Surg, Vol. 34, pp. 1083 – 1088.
31. Shtein, R.M. (2011) Post-LASIK dry eye, Expert. Rev. Ophthalmol, Vol. 6(5), pp. 575 - 582.