Original article

Comparison of Modern Surgical Techniques in a Treatment of Myopia

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Abstract

Aim: To examine whether there is a difference in the outcomes of surgical techniques photorefractive keratectomy (PRK), laser in situ keratomileusis (LASIK) and implantable collamer lens (ICL) for: short-term visual outcome after 6 months, long-term visual outcome after 24 months, procedures safety and remaining refractive error after surgery.

Methods: The research was conducted on patients with myopia and myopic astigmatism. Data was collected on the surgical technique performed binocularly: PRK, LASIK or ICL. Visual acuity was measured: before the procedure, 6 months after the procedure and 24 months after the procedure. Data were collected on the occurrence of complications and performed additional corrections.

Results: The research was conducted on 150 patients. The median age was 33 years with an interquartile range of 28 to 39 years. The visual outcome was satisfactory in all three groups during two measurement periods after 6 months and after 24 months after procedures. Complications in this study occurred in 13 patients (8,7 %), mostly in LASIK group with total of 11 patients. Suboptimal refractive result that was corrected by additional correction amounts 1,3 % meaning only 2 of patients underwent the correction procedure due to suboptimal refractive error.

Conclusion: Short-term and long-term visual outcome after binocularly performed PRK, LASIK and ICL showed success in all groups. ICL and PRK showed the highest safety rate, while LASIK had more frequent complications in this study. A suboptimal refractive result occurred rarely and were additionally corrected if needed..

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Introduction

Definition

Myopia is a refractive error in which image of an object is projected in front of the retina which is the result of a discordance of the axial length and refractive power of the eye (1). Myopia can be classified as axial, refractive and accommodative myopia. Axial myopia is the result of stretching the posterior pole of the eye which causes the optical axis to lengthen more than 2,4 centimeters. Refractive myopia is most often caused by too steep cornea, a more curved anterior surface of the lens, sclerosis of the lens nucleus, luxation of the lens in the anterior chamber of the eye and pathological conditions of the cornea such as keratectasia, microcornea and keratoconus. Accommodative myopia is the result of accommodation spasm, in which lens rounds and moves forward and causes nearsightedness (2).

Public health concerns

According to the World Health Organization, a third of the World's population - about 2,6 billion people, suffered from myopia in 2020. It is predicted that by the year 2030 this number is going to reach 3,4 billion. Accordingly, by the 2050 almost half of the World's population or about 5 billion people will suffer from myopia (3).

Refractive surgery

Refractive surgery refers to surgical procedures that change the refractive power of the eye. Cornea and lens account for the majority of the refractive power of eye, so refractive surgery procedures are performed on cornea and lens (1).

Refractive surgery developed dramatically throughout the 20th century. Development of new procedures and platforms continues until today. We are going to mention some of the most significant techniques of refractive surgery throughout history: Incisional procedures that include radial keratotomy, astigmatic keratotomy, and limbal relaxing incisions. Lamellar non-laser procedures that include keratomileusis, automated lamellar keratoplasty and keratophakia. Thermal procedures that include radial intrastromal thermokeratoplasty, laser thermokeratoplasty and conductive keratoplasty (4).

Today we mostly relay on surface and incisional methods: Photorefractive Keratectomy (PRK), Laser in-situ Keratomileusis (LASIK) and Kerato-refractive Lenticule Extraction (KLEx).

PRK is used to correct myopia up to 7 diopters. In this procedure the epithelial layer of the cornea is removed followed by controlled ablation of the corneal surface stroma with an excimer laser (5). The epithelium heals from the periphery to the center within 4 days. After the procedure, the corneal epithelium goes through a hyperplastic phase in which the refractive status of the eye can vary before final stabilization (6).

LASIK is used to correct myopia up to 10 diopters with astigmatism up to 6 diopters. LASIK involves excimer laser ablation of the corneal stroma beneath a corneal flap created with a microkeratome or femtosecond laser. Laser vision correction procedures for myopia thins cornea in controlled manner thus correcting the shape of the cornea by reducing the central curvature of the cornea. Eye tracking devices use infrared tracking or cameras to move the laser ablation beam according to the direction of eye saccades. The flap characteristics, energy and incision direction must be prepared and programmed before the procedure (5).

KLEx, also known as Small Incision Lenticular Extraction (SMILE), is performed with femtosecond laser that creates a lenticle that is then surgically dissected through an entrance incision of 2 millimeters. Lenticular extraction can correct myopia and myopic astigmatism. The advantage of this technique lies in the quick recovery and reduced risk of developing dry eye due to the smaller amount of damage to the corneal nerves (7).

Refractive procedures also include Implantable collamer lens (ICL), posterior chamber phakic

intraocular lens that is implanted behind the pupil, in the posterior chamber between the iris and the lens (8). ICL is approved for correction of myopic astigmatism with spherical equivalent ranging from -3.0D to ≤-15.0D with cylinder of 1.0D to 4.0D (9).

Preoperative examination and planning of the procedure

Preoperative examination consists of a biomicroscope examination of the anterior and posterior segments of the eye and measurement of intraocular pressure using ICARE tonometer. It is necessary to determine the visual acuity for each patient: monocular uncorrected and best corrected distance visual acuity. It is mandatory to record pupillography, topography and corneal tomography with a topographic curvature system, pachymetry, biometry, wavefront aberrometry, tear film assessment, determination of ocular dominance, ocular motility and specular microscopy. Finding dominant eye is also helpful if minimonovision is planned. Considering the collected data clinician is then able to decide on the type of personalized procedure profile. It is also important to discuss the reasons for undergoing refractive surgery in order to identify patients with unrealistic expectations. It is important to explain that refractive procedures primarily serve to reduce dependence on spectacles (10).

Participants and methods

A historical cohort study was conducted including patients with myopia and myopic astigmatism who were treated at the University Eye Hospital Svjetlost Zagreb in a 3-year period (from 2018 to 2021). The total number of subjects was 150 patients. Data collection was performed by reviewing the medical documentation for each individual subject. Basic demographic data of the subjects (age, gender) was collected. Data on the binocularly performed surgical technique were extracted for each subject: PRK, LASIK or ICL. Snellen charts were used to determine corrected and uncorrected distant visual acuity for the right and left eye in three time periods: before the procedure, 6 months after the procedure and 24 months after the procedure. Data of complication, residual refractive error and additional correction has been collected.

Results

The study was conducted on 150 subjects. 50 patients (33.3%) differed according to the binocularly performed surgical technique: PRK, LASIK and ICL. Out of total number of subjects, 63 (42%) were male and 87 (58%) were female, with no significant difference in distribution according to the type of procedure (Table 1).

Table 1. Distribution of subjects by gender and type of procedure

	Number (%) of patients in relation to the performed intervention				*P**
	PRK	**LASIK**	**ICL**	**Total**	
Sex					
Male	20 (40)	21 (42)	22 (44)	63 (42)	0,92
Female	30 (60)	29 (58)	28 (56)	87 (58)	
Total	50 (100)	50 (100)	50 (100)	150 (100)	

*χ^2 test

The median age of the subjects was 33 years (interquartile range 28 to 39 years) ranging from a minimum of 22 to a maximum of 52 years. The subjects who underwent ICL were significantly younger than those who underwent LASIK (median 30 vs. 37 years) (Kruskal Wallis test, P = 0.002) (Table 2).

Table 2. Differences in the age of the subjects by type of procedure

	Median (interquartile range)			P*
	PRK	LASIK	ICL	
Age (years)	32 (28 – 39)	37 (30 – 42)	30 (27 – 35)	0,002†

*Kruskal Wallis test (post hoc Conover)

† at the P < 0.05 level, LASIK vs. ICL are significantly different

Visual acuity of the right eye at all three measurement points was significantly lower in subjects who underwent ICL compared to the other two types of procedure (Kruskal Wallis test, P < 0.001) (Table 3)

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Table 3. Differences in age of subjects in relation to type of procedure

	Median (interquartile range)			P*
	PRK	LASIK	ICL	
Age (years)	32 (28 – 39)	37 (30 – 42)	30 (27 – 35)	0,002†

*Kruskal Wallis test (post hoc Conover)

† at the P < 0.05 level, LASIK vs. ICL are significantly different

In all three groups, with respect to the type of procedure, the visual acuity of the right eye before the procedure was significantly worse compared to the time after 6 or 24 months (Friedman test, P < 0.001) (Table 4).

Table 4. Differences in visual acuity of the right eye at three measurement points in relation to the type of procedure

	Median (interquartile range) of right eye visual acuity (VOD) in relation to the procedure			P*
	PRK	LASIK	ICL	
Before procedure	0,05 (0,05 – 0,10)	0,10 (0,05 – 0,20)	0,03 (0,02 – 0,03)	**<0,001**†
After 6 months	1,0 (1,0 – 1,0) [min 0,9 max 1]	1,0 (1,0 – 1,0) [min 0,9 max 1]	1,0 (0,9 – 1,0) [min 0,3 max 1]	**<0,001**†
After 24 months	1,0 (1,0 – 1,0) [min 0,9 max 1]	1,0 (1,0 – 1,0) [min 0,9 max 1]	1,0 (0,9 – 1,0) [min 0,3 max 1]	**<0,001**†

*Kruskal Wallisov test (post hoc Conover)

† at the P < 0.05 level, ICL vs. (PRK, LASIK) are significantly different

Visual acuity of the left eye was significantly lower at all three measurement points in subjects who underwent ICL compared to the other two types of procedure (Kruskal Wallis test, P < 0.001 for pre-procedure and after 24 months; P = 0.003 after 6 months) (Table 5).

In all three groups, with regard to the type of procedure, visual acuity in the left eye was significantly worse before the procedure compared to after 6 or 24 months (Friedman test, P < 0.001) (Table 6).

Table 5. Differences in visual acuity of the right eye in relation to the measurement points according to the type of procedure

	Median (interquartile range) of right eye visual acuity (VOD) relative to measurement points			P*
	Before procedure	After 6 months	After 24 months	
PRK	0,05 (0,05 – 0,10)	1,0 (1,0 – 1,0)	1,0 (1,0 – 1,0)	**<0,001**†
LASIK	0,10 (0,05 – 0,20)	1,0 (1,0 – 1,0)	1,0 (1,0 – 1,0)	**<0,001**†
ICL	0,03 (0,02 – 0,03)	1,0 (0,9 – 1,0)	1,0 (0,9 – 1,0)	**<0,001**†

*Friedman test (post hoc Conover)

† at the P < 0.05 level, they are significantly different before the procedure vs. (6, 24 months)

Table 6. Differences in visual acuity of the left eye at three measurement points in relation to the type of procedure

	Median (interquartile range) of visual acuity of the left eye (VOS) in relation to measurement points			P*
	Before procedure	After 6 months	After 24 months	
PRK	0,05 (0,05 – 0,15)	1,0 (0,95 – 1,0)	1,0 (1,0 – 1,0)	**<0,001**†
LASIK	0,075 (0,05 – 0,20)	1,0 (1,0 – 1,0)	1,0 (1,0 – 1,0)	**<0,001**†
ICL	0,03 (0,02 – 0,05)	1,0 (0,9 – 1,0)	1,0 (0,9 – 1,0)	**<0,001**†

*Friedman test (post hoc Conover)

† at the P < 0.05 level, they are significantly different before the procedure vs. (6, 24 months)

Complications were experienced by 13 (8.7%) patients. Two patients required additional correction (1.3%). Out of a total of 13 (8.7%) patients with complications, there are significantly more, 11 (22%) of them from the group that underwent LASIK compared to the other two procedures (Fisher's exact test, P < 0.001), while in the correction there is no significant differences in relation to the type of intervention (Table 7).

Table 7. Distribution of patients according to complications and correction in relation to the type of procedure

	Number (%) of patients in relation to the intervention				P*
	PRK	LASIK	ICL	Total	
Complications					
No	48 (96)	39 (78)	50 (100)	137 (91,3)	**<0,001**
Yes	2 (4)	11 (22)	0	13 (8,7)	
Additional correction					
No	49 (98)	50 (100)	49 (98)	148 (98,7)	>0,99
Yes	1 (2)	0	1 (2)	2 (1,3)	
Total	50 (100)	50 (100)	50 (100)	150 (100)	

* Fisher's exact test

Discussion

Refractive surgery is one of the solutions in the treatment of myopia, which affects an increasing number of people globally. This study was conducted on a predominantly young population; the median age of the subjects was 33 years, with an interquartile range of 28 to 39 years. Surgical procedures were approved in individuals older than 18 years who had a stable refractive error during the previous 1–2 years. Although surgery may be indicated in younger patients who otherwise do not tolerate conventional therapy with glasses and contact lenses, caution is needed because refractive error is often unstable at this age. Stable refractive error is generally defined as a change in refraction of 0.5 diopters over the previous 1–2 years. Each patient presenting for screening should be asked to stop wearing contact lenses for one week for soft non-toric lenses, 2 weeks for toric lenses, and at least 3 weeks for rigid lenses, and asked to bring their previous glasses for assessment of refractive stability (5).

In this study, 58% of the subjects were women, although there is no significant record of the influence of gender differences on the induction and outcomes of the procedure. It is important to note that pregnancy and breastfeeding are contraindications for surgical procedures and their performance is not recommended (11).

Visual acuity outcome analyzed in this study was satisfactory in all three groups at two measurement periods, after 6 months and after 24 months after procedure.

Long-term studies with follow-up periods of at least 10 years have shown that PRK and LASIK have a very high level of safety and that late complications occurred rarely (12). A study comparing LASIK and PRK indicates that LASIK allows faster visual recovery and is a less painful technique compared to PRK. These studies also indicate that techniques provide similar results at one year follow-up after surgery, but further studies are suggested (13).

Complications recorded during this study occurred in 13 patients (8.7%), mostly from the LASIK group with overall 11 patients experiencing complications. Specific cases of complications recorded in this study are: dry eye, hypocorrection, corneal erosion at the 6-month follow-up, eye trauma at the 24-month follow-up, vision variation at the 24-month follow-up and amblyopia. In general, the occurrence of postoperative dry eye is a problem with LASIK procedures, which has also been shown in studies where LASIK was compared with other surgical techniques in the surgical treatment of myopia (14). Trauma is a rare complication, but can occur. There are several recorded cases in the literature; one case report showed a patient who had eye trauma with a sheet of paper that caused flap dislocation and subsequent epithelial ingrowth four years after LASIK procedure (15).

There are many types of ICL-related complications, but common intraoperative and postoperative complications mainly include abnormal ICL position, corneal endothelial cell loss and corneal decompensation, high intraocular pressure and secondary glaucoma, and cataract (16). One study showed that ICL in moderate and high refractive error is an effective and relatively safe technique. The most common late complication is the formation of cataracts. This complication can be effectively corrected surgically with good refractive outcomes (17).

Suboptimal refractive result was recorded in 2 patients who required additional correction, one in PRK group and one in ICL group. Therefore, a total of 1,3% of patients underwent a additional correction procedure due to suboptimal refractive error.

Studies point the success of additional correction of primary LASIK with the PRK method as well as performing LASIK re-lift with significantly greater success, but with an increased risk of epithelial ingrowth complication due to manipulation (18). Study that followed PRK outcome after primary LASIK in 4 years period showed favorable results (19). In study that followed long-term outcome of additional correction performed 3 years after

primary LASIK indicated a higher risk of clinically significant epithelial ingrowth (20).

Additional correction after ICL surgery is performed for residual refractive error or astigmatism that was not completely corrected by primary procedure. One study showed that about 4,8% eyes that underwent ICL lens implantation required additional corrective procedures such as LASIK or PRK surgery or rotation of the ICL lens. In cases where additional correction is needed, LASIK or PRK is often used to improve the accuracy of the refractive correction, especially when minor residual errors are present. In most cases, re-corrections are necessary for a small number of patients and often lead to significant improvements in visual outcomes and patient satisfaction.

Conclusion

1. Short-term visual outcome in control 6 months after binocularly performed PRK, LASIK and ICL showed success in all groups.

2. The long-term visual outcome in control 24 months after binocularly performed PRK, LASIK and ICL showed success in all groups.

3. In the study, ICL and PRK showed the highest safety rate while LASIK had more frequent complications.

4. A suboptimal refractive result rarely occurs and can be corrected by additional correction in cases when it is required.

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Usporedba modernih kirurških tehnika u liječenju kratkovidnosti

Sažetak

Cilj: Istražiti postoji li razlika u ishodima kirurških tehnika fotorefraktivne keratektomije (PRK), laserske in situ keratomijelize (LASIK) i ugradbenih fakičnih leća (ICL) za: kratkoročni vidni ishod nakon šest mjeseci, dugoročni vidni ishod nakon 24 mjeseca, sigurnost zahvata i ostatna refrakcijska pogreška nakon operacije.

Metode: Istraživanje je provedeno na ispitanicima s kratkovidnošću i astigmatizmom. Za svakoga ispitanika prikupljeni su podaci o binokularno provedenoj kirurškoj tehnici: PRK, LASIK ili ICL. Vidna oštrina je mjerena: prije zahvata, 6 mjeseci nakon zahvata i 24 mjeseca nakon zahvata. Prikupljeni su podatci o postojanju komplikacija i provedenim dokorekcijama..

Rezultati: Istraživanje je provedeno na 150 pacijenata. Medijan dobi ispitanika je 33 godine, interkvartilnog raspona od 28 do 39 godina. Vidni ishod je bio zadovoljavajući u sve tri skupine kroz dva perioda mjerenja nakon 6 mjeseci i nakon 24 mjeseca od provedenih zahvata. Komplikacije u ovoj studiji su se javile kod 13 pacijenata (8,7 %), pretežito iz LASIK skupine koja broji 11 pacijenata sa komplikacijom. Suboptimalni refrakcijski rezultat koji je bio ispravljen dokorekcijom iznosi 1,3 % pacijenata koji su zbog suboptimalne refrakcijske greške ponovno podvrgnut zahvatu korekcije.

Zaključak: Kratkoročni i dugoročni vidni ishod nakon binokularno provedenih PRK-a, LASIK-a i ICL-a pokazao je uspješnost u svim skupinama. U istraživanju su najveću sigurnost zahvata, odnosno najmanji broj komplikacija, pokazali ICL i PRK, dok su kod LASIK-a bile češće komplikacije. Suboptimalni refrakcijski rezultat se rijetko javlja te se može ispraviti dokorekcijom u slučajevima koji to zahtijevaju.