Elliptical versus circular flap configuration in myopic eyes undergoing femtosecond laser in situ keratomileusis surgery: A contralateral eye study

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Purpose: To study whether a customized elliptical flap configuration offers any visual, refractive, or biomechanical advantage over the “conventional” circular flaps in patients undergoing myopic laser in situ keratomileusis (LASIK). Methods: A prospective interventional contralateral eye study was undertaken enrolling 290 eyes of 145 myopic patients (≤6.0D) undergoing LASIK, wherein the corneal flap was created in one eye using a customized elliptical flap configuration versus a conventional circular flap configuration in the other eye. Postoperatively, we compared the visual outcomes, change in higher-order aberrations, corneal asphericity, and corneal biomechanics. Results: The visual outcomes, including higher-order aberrations, were comparable between the two groups. Changes in spherical aberration (mean: 0.234–0.331 versus 0.234–0.42; \( P = 0.644 \)), corneal asphericity (−0.32–0.34 versus −0.34–0.45; \( P = 0.42 \)), corneal hysteresis (9.35–7.23 versus 9.4–6.71; \( P = 0.489 \)), corneal resistance factor (9.71–7.40 versus 10.38–6.9; \( P = 0.181 \)) were comparable between the elliptical and circular groups, respectively. Conclusion: We evaluated the usefulness of a customized elliptical flap configuration for performing LASIK surgery. Our data suggests that elliptical flaps may be associated with superior visual and biomechanical performance compared to circular flaps. This is certainly relevant in eyes with “borderline” pre-LASIK profile to improve patient satisfaction and safety after surgery.

Key words: Circular, elliptical, femtosecond LASIK

Refractive surgery, since its inception, has been an ever-evolving science. Be it the instrumentation, technology, or techniques involved in performing this surgery, the ability of refractive practices and surgeons worldwide to experiment and embrace new techniques or modifications of existing caveats is a major factor in the ever-improving outcomes of refractive surgery. One such arm of refractive surgery is the process of construction of a LASIK flap, which has transitioned from a variety of microkeratomes to femtosecond lasers. One of the advantages of a LASIK flap created using femtosecond laser is the ability to customize the flap creation, unlike that with the microkeratome.\[1\] Femtosecond LASIK flaps can be precisely programmed in terms of their size, side cut angle, hinge length as well as flap thickness in order to optimize the outcomes of refractive surgery.\[2\] Newer technology including the iFS femtosecond laser (Johnson and Johnson Vision Care, Inc.) has the ability to produce customized elliptical corneal flaps rather than circular ones.\[3\] It is believed that an elliptical flap prevents resection of the vital peripheral corneal stromal fibers that contribute greatly to the biomechanical strength of the cornea. A wider hinge angle is also possible, which increases the flap stability.\[4\] The flap hinge moves peripherally and thus allows us to maximize the stromal bed exposure for full delivery of the excimer laser. Some investigators have suggested this may contribute to lesser-induced corneal aberrations, thereby improving visual outcomes with elliptical flaps.\[5\] However, there is no published literature regarding the actual benefit of an elliptical flap configuration when used in a clinical setting.

A single non-peer-reviewed publication compared visual outcomes of elliptical and circular flap LASIK and concluded that there was no visual benefit in eyes undergoing LASIK using elliptical flaps. Each patient underwent either elliptical or circular flap LASIK. Thus, no contralateral eye comparison was done. Also, the authors did not study the influence of elliptical flap configuration on the biomechanical properties of the cornea or corneal asphericity.\[5\]

In this study, we report the performance of the eyes undergoing LASIK surgery using a customized elliptical flap configuration versus “conventional” circular flaps. This comparison of the visual outcomes (including ocular higher-order aberrations), corneal asphericity, and biomechanical characteristics of the cornea with elliptical flap customization will help establish the usefulness of this intervention in clinical practice.

Methods

This randomized, prospective, interventional, clinical study was carried out on 290 contralateral eyes of 145 patients attending the Refractive Surgery Clinic. Ethical clearance was obtained by the institutional ethical committee vide NK/6677/Study/125. The study adhered to the tenets of the declaration of Helsinki and informed consent was obtained from all patients included in the study.

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Surgical technique

The surgical parameters of the femtosecond laser flaps were similar in both the groups, including formation of nasal hinge, constant flap thickness of 100 microns, hinge length of 4 mm, hinge angle of 55 degrees, and flap edges at 90 degrees. Minimum horizontal flap diameter setting was kept at 8.8 mm. However, for creating an elliptical flap group, 2% oversizing of flap diameter was done (for example, for a circular flap of horizontal diameter of 9.0 mm, 2% oversizing for creating elliptical flap resulted in a horizontal diameter of 9.18 mm). All patients underwent excimer laser photoablation using the wavefront-optimized ablation profile and a fixed 6.0-mm optical zone. Intraoperative complications, if any, were noted. Postoperative follow-up was scheduled at the 1st day, 1-week, 3 weeks, and 12 weeks. For the purpose of analysis, the preoperative data were compared with the data obtained at the 12-week follow-up. Postoperative steroid antibiotic antibiotic drops were prescribed for 2 weeks to all the patients.

Results

This study comprised 145 patients (290 eyes; 145 eyes in each treatment group). The mean age of the patients was 24.10 ± 3.73 years (range: 18–36 years) (elliptical group: 24.35 ± 3.63; circular group: 23.82 ± 3.84 years). Eighty-two (56.6%) patients were females and sixty-three (43.4%) were males.

Table 1: Between-group comparison of preoperative characteristics and parameters

| Parameter               | Elliptical Group (n=145) | Circular Group (n=145) | P       |
|-------------------------|--------------------------|------------------------|---------|
| Sphere (D)              | −4.14±0.03               | −4.12±0.02             | 0.932   |
| Cylinder (D)            | −0.52±0.55               | −0.51±0.55             | 0.804   |
| MRSE (D)                | −4.3±2.15                | −4.35±2.1              | 0.858   |
| Pachymetry (micron)     | 530±32.76                | 537.1±30.97            | 0.897   |
| Flat Keratometry (D)    | 43.27±2.72               | 42.32±2.45             | 0.925   |
| Steep Keratometry (D)   | 44.16±1.46               | 44.38±1.53             | 0.532   |
| Optical Zone (mm)       | 6.00                     | 6.00                   |         |
| RSB (micron)            | 352.37±29.95             | 354.56±32.36           | 0.157   |

D=Dioptries, mm=millimeters
Predictability
The mean MRSE 3 months postoperatively was 0.03 ± 0.1 and 0.02 ± 0.1 in the elliptical group and circular group, respectively (P = 0.858) [Table 2]. Both the groups had similar predictability (P = 0.858).

Corneal biomechanics
Both the corneal hysteresis (CH) and corneal resistance factor (CRF) decreased postoperatively in both groups. The CH changed from 9.35 ± 1.67 to 7.7 ± 3.04 (P = 0.02) in the elliptical LASIK group and from 9.4 ± 1.45 to 7.1 ± 1.14 (P = 0.012) in the circular LASIK group. CRF changed from 9.71 ± 1.59 to 7.4 ± 3.89 (P = 0.04) in the elliptical LASIK group and from 10.38 ± 1.56 to 6.93 ± 1.65 (P = 0.023) in the circular LASIK group. The amount of change was less in the elliptical group as compared to the circular group (CH P = 0.02 versus 0.012; CRF P = 0.04 versus 0.023) although it was not statistically significant.

Corneal asphericity
There was a significant increase in the value of corneal asphericity in both groups (P = 0.03 and 0.02). Although, corneal asphericity changed from −0.32 ± 0.02 to 0.34 ± 0.12 in elliptical LASIK group and from −0.34 ± 0.03 to 0.45 ± 0.13 in the circular LASIK group, there was no significant difference between the two groups (P = 0.42).

Higher-order aberrations
Preoperatively, ocular (whole-eye) HOAs at 6.0-mm pupil diameter were comparable between the two groups. At 3 months, there was statistically significant induction of a majority of the ocular HO aberrations, including total, spherical, coma 0, trefoil 0, and trefoil 90, in both groups when compared with the preoperative values [Table 3]. The total HOAs changed from 0.62 ± 0.32 to 1.12 ± 0.47 in the elliptical group (P = 0.002) and from 0.64 ± 0.30 to 1.14 ± 0.41 in the circular LASIK group (P = 0.011). The spherical aberration changed from 0.234 ± 0.44 to 0.33 ± 0.5 (P = 0.001) in the elliptical group and from 0.234 ± 0.24 to 0.42 ± 0.53 (P = 0.000) in the circular group. Intergroup comparison at 3 months did not show any statistically significant difference in any of the aberrations between the two groups (P > 0.05).

Discussion
The introduction of femtosecond lasers has significantly improved the safety and outcomes following refractive surgery.⁶⁻⁹ Femtosecond lasers create flaps that are more precise, and tend to have a more uniform and predictable thickness, shape, and hinge width. However, corneal flaps weaken the cornea, besides introducing corneal aberrations in patients undergoing LASIK. There is an ever-increasing focus on modifications in the architecture of the corneal flap, which is aimed at minimizing the induced corneal aberrations and maintaining better stability of the cornea. Our study presents one such modification of flap construction, which may favorably influence the outcomes of myopic LASIK surgery. To our knowledge, this is the first large, prospective study comparing the outcomes of conventional circular flap and elliptical flap LASIK.

In the present study, the visual outcomes were comparable between the two groups. These visual outcomes were consistent with those published in several other studies.⁶⁻¹⁰ In a comparative case series, none of the eyes in the femtosecond LASIK group lost any lines of Snellen visual acuity, and 12 eyes (25.0%) gained 1 line.¹¹ This was consistent with our study in which none of the eyes lost any line of Snellen visual acuity, 17 (12%) patients in elliptical group and 15 (10%) patients in circular group gained 1 line in visual acuity. In our study, predictability was comparable between the two groups; the mean MRSE postoperatively was 0.03 ± 0.1 and 0.02 ± 0.1 in the elliptical and circular group, respectively. In a retrospective analysis of 106 eyes undergoing femtosecond LASIK, 91% eyes achieved MRSE of ± 0.5D.¹² In another study by Chan et al.,¹³ (51 eyes), the mean postoperative spherical equivalent was −0.30 (0.26) D 12 months after surgery. Thirty-seven eyes (93%) in the femtosecond group were within 0.5 D of the target refractive change. The visual outcomes in our series also compares favorably with the results of Hassan et al.,¹⁴ Calvo et al.,¹⁵ and Jain et al.²⁰ for femtosecond laser LASIK. However, there is no study describing the influence of elliptical flap configuration on visual outcomes in LASIK.

We also compared the postoperative ocular higher-order aberrations. We noted a significant increase in the total higher-order aberrations, spherical aberrations, coma, trefoil, and tetrafoil in both groups after the refractive surgery. However, the difference was not statistically significant between the two groups. There is no literature comparing the difference in the induction of higher-order aberrations when an elliptical or circular flap configuration is used. Overall, the postoperative higher-order aberration profile was similar to that previously reported in the literature.¹⁵⁻¹⁸ The results of our study were consistent with a study by Jain et al.¹⁴ In this study, the increase in total HOA was 0.43-µm RMS and in spherical aberrations was 0.38-µm RMS. Similarly, in our study, the quantum of increase in total higher-order aberrations was 0.49 in the elliptical group and 0.5 in the circular group, whereas the increase in spherical aberration was 0.097 in the elliptical group and 0.186 in the circular group. Although, the intergroup difference was not statistically significant, the spherical aberrations increased to a lesser degree in the elliptical group. This may imply a better visual performance of patients undergoing LASIK with elliptical flap configuration.

It is well known that LASIK surgery leads to weakening of the cornea because of the cutting of the corneal stromal fibers along with corneal thinning associated with excimer laser photoablation.¹⁹⁻²⁰ Gatinel et al.²¹ reported the effect of corneal flap construction on corneal biomechanical strength. They performed ORA on an eye where only the flap had been constructed but not lifted to perform excimer laser ablation. They showed an immediate decrease in CH as well as CRF in

Table 2: Between-group comparison of refractive outcomes

|                     | Group I (Elliptical LASIK) | Group II (Circular LASIK) | P       |
|---------------------|---------------------------|---------------------------|---------|
|                     | Preop | Postop | P       | Preop | Postop | P       |
| Spherical error (D) | −4.14±0.03 | 0.02±0.13 | 0.001* | −4.12±2.02 | 0.02±0.25 | 0.011* | 0.932 |
| Cylindrical error (D) | −0.52±0.54 | −0.006±0.05 | 0.3 | −0.51±0.55 | 0.004±0.09 | 0.2 | 0.804 |
| MRSE (D)            | −4.3±2.15 | 0.03±0.1 | 0.002* | −4.35±2.1 | 0.02±0.1 | 0.025* | 0.858 |

MRSE=Mean Refractive Spherical Equivalent, D=Dioptre, *Statistically significant (P<0.05)
eyes where only flap had been created without excimer laser photoablation. Several other factors, including ablation depth, central corneal thickness, flap thickness, flap configurations, and surgical techniques, have been associated with changes in corneal biomechanics after LASIK surgery. This is reflected clinically as a decrease in CH and corneal biomechanics (CRF).
post LASIK surgery.\textsuperscript{[25,26]} In the present study, on comparing the two groups, the change in both corneal hysteresis as well as corneal resistance factor was not significant (CH $\textit{p} = 0.489$; CRF $\textit{p} = 0.181$). Thus, though not statistically significant, elliptical flaps caused lesser quantum of change of corneal biomechanics. This may be because of the more symmetrical distribution of the forces due to a more symmetrical flap configuration. This would certainly assume importance in patients with thin corneas or borderline biomechanical parameters where LASIK is being performed anyway. In a study by Elmodadder \textit{et al.},\textsuperscript{[27]} the impact of corneal flap creation on biomechanics was evaluated using ORA. They found a significant decrease in CH and CRF postoperatively (11.66 ± 1.41 mm of hg to 8.5 ± 1.53; 11.51 ± 1.25 to 9.49 ± 1.30) in the femtosecond LASIK group. The quantum of decrease in CH (3.1 in this study and 2.02 in our study) as well as CRF (2.02 in this study and 2.31 in our study) was comparable.

In another prospective comparative study by Zhang \textit{et al.},\textsuperscript{[28]} 80 eyes were studied for changes in corneal biomechanics after femtosecond LASIK. They found a significant decrease in CH as well as CRF (CH 10.83 ± 1.60 to 8.00 ± 1.32; CRF 10.71 ± 1.74 to 6.82 ± 1.40). The decrease in both the parameters was comparable.

Myopic refractive surgery also causes the central cornea to flatten, leading to a change in the curvature from prolate to oblate. Several studies have concluded that the change in corneal asphericity (from a normal “prolate” or negative $Q$ to “oblate” or positive $Q$) contributes to the increase in spherical aberrations, and thereby the visual performance after LASIK. “Oblateness” of the cornea and the co‑incident induction of spherical aberration has been correlated with decrease in contrast sensitivity as well as degradation of image quality thereby causing a poor low contrast vision, especially in dim light when the pupils dilate.\textsuperscript{[29]} It is logical, therefore, that procedures which induce a lesser change in corneal asphericity are preferable in patients undergoing refractive surgery. We noted a positive change in the corneal asphericity in all eyes (−0.32 ± 0.02 to 0.34 ± 0.12 in elliptical versus −0.34 ± 0.03 to 0.45 ± 0.13 in the circular group). The quantum of change in corneal asphericity was not statistically significant between both the groups. Our results are similar to those published by Bottos \textit{et al.},\textsuperscript{[30]} where the mean $Q$ value changed from −0.28 ± 0.11 to 0.35 ± 0.44 post LASIK surgery. However, it appears important that, although statistically non-significant, the quantum of change was lesser in the elliptical group compared to the circular group (preoperative versus postoperative change of mean $Q$ value of 0.68 versus 0.79, $\textit{p} = 0.42$). This may be due to a more symmetrical geometrical configuration of the elliptical flap, thus retaining the normal prolate configuration of the cornea after surgery.

**Conclusion**

In conclusion, we found no significant differences in terms of visual outcome (including higher-order aberrations) and corneal biomechanics in patients undergoing LASIK with elliptical or circular flap configuration. However, patients with elliptical flap configuration had better corneal biomechanical stability with lesser-induced spherical aberrations. Thus, the results of our study add a new perspective on the usefulness of customized LASIK flap creation using a femtosecond laser. This simple modification is another small step in making LASIK surgery safer for our patients, especially in the so-called “borderline” cases with thinner, and biomechanically “borderline,” preoperative corneal parameters. This study has a minimum bias as it was a contralateral eye study and we can certainly assume the differences between both eyes of the same patient to be non-significant.

**Declaration of patient consent**

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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**Conflicts of interest**

There are no conflicts of interest.

**References**

1. Pajic B, Västindis J, Pajic-Eggspeuhler B, Gatzioufas Z, Hafezi F. Femtosecond laser versus mechanical microkeratome-assisted flap creation for LASIK: A prospective, randomized, paired-eye study. Clin Ophthalmol 2014;8:1883–9.
2. Knox Cartwright NE, Tyrer JR, Jaycock PD, Marshall J. Effects of variation in depth and side cut angulations in LASIK and thin‑flap LASIK using a femtosecond laser: A biomechanical study. J Refract Surg 2012;28:419–25.
3. Slade SG. The use of the femtosecond laser in the customization of
corneal flaps in laser in situ keratomileusis. Curr Opin Ophthalmol 2007;18:314–7.
4. Aristeidou A, Taniguchi EV, Tsatsos M, Muller E, McAlinden C, Pineda R, et al. The evolution of corneal and refractive surgery with the femtosecond laser. Eye Vis (Lond) 2015;2:12.
5. Probst LE. Circular, elliptical flap comparison takes shape. Modern Medicine Feature Articles. Ophthalmology Times July 1, 2013.
6. Kahuam-López N, Navas A, Castillo-Salgado C, Graue-Hernandez EO, Jimenez-Corona A, Ibarra A. Laser-assisted in-situ keratomileusis (LASIK) with a mechanical microkeratome compared to LASIK with a femtosecond laser for LASIK in adults with myopia or myopic astigmatism. Cochrane Database Syst Rev 2020;7:CD012946.
7. Shortt AJ, Allan BD, Evans JR. Laser-assisted in-situ keratomileusis (LASIK) versus photorefractive keratectomy (PRK) for myopia. Cochrane Database Syst Rev 2013;1:CD005135.
8. Zhang ZH, Jin H, Suo Y, Patel SV, Montes-Mico R, Manche EE, et al. Femtosecond laser and versus mechanical microkeratome laser in situ keratomileusis for myopia: Meta-analysis of randomized controlled trials. J Cataract Refract Surg 2011;37:2151–9.
9. Liu HH, Hu Ying, Cui HP. Femtosecond laser in refractive and cataract surgerys. Int J Ophthalmol 2015;8:419-26.
10. Nordan LT, Slade SG, Baker RN, Suarez C, Juhasz T, Kurtz R. Femtosecond laser flap creation for laser in situ keratomileusis: Six-month follow-up of initial U.S. clinical series. J Refract Surg 2003;19:9-14.
11. Munoz G, Diego A, Blasco T, Gracia-Lazo S, Cervino-Exposito A. Long-term comparison of corneal aberration changes after laser in situ keratomileusis: Mechanical microkeratome versus femtosecond laser flap creation. J Cataract Refract Surg 2010;36:1934–44.
12. Kezirian GM, Stonecipher KG. Comparison of the IntraLase femtosecond laser and mechanical keratomes for laser in situ keratomileusis. J Cataract Refract Surg 2004;30:804–11.
13. Chan A, Ou J, Manche EE. Comparison of the femtosecond laser and mechanical keratome for laser in situ keratomileusis. Arch Ophthalmol 2008;126:1484–90.
14. Hassan A, Massoud T, Nouby G, Fathilla A. Comparison of visual outcomes and higher order aberrations of wavefront-optimized and wavefront-guided myopic laser in situ keratomileusis. Egypt J Cataract Refract Surg 2017;23:1-10.
15. Calvo R, McLaren JW, Hodge DO, Bourne WM, Patel SV. Corneal aberrations and visual acuity after laser in situ keratomileusis: Femtosecond laser versus mechanical microkeratome. Am J Ophthalmol 2010;149:785–93.
16. Jain AK, Malhotra C, Pasari A, Kumar P, Moshisfar M. Outcomes of topography-guided versus wavefront-optimized laser in situ keratomileusis for myopia in virgin eyes. J Cataract Refract Surg 2016;42:1302–11.
17. Xia LK, Ma J, Liu HN, Shi C, Huang Q. Three-year results of small incision lenticule extraction and wavefront-guided femtosecond laser-assisted laser in situ keratomileusis for correction of high myopia and myopic astigmatism. Int J Ophthalmol 2018;11:470-7.
18. Gobbe M, Reinstein DZ, Archer TJ. LASIK-induced aberrations: Comparing corneal and whole-eye measurements. Optom Vis Sci 2015;92:447-55.
19. Farah SG, Azar DT, Gurdal C, Wong J. Laser in situ keratomileusis: Literature review of a developing technique. J Cataract Refract Surg 1998;24:989–1006.
20. Pallikaris IG, Papatzanaki ME, Siganos DS, Tsilimbaris MK. A corneal flap technique for laser in situ keratomileusis. Human studies. Arch Ophthalmol 1991;109:1699-702.
21. Gatinel D, Chaabouni S, Adam P-A, Munc J, Puech M, Hoang-Xuan T. Corneal hysteresis, resistance factor, topography, and pachymetry after corneal lamellar flap. J Refract Surg 2007;23:76–84.
22. Jonas JB, Vosmerbaeumer U. Femtosecond laser penetrating keratoplasty with conical incisions and positional spikes. J Refract Surg 2004;20:397.
23. Luce DA. Determining in vivo biomechanical properties of the cornea with an ocular response analyzer. J Cataract Refract Surg 2005;31:156–62.
24. Ortiz D, Piñero D, Shabayek MH, Arnalich-Montiel F, Alió JL. Corneal biomechanical properties in normal, post-laser in situ keratomileusis, and keratoconic eyes. J Cataract Refract Surg 2007;33:1371–5.
25. Pepose JS, Feigenbaum SK, Qazi MA, Sanderson JP, Roberts CJ. Changes in corneal biomechanics and intraocular pressure following LASIK using static, dynamic, and noncontact tonometry. Am J Ophthalmol 2007;143:39-47.
26. Kamiya K, Shimizu K, Ohmoto F. Comparison of the changes in corneal biomechanical properties after photorefractive keratectomy and laser in situ keratomileusis. Cornea 2009;28:765–76.
27. Elmoddather M, Nooredin A. Biomechanical corneal changes post LASIK with mechanical microkeratome flap versus femtosecond flap. Egypt J Hosp Med 2018;3:7574-9.
28. Zhang J, Zheng L, Zhao X, Xu Y, Chen S. Corneal biomechanics after small-incision lenticule extraction versus Q-value guided femtosecond laser-assisted in situ keratomileusis. J Current Ophthalmol 2018;28:181-7.
29. Ang RT, Martinez GA, Caguioa JB, Reyes KB. Comparison in the quality of vision and spherical aberration between spherical and aspheric intraocular lenses. Philipp J Ophthalmol 2008;33:9-12.
30. Botos KM, Leite MT, Aventura-Isidro M, Bernabe-Ko J, Wongpitoonpiya N, Ong-Camara NH, et al. Corneal asphericity and spherical aberration after refractive surgery. J Cataract Refract Surg 2011;37:1109–15.