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# Results of laser enhancement for residual myopia after primary laser *in situ* keratomileusis

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## Abstract:

**PURPOSE:** The purpose of the study is to evaluate and analyze the results and outcomes after laser enhancement for residual myopia after primary laser *in situ* keratomileusis (LASIK).

**MATERIALS AND METHODS:** This retrospective interventional consecutive case series clinical study was performed on 112 consecutive eyes (82 patients) that had undergone primary LASIK before the enhancement procedure. The study was done in the Refractive Surgery Unit in Yemen Magrabi Hospital between 2006 and 2014. The retreatment was for residual myopia with or without astigmatism. Either the original flap was lifted or surface ablation was performed. Parameters evaluated were uncorrected visual acuity (UCVA) and best spectacle-corrected visual acuity (VA), spherical equivalent (SE) refraction, corneal topography, and pachymetry. Complications after laser enhancement were also evaluated.

**RESULTS:** Mean age of the study group was  $26.72 \pm 6.89$  years (range from 18 to 44 years). Males accounted for 37/82 (45.1%) and females for 45/82 (54.9%). The right eye was treated in 67/112 (59.8%) and the left eye in 45/112 (40.2%). Before primary LASIK, the mean SE (MSE) was  $-5.78 \pm 1.89$  D. Before enhancement, the MSE was  $-1.32 \pm 0.61$  D (range  $-3.25$  D to  $-0.50$  D), and none of the eyes had an UCVA of 20/40 or better. Twelve months after retreatment, the percentage of eyes having UCVA of 20/40 or better increased to 67.9% (76 of 112). There were no vision-threatening complications seen.

**CONCLUSION:** Retreatment or enhancement after LASIK surgery by lifting the original flap or surface ablation is a safe and effective method for the treatment of regressed or undercorrected myopia. The risk of postoperative complications is very minimal.

## Keywords:

Laser *in situ* keratomileusis, myopia, residual refractive error, retreatment, Yemen

## Introduction

Errors of refraction are treated by laser *in situ* keratomileusis (LASIK), which is widely used for getting a perfect and high-quality visual acuity (VA) in near and long distances without using eyeglasses and contact lenses.<sup>[1]</sup> Excimer laser corneal refractive surgery has become a safe and effective method of eliminating refractive error.<sup>[1]</sup>

LASIK is used for a wide range of refractive errors such as mild-to-moderate myopia and astigmatism.<sup>[2]</sup> LASIK has become the first choice and the most effective refractive procedure for the treatment of low-to-moderate myopia and astigmatism.<sup>[3]</sup> LASIK is limited to lower levels of myopia to preserve the integrity of the cornea and the quality of postoperative vision.<sup>[4]</sup> LASIK remains the most commonly performed procedure; however, surface ablation procedures, including photorefractive keratectomy (PRK), laser epithelial

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keratomileusis, and epi-LASIK, have gained popularity recently due to an increased safety profile by eliminating flap-related complications and reducing the incidence of postoperative ectasia.<sup>[3]</sup>

In our unit, maximum correction of LASIK has changed over the years. When we started in 2006, the maximum correction was limited to  $-10.0$  D, and since 2010, it was limited to  $-8.00$ , and since 2014, it was limited to  $-7.00$ .<sup>[4]</sup> The main reason for the change in the power corrected by LASIK was that best spectacle-corrected VA (BSCVA) is lost after correction of moderate-to-high myopia because of excessive flattening.<sup>[5]</sup> Another reason was the good results of phakic posterior chamber intraocular lens for the moderate-to-high myopes regarding the quality of vision.<sup>[6]</sup>

LASIK is a safe and effective surgery, but it has some complications.<sup>[7]</sup> Undercorrection and regression of myopia are one of the complications after LASIK.<sup>[8]</sup> The degree of residual refraction is often unpredictable, and some patients require retreatment or enhancement after LASIK; it is the responsibility of the refractive surgeon to inform patients regarding this complication.<sup>[8]</sup> The amount of correction and the predictability of visual results after LASIK depend on several factors such as the dioptric power of the eye, the amount of myopia, the combinations of ametropias (myopia and astigmatism), different ablation profiles, and the individual variations in wound healing.<sup>[9,10]</sup>

The retreatment rates after LASIK have been reported to vary from 4.7% to 37.9%.<sup>[7,8,10-12]</sup> The amount of residual myopia increases as the patients' myopia increase, and usually high myopes require retreatment procedures more often than lower myopes.<sup>[10]</sup> Due to the decrease in VA, it may be necessary and useful to perform an enhancement procedure to refine the results obtained after the first surgery. Usually, the procedure is done after evidence of refractive stability.

There are two options for performing the reablation, either lifting the original flap with blunt dissection and performing the laser within the stroma or doing surface ablation (PRK) on the previous flap.<sup>[8,10]</sup> The retreatment is usually done 6 or 12 months after primary LASIK.

The purpose of this study was to evaluate and analyze the results of retreatment (enhancement) after primary LASIK for myopia in Yemen Magrabi Eye Hospital in Sana'a, Yemen.

## Patients and Methods

LASIK is the main refractive surgical procedure performed at our refractive unit in Yemen Magrabi Hospital between

January 2006 and December 2014. The primary LASIK is performed with Moria M2 Microkeratome (Antony, France) and the Nidek EC-5000 excimer laser (Nidek Co, Gamagori, Japan) from 2005 to 2010 and VISX Star laser (VISX Inc., Santa Clara, CA, USA) from 2010 to 2014.

This retrospective interventional consecutive case series clinical study was performed on 112 consecutive eyes of 82 patients (51 males and 61 female) who had undergone primary LASIK 6 months before the enhancement procedure. Patients were offered enhancement if they were dissatisfied with the uncorrected VA (UCVA) and requested for further surgery, and the refraction was stable for at least 6 months. No enhancements were performed before 6 months after the primary LASIK and for patients with topographic changes suspicious to have post-LASIK ectasia.

Retreatment or enhancement was done in eyes previously treated by myopic LASIK showing an undercorrection due to either a refractive regression or a primary undercorrection. Thirty patients had a bilateral procedure. The retreatment was for residual myopia with or without astigmatism. All eyes had residual myopia  $\geq -0.75$  D spherical equivalent (SE) and evidence of refractive stability.

Preoperative UCVA and BSCVA, manifest and cycloplegic refraction, corneal topography, pachymetry, and detailed fundus examination were done. Complications after LASIK enhancement were also evaluated. The exclusion criteria for retreatment were corneal scarring, a central corneal thickness of  $<410$   $\mu\text{m}$  (250  $\mu\text{m}$  of stromal bed and 160  $\mu\text{m}$  of corneal flap), and presence of keratectasia or severe dry eye.

Informed consent was obtained from all the patients before the procedure. The retreatment was done either by lifting the original flap and ablating on the stroma or by surface ablation after removal of the epithelium. PRK enhancements were done when an in-the-bed enhancement was not advisable because of residual stromal thickness limitations. The PRK ablation parameters (diameter and attempted correction) were selected to avoid theoretical flap perforation. The deepest ablation was 60  $\mu\text{m}$ , for a  $-3.50$  D correction.

The Excimer laser Nidek EC-5000 from 2005 to 2010, and VISX S4 from 2010 to 2014 were used for the retreatment procedure, with the same nomograms. All surgery was performed under topical anesthesia using Benoxinate (Epico, Egypt). The eye was cleaned with 5% povidone-iodine solution. The eye was draped, the lids were drawn back with Steri-Strips and the lashes were enclosed in Tegaderm (3M), which was wrapped around each lid margin. A speculum was used to keep

the palpebral fissure wide open and the eyelashes out of the field.

In case of flap-lifting LASIK, the cornea was marked with a gentian violet tip marker (Acculine, Accu-line Products, Inc. Hyannis, MA, USA) and the original flap was lifted using blunt dissection. In this series, no second microkeratome cut was required. In case of PRK, the epithelium was removed after applying alcohol for 20 s. Once the ablation was completed, the stromal bed was cleaned with balanced salt solution and a bandage contact lens was applied. No mitomycin C (MMC) was used in all cases.

The patients were examined at the slit lamp ½ h after surgery by the resident and the patients sent home. Ciprofloxacin 0.3% (Ciloxan, Alcon, USA) and prednisolone acetate 1% (Predforte, Allergan, USA) four times daily in a tapering dose along with preservative-free Tears Naturale Free (Alcon, USA) for 1 month were prescribed. The patients were seen at day 1, day 3, 1 week, and 1 and 6 months.

The study was approved by the Research and Ethics Committee of Yemen Magrabi Eye Hospital (Approval Number: 002/2018), and the procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional or regional), and with the Helsinki Declaration of 1975, as revised in 2000. The risk of the surgery was fully explained to the patients in accordance with the Helsinki Declaration, and verbal informed consent was obtained.

## Results

The mean age of the study group was  $26.72 \pm 6.89$  years (range from 18 to 44 years). Males accounted for 37/82 (45.1%) and females for 45/82 (54.9%). The right eye was treated in 67/112 (59.8%) and the left eye in 45/112 (40.2%).

Before primary LASIK, the mean SE (MSE) was  $-5.78 \pm 1.89$  D. Before enhancement, the MSE was  $-1.32 \pm 0.61$  D (range  $-3.25$  to  $-0.50$ ). Before retreatment, the mean spherical power and cylindrical power were  $-1.32$  D and  $-0.48$  D, respectively, which improved to  $-0.13$  D and  $-0.08$  D 6 months after surgery. The demographic data are shown in Table 1.

Before enhancement, none of the eyes had an UCVA of 20/40 or better, and after retreatment, this percentage increased to 67.9% (76 of 112) at 12 months. Preenhancement UCVA ranged from counting fingers (CF) to 20/100, and BSCVA ranged from 20/70 to 20/20. Postenhancement UCVA ranged from 20/200 to 20/20, and BSCVA ranged from 20/50 to 20/20.

**Table 1: Patient demographics**

Variants	Demographic
Gender (82 patients) (%)	
Male	37 (45.1)
Female	45 (54.9)
Laterality (112 eyes) (%)	
Right (OD)	67 (59.8)
Left (OS)	45 (40.2)
Age (years)	
Mean	$26.72 \pm 6.89$ (Range 18-44)
Before primary LASIK	
SE (D)	$-5.78 \pm 1.89$
Pachymetry ( $\mu\text{m}$ )	$543.85 \pm 32.38$ (Range 476-623)
Before enhancement	
SE (D)	$-1.32 \pm 0.61$
Pachymetry ( $\mu\text{m}$ )	$481.83 \pm 34.16$ (Range 428-566)

LASIK=Laser *in situ* keratomileusis, SE=Spherical equivalent, D=Diopter, OD=Oculus dexter, OS=Oculus sinister

The UCVA improved to 20/20 in 49 (43.8%) eyes and 20/40 or better in 104 (92.8%) eyes. The BSCVA was maintained in 55 eyes (49.1%); 30 (26.8%) gained one line and 24 (21.4%) gained two lines or more of BSCVA, whereas 2 eyes (1.8%) lost one line and 1 eye (0.9%) lost two lines or more.

Ninety-four eyes (83.9%) were emmetropic (i.e., SE within  $\pm 0.50$  D). One hundred and six (94.6%) eyes were within  $\pm 1.00$  D of emmetropia. These results compare favorably with those in the literature [Table 2]. The mean preoperative pachymetry was  $543.85 \pm 32.38 \mu\text{m}$  (range 476–623  $\mu\text{m}$ ). The mean postoperative pachymetry was  $481.83 \pm 34.16 \mu\text{m}$  (range 428–566  $\mu\text{m}$ ). The enhancement refractive surgery was performed after a mean of  $15.5 \pm 4.2$  months (range 6–36 months). Minimum follow-up period was 12 months.

No sight-threatening complications such as infection, haze, visually significant flap striae, deep lamellar keratitis, corneal ectasia, or retinal complications occurred postoperatively. Two eyes developed epithelial ingrowth which was limited to the peripheral cornea and did not cause visual complications or require active treatment. After the enhancement surgery, the corneal topography showed a uniform central ablation in all eyes with the exception of one which had slightly decentered ablation.

## Discussion

LASIK is the most popular refractive surgery to correct myopia and astigmatism.<sup>[1,3]</sup> One of the complications of LASIK is under or overcorrection, and residual myopia either due to undercorrection or regression is common in most refractive procedures.<sup>[2,7]</sup> Factors associated with

**Table 2: Comparison of studies of laser *in situ* keratomileusis and photorefractive keratectomy enhancement**

Study	Eyes	SE (mean) D	UCVA $\geq$ 20/40 (%)	$\pm$ 0.50 D (%)	$\pm$ 1.00 D (%)	Lost lines %
Lyle and Jin <sup>[12]</sup>	157	-1.28 $\pm$ 0.57	98.1	81.5	97.5	1.3
Febbraro <i>et al.</i> <sup>[13]</sup>	52	-0.77 $\pm$ 0.94	100	87	96	3
Rashad <sup>[14]</sup>	35	-2.17 $\pm$ 0.82		91.5		0
Agarwal <i>et al.</i> <sup>[15]</sup>	50	-4.30 $\pm$ 1.83		62	88	2
Netto and Wilson <sup>[16]</sup>	334	-1.2 $\pm$ 0.6	92	80.5	96	6
Beerthuisen and Siebelt <sup>[11]</sup>	18	-0.63 $\pm$ 0.87				0
Saeed <i>et al.</i> <sup>[17]</sup>	22	-1.23 $\pm$ 0.95	86.4		77.3	0
Current study (2014)	102	-1.32 $\pm$ 0.61	92.8	83.9	94.6	2.7

D=Diopter, SE=Spherical equivalent, UCVA=Uncorrected visual acuity

regression includes the degree of the refractive error (myopia or astigmatism) and the patients' age (higher risk in young patients).<sup>[9]</sup> Other possible mechanisms for regression are proliferation of keratocytes in the corneal stroma and epithelial hyperplasia. Early regression of refractive effect after LASIK appears to be a consequence of an increase in corneal thickness associated with central corneal steepening.

Higher myopia usually has a higher rate of residual myopia compared to moderate and low myopia.<sup>[8]</sup> In myopia  $>$ -10.00 D, the patient satisfaction is usually poor.<sup>[7]</sup> Higher initial corrections and residual astigmatism were associated with a significantly higher rate of retreatment. Patients older than 40 years were at greater risk for retreatment.<sup>[8]</sup>

Retreatment is usually done either by lifting the original flap<sup>[16]</sup> or creating a second flap.<sup>[18]</sup> Reelevating the flap is relatively safe and predictable, with a low risk of sight-threatening complications.<sup>[16,19]</sup> The results with doing a new flap are less satisfactory compared to those done by lifting the original flap even if it is lifted years later.<sup>[18]</sup> Both procedures are safe, effective, and highly predictable for enhancements, but flap complications may be more likely with recutting.<sup>[18]</sup> Rare complications of flap-lifting retreatment are a higher risk of epithelial ingrowth.<sup>[20]</sup>

Intraoperative pachymetry of the stromal bed during retreatment is strongly recommended as the residual stromal bed and flap thickness changes between primary and retreatment. There is a tendency for the measured stromal bed at retreatment to be thinner and for the flap to be thicker than previously measured.<sup>[21]</sup> Intraoperative pachymetry and ablation depth measurements proved to be precise tools to predict stromal bed thickness before enhancement in eyes that had had primary myopic LASIK. This information may help in planning LASIK enhancements.<sup>[22]</sup>

PRK is performed when there is a concern about the remaining corneal thickness.<sup>[23]</sup> However, there are some disadvantages of PRK - mainly the development

of corneal haze and the limited effectiveness in the correction of high myopia.<sup>[24]</sup> Some authors strongly advise against PRK as an option to correct eyes previously treated by LASIK.<sup>[25]</sup> Others found that alcohol-assisted PRK retreatment on the surface of a LASIK flap is safe and effective in correcting small amounts of residual myopia.<sup>[11,23]</sup> After PRK, there is an increase in the tendency for the development of haze,<sup>[25]</sup> and some use MMC to reduce the haze while others do not.<sup>[24,26]</sup>

The UCVA after retreatment was 20/20 or better in 43.8% and 20/40 or better in 92.8% of eyes.<sup>[16]</sup> The SE was within  $\pm$  1.0 D in 94.6% of the eyes and within  $\pm$  0.5 D in 83.9% after retreatment.<sup>[16]</sup> About 1.8% lost one line of BSCVA and 0.9% lost two lines.

No sight-threatening complications such as infection, corneal ectasia, or retinal complications occurred postoperatively. All flap-lifting cases went smooth and without any complications such as torn flap or the development of macrostriae postoperatively. In our study, two eyes developed epithelial ingrowth, which was limited to the peripheral cornea and did not cause visual complications or require active treatment. Five eyes developed mild subepithelial corneal haze after retreatment with PRK and left no effect on patients' final vision.

We waited for minimum 6 months before retreatment, but many studies have shown that retreatment for LASIK in 6 weeks after the initial procedure is effective with minimal complications and good results.<sup>[13]</sup>

The main limitation of this study is that retreatment data can have a negative bias because patients with satisfactory refractive outcome usually do not return for follow-up, and patients who are happy with their results—even if they have residual myopia—are not keen to have reoperation. All these cases are not included in the data and not represented in this study, and this is also true for all published studies regarding retreatment. One of the limitations of this study is that retreatment by flap-lifting LASIK or PRK is not compared to each other.

## Conclusion

In summary, results in this and other studies indicate that retreatment after primary LASIK for residual myopia is a safe and effective procedure. To get good results, it is necessary to select patients properly, do the appropriate investigations, and wait for at least 6 months for residual myopia to stabilize. Enhancement can be done by lifting the previous flap or surface ablation on top of the flap, and both procedures are safe with minor complications. Further studies are needed to compare different techniques of treatment of residual refractive errors.

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## Conflicts of interest

The authors declare that there are no conflicts of interests of this paper.

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