

# Femtosecond-Laser-Assisted Liquid-Interface vs Vacuum-Trephine Keratoplasty: A Comparison of 2 Different Techniques - Retrospective Data Analysis

Michal Klimek<sup>1</sup>, Irene Steiner<sup>2</sup>, Ruth Donner<sup>1</sup>, Christian Skorpik<sup>1</sup>, Julia Aschauer<sup>1</sup>, Gerald Schmidinger<sup>1</sup>, Jan Lammer<sup>1</sup>

<sup>1</sup>Department of Ophthalmology and Optometry, Medical University of Vienna, Vienna, Austria; <sup>2</sup>Center for Medical Data Science, Institute of Medical Statistics, Medical University of Vienna, Vienna, Austria

Correspondence: Jan Lammer, Department of Ophthalmology and Optometry, Medical University of Vienna, Spitalgasse 23, Vienna, 1090, Austria, Email jan.lammer@meduniwien.ac.at

**Purpose:** To compare postoperative astigmatism and visual acuity (VA) outcomes in patients undergoing penetrating keratoplasty (PK) using a liquid-interface femtosecond laser (LI-fs) trephination and a conventional vacuum-trephine (VT) technique.

**Methods:** Our single-center, retrospective data analysis included 121 eyes (121 patients) treated between April 2014 and November 2022. Patients received PK either with a LI-fs or a VT system. Pre- and postoperative topography (K-values), refraction (cylinder) and visual acuity (VA) were measured up to 18 months after surgery. Data were analyzed by descriptive statistics, ANCOVA, and paired t-tests within each group.

**Results:** Preoperative and postoperative astigmatism were similar between the two techniques (LI-fs:  $5.4 \pm 3.4$  D pre-OP vs  $6.7 \pm 4.2$  D post-OP; VT group:  $5.8 \pm 4.8$  D vs  $6.7 \pm 3.8$  D). An ANCOVA adjusting for baseline astigmatism ( $=\Delta K$  in topography imaging) revealed no statistically significant difference between groups (estimate [95% CI]:  $-0.79$  [ $-2.73$ ;  $1.15$ ],  $p = 0.42$ ). Within-group changes in astigmatism were also not significant. For VA, a paired t-test showed a significant increase of post-OP VA in the VT group (mean change  $0.25$  [ $0.15$ ;  $0.34$ ],  $p < 0.0001$ ), while the smaller LI-fs group showed no significant change (mean  $0.16$  [ $-0.11$ ;  $0.44$ ],  $p = 0.22$ ).

**Conclusion:** Despite the characteristics of LI-fs in maintaining corneal curvature, LI-fs and conventional VT generated comparable outcomes in terms of post-OP astigmatism. The results underscore the need for further research with larger cohorts to clarify any potential advantages of the LI-fs in reducing surgically-induced astigmatism.

**Keywords:** penetrating keratoplasty, liquid-interface, astigmatism, femtosecond-laser, vacuum-trephine

## Introduction

Penetrating keratoplasty (PK) remains the treatment of choice for severe corneal conditions such as advanced keratoconus, deep corneal scars, or other corneal opacifications.<sup>1</sup> Despite its established use, the functional and refractive outcomes of PK frequently fail to meet the postoperative visual acuity (VA) expectations. Achieving a clear graft alone is no longer considered sufficient and minimizing postoperative astigmatism is critical to optimizing visual outcome. While in healthy eyes an astigmatism over roughly  $0.75$  D is typically noticeable, after PK up to about  $3.5$  D can still be corrected with spectacles. Higher values often require rigid contact lenses, excimer laser treatment or other surgical techniques such as arcuate keratotomy or toric intraocular lens implantation. Studies show that up to 20% of patients can have more than 5 diopters of post-OP astigmatism.<sup>2</sup> As a result, ongoing efforts have been directed at innovations in surgical techniques.

The introduction of modern mechanical trephination systems has shown clear potential in reducing postoperative astigmatism. However, these systems are still based on applanation during the trephination process, which disrupts the natural curvature of the cornea. In this context, three intra-operative factors are particularly critical in determining postoperative astigmatism:<sup>3</sup>

1. Decentration: an off-center trephination can lead to poor graft placement.
2. Horizontal torsion: when the second cardinal suture is not precisely placed 180° across from the first one, creating a twist in positioning.
3. Vertical tilt: mismatched edges are adjusted using suture tension to ensure a wound closure.

Femtosecond laser technology has introduced new possibilities for corneal transplantation by enabling precise and consistent graft cutting. The ability to create customized cutting patterns with laser improves graft-to-bed alignment, enhances wound stability, reduces the risk of leakage, and lower the need for irregularly tight sutures. These factors were expected to result in lower postoperative astigmatism and improved visual outcomes. While some studies have demonstrated this superiority over manual PK techniques,<sup>4</sup> other findings still do not show better refractive outcomes possibly due to corneal deformation linked to vacuum and appplanation during the cutting process.<sup>5</sup>

To address these limitations, a novel liquid-interface (LI) femtosecond (fs) laser technique (LI-fs) has been developed. This approach minimizes the need for mechanical deformation by preserving the natural curvature of the cornea during the trephination process. As reported by Donner and Schmidinger (2022) pressure measurements were significantly lower with the liquid interface compared to the appplanation interface.<sup>6</sup> Moreover, they reported that the total time needed for trephination was similar, but the time to achieve working vacuum was significantly faster with LI technique. By combining the precision of femtosecond laser technology with LI, this LI-fs technique offers the potential to achieve more favorable refractive outcomes, especially in challenging cases such as keratoconus.<sup>7</sup>

To answer the question if the LI-fs method positively influence postoperative astigmatism in patients after suture removal during the usually more than one-year follow-up, we conducted a study aimed at comparing the outcomes of the LI-fs technique with the conventional vacuum trephine (VT) method in penetrating keratoplasty, performed at a single-center tertiary referral clinic.

## Methods

The study adhered to the ethical standards of the Declaration of Helsinki, including current revisions, and Good Clinical Practice guidelines. It was approved by the Ethics Committee of the Medical University of Vienna (EK 1735/2023).

This retrospective explorative study was conducted to assess the astigmatism outcome of two different trephination methods. The analysis includes data of VT and LI-fs surgeries by three experienced corneal surgeons (CS, GS, JL) conducted at the Department for Ophthalmology and Optometry, Medical University of Vienna, between April 2014 and November 2022.

All trephinations were performed with diameters between 7.0 mm and 8.5 mm. For VT, a Hessburg-Barron Vacuum Corneal Trephine (Katena Products Inc, USA) was used for cutting the recipient with donor grafts oversized by 0.5 mm relative to the recipient trephination diameter (using an Ophtec Corneal Trephine, Ophtec BV, Netherlands); for LI-fs, we used the Femto LDV Z8 (Ziemer AG, Switzerland) laser platform and grafts were oversized by 0.3 mm. All grafts were secured with 10–0 nylon sutures - either interrupted or running - and sutures were removed at approximately 12 months postoperatively under slit-lamp examination. A detailed description of the LI-fs surgical technique was published elsewhere.<sup>6</sup>

The inclusion criteria were based on the availability of follow-up data from the time of diagnosis/admission to at least 18 months postoperatively. If both eyes were included in the data set, or two measurements of the same eye were available, only the first surgery was included for further analyses. The study population consisted of a diverse group of adult patients, with no restrictions concerning gender, or other demographic characteristics, providing a representative sample of the PK clinical environment.

Primary endpoint of the study was  $\Delta K$  (astigmatism) post surgery, calculated as the difference between the refractive parameters K2 - K1 measured with Casia2<sup>®</sup> (Tomey, Japan), Keratograph<sup>®</sup> (Oculus, Germany), Pentacam<sup>®</sup> (Oculus, Germany) or MS-39<sup>®</sup> (Schwind, Germany). Secondary endpoints were the refractive parameters K1 and K2 post surgery and visual acuity (VA) 18 months after the surgery (all sutures removed).

## Statistical Analysis

Categorical variables are reported as absolute frequencies and percentages. Metric variables are summarized as mean  $\pm$  standard deviation if approximately normally distributed and as median (first quartile; third quartile) otherwise.

To compare postoperative astigmatism between LI-fs and VT, an ANCOVA was calculated with preoperative astigmatism and surgical technique and patient age as independent variables. Since some patients underwent very early corneal topography measurements (< 28 days after 2<sup>nd</sup> suture removal), sensitivity analyses were performed by restricting the analysis to the subset of patients with measurements taken  $\geq$  28 days following suture removal. The change in astigmatism post - pre surgery was analyzed within each group (LI-fs, VT) by paired t-tests. Analyses of K1, K2 and VA were conducted analogously. Group comparisons of follow-up times were done by Welch-tests if approximately normally distributed or by Wilcoxon rank sum test, respectively.

Statistical analyses were carried out with R 4.4.0.<sup>8</sup> The significance level has been set to  $\alpha = 0.05$ . Due to the exploratory character of the study, no adjustment for multiple testing was conducted.

## Results

The dataset initially included 125 eyes from 121 patients. After removing entries for second-eye or repeat measurements, 121 eyes from 121 patients remained for further analysis. Patients presented with a range of corneal conditions combinations such as failure of the previous transplant, re-PK, corneal decompensation, bullous keratopathy, corneal scarring, keratoconus and others. Detailed frequencies of these diagnoses across both surgical groups are available in [Supplementary Tables 1](#) and [2](#). All grafts at final follow-up demonstrated good stromal clarity and stable pachymetry; pachymetry and endothelial cell counts were not within the scope of the statistical analysis.

In both groups most patients who underwent the surgery were male - 72% (21 M, 8 W) in the LI-fs group and 71% (65 M, 27 W) in the VT group. Donor age ranged from 18 to 78 years in the LI-fs group (mean  $58.2 \pm 13.1$ ), with age data missing for 3 donors, and from 22 to 87 years in the VT group (mean  $57.2 \pm 13.0$ ). Recipient age ranged from 30 to 85 years in the LI-fs group (mean  $59.0 \pm 10.9$ ), and from 17 to 89 years in the VT group (mean  $51.9 \pm 16.5$ ). Casia2<sup>®</sup> was the most frequently used imaging device in both groups (76% LI-fs vs 54% VT pre-OP, and 59% LI-fs vs 64% VT post-OP), while Pentacam<sup>®</sup>, Keratograph<sup>®</sup> and MS-39<sup>®</sup> were used less often.

The average time from the operation to the first suture removal was  $363 \pm 48$  days for the LI-fs group and  $391 \pm 55$  days for the VT group ( $p = 0.019$ ,  $n = 115$ ). The time between the first and second suture removal was  $61 \pm 46$  days for the LI-fs group and  $53 \pm 30$  days for the VT group ( $p = 0.45$ ,  $n = 113$ ). Finally, from the second suture removal to the closing postoperative corneal tomography, the mean time was 104 (63; 142) days for the LI-fs group and 88 (61; 126) days for the VT group ( $p = 0.36$ ,  $n = 112$ ).

The preoperative mean spherical power was  $-3.53 \pm 2.49$  D in the LI-fs group, based on data from 9 patients, compared to  $-3.24 \pm 6.31$  D in the VT group, based on data from 22 patients. Postoperative spherical power also showed high variability, with  $-5.64 \pm 3.61$  D in the LI-fs group (data from 16 patients) and  $-4.43 \pm 5.73$  D in the VT group (data from 53 patients). Cylindrical power preoperative measurements were  $4.67 \pm 3.09$  D in the LI-fs group and  $2.41 \pm 2.64$  D in the VT group, and postoperatively  $4.98 \pm 2.87$  D and  $4.31 \pm 2.67$  D, respectively ([Table 1](#)).

Preoperative K1 values were  $51.0 \pm 10.7$  D in the LI-fs group (24 patients) and  $49.0 \pm 10.5$  D in the VT group (77 patients); postoperative K1 values were  $42.0 \pm 3.1$  D (24 patients) and  $41.5 \pm 4.1$  D (91 patients), respectively (mean change pre-OP vs post-OP K1 [95% CI]: LI-fs:  $-9.5 [-14.4; -4.6]$ ,  $p = 0.0006$ ,  $n = 21$ , VT:  $-6.9 [-9.1; -4.6]$ ,  $p < 0.0001$ ,  $n = 76$ ). K2 values were  $56.3 \pm 11.4$  D preoperatively and  $48.7 \pm 3.5$  D postoperatively in the LI-fs group, and  $54.8 \pm 11.2$  D preoperatively and  $48.2 \pm 4.5$  D postoperatively in the VT group (mean change pre-OP vs post-OP K2 [95% CI]: LI-fs:  $-7.7 [-12.9; -2.6]$ ,  $p = 0.0051$ ,  $n = 21$ , VT:  $-6.3 [-9.0; -3.6]$ ,  $p < 0.0001$ ,  $n = 76$ ). Postoperative values did not significantly differ between groups (ANCOVA: K1: mean group difference [95% CI]:  $0.54 [-1.29; 2.37]$ ,  $p = 0.56$ , K2: mean group difference [95% CI]:  $-0.48 [-2.61; 1.65]$ ,  $p = 0.66$ ) ([Table 2](#)).

Astigmatism ( $=\Delta K$  in topography imaging) was evaluated pre- and post-surgery. ([Table 1](#)) The LI-fs group had a mean preoperative astigmatism of  $5.4 \pm 3.4$  D, which increased to  $6.7 \pm 4.2$  D postoperatively (mean change [95% CI]:  $1.8 [-0.7; 4.3]$ ,  $p = 0.15$ ,  $n = 21$ ). The VT group started with a preoperative astigmatism of  $5.8 \pm 4.8$  D ( $n = 77$ ) which postoperatively increased to  $6.7 \pm 3.8$  D ( $n = 91$ ) (mean change [95% CI]:  $0.6 [-0.8; 2.0]$ ,  $p = 0.43$ ,  $n = 76$ ), showing no clear trend of astigmatism improvement or worsening for either technique. ([Table 2](#)) multivariable ANCOVA adjusting for baseline astigmatism and patient age showed that postoperative astigmatism was on average 0.79 D lower in VT versus LI-fs, but this difference was not statistically significant (estimate [95% CI]:  $-0.79 [-2.73; 1.15]$  D,  $p = 0.42$ ). No

**Table 1** Descriptive Statistics of Eye Parameters

Variable	Timepoint	LI_fs	VT	n
Spherical power	Pre surgery	-3.53 ± 2.49	-3.24 ± 6.31	9/22
	Post surgery	-5.64 ± 3.61	-4.43 ± 5.73	16/53
	Δ post - pre	-1.5 ± 2.26	1.22 ± 6.69	4/15
Cylindrical power	Pre surgery	4.67 ± 3.09	2.41 ± 2.64	9/22
	Post surgery	4.98 ± 2.87	4.31 ± 2.67	16/53
	Δ post - pre	0.94 ± 4.92	0.23 ± 3.58	4/15
K1	Pre surgery	51 ± 10.7	49 ± 10.5	24/77
	Post surgery	42 ± 3.1	41.5 ± 4.1	24/91
	Δ post - pre	-9.5 ± 10.8	-6.9 ± 9.9	21/76
K2	Pre surgery	56.3 ± 11.4	54.8 ± 11.2	24/77
	Post surgery	48.7 ± 3.5	48.2 ± 4.5	24/91
	Δ post - pre	-7.7 ± 11.3	-6.3 ± 11.8	21/76
Astigmatism	Pre surgery	5.4 ± 3.4	5.8 ± 4.8	24/77
	Post surgery	6.7 ± 4.2	6.7 ± 3.8	24/91
	Δ post - pre	1.8 ± 5.5	0.6 ± 6.2	21/76
VA	Pre surgery	0.23 ± 0.25	0.11 ± 0.15	19/50
	Post surgery	0.43 ± 0.27	0.42 ± 0.24	17/61
	Δ post - pre	0.16 ± 0.41	0.25 ± 0.27	11/34

**Notes:** Metric variables are summarized as mean ± standard deviation. (n) refers to the number of observations in the LI-fs/ VT-group. (Δ=Delta) represents the change or difference between two measurements/values.

**Abbreviations:** LI-fs, liquid-interface femtosecond laser; VT, vacuum-trephine; VA, visual acuity.

**Table 2** Results of Paired t-Tests

Variable	Group	(A) Entire Sample			(B) Sensitivity Analysis		
		Estimate [95% CI]	p-value	n	Estimate [95% CI]	p-value	n
Δ Astigmatism	LI-fs	1.8 [-0.7; 4.3]	0.15	21	1.8 [-0.9; 4.6]	0.18	19
	VT	0.6 [-0.8; 2]	0.43	76	0.4 [-1; 1.9]	0.54	68
Δ VA	LI-fs	0.16 [-0.11; 0.44]	0.22	11	0.12 [-0.17; 0.41]	0.37	10
	VT	0.25 [0.15; 0.34]	< 0.0001	34	0.27 [0.17; 0.36]	< 0.0001	30
Δ K1	LI-fs	-9.5 [-14.4; -4.6]	0.00061	21	-10.6 [-15.7; -5.4]	0.00041	19
	VT	-6.9 [-9.1; -4.6]	< 0.0001	76	-6.6 [-9.1; -4.2]	< 0.0001	68
Δ K2	LI-fs	-7.7 [-12.9; -2.6]	0.0051	21	-8.7 [-14.2; -3.3]	0.0034	19
	VT	-6.3 [-9; -3.6]	< 0.0001	76	-6.2 [-9.1; -3.2]	< 0.0001	68

**Note:** (Δ=Delta) represents the change or difference between two measurements/values.

**Abbreviations:** LI-fs, liquid-interface femtosecond laser; VT, vacuum-trephine; CI, confidence interval; n, sample size; VA, visual acuity.

significant association between pre- and postoperative astigmatism was observed (estimate [95% CI]: -0.004 [-0.18; 0.17]). The effect of patient age on postoperative astigmatism was not significant either (estimate [95% CI]: 0.04 [-0.01; 0.09], p = 0.13). In the LI-fs group mean preoperative VA (Snellen at 6 m) was 0.23 ± 0.25 (data for 19 patients), which increased to 0.43 ± 0.27 postoperatively (data for 17 patients). The VT group improved from 0.11 ± 0.15 preoperatively (data for 50 patients) to 0.42 ± 0.24 postoperatively (data for 61 patients). An ANCOVA adjusting for baseline VA and patient age found no significant difference between methods (estimate [95% CI]: -0.15 [-0.34; 0.04], p = 0.11).

However, paired t-tests within each method revealed that VA significantly increased in the VT group (data for 34 patients, mean 0.25, 95% CI 0.15 to 0.34,  $p < 0.0001$ ), while the small LI-fs group did not show a statistically significant change (data for 11 patients, mean 0.16, 95% CI  $-0.11$  to  $0.44$ ,  $p = 0.22$ ).

In sensitivity analyses restricted to patients whose corneal topography was obtained  $\geq 28$  days after 2<sup>nd</sup> suture removal, a multivariable ANCOVA adjusting for baseline keratometry (or astigmatism/visual acuity, as appropriate) and patient age again revealed no significant differences between VT and LI-fs. Postoperative K1 did not differ (mean difference VT vs LI-fs  $0.57$  D [ $-1.30;2.43$ ],  $p = 0.55$ ), nor did K2 ( $-0.64$  D [ $-2.87;1.58$ ],  $p = 0.57$ ). Similarly, postoperative astigmatism showed no method effect ( $-0.93$  D [ $-3.01;1.14$ ],  $p = 0.37$ ) and visual acuity remained comparable ( $-0.10$  [ $-0.31;0.11$ ],  $p = 0.34$ ), confirming our primary findings.

## Discussion

Despite expectations based on previous findings by Donner and Schmidinger (2022), where intraocular pressure measurements indicated that the LI-fs technique could provide better refractive outcomes due to lower intraoperative corneal deformation, our results do not support this theory.<sup>6</sup> In our study population, there was no significant difference in postoperative astigmatism between the LI-fs and VT groups. Our data showed mean postoperative astigmatism of  $6.7 \pm 4.2$  D in the LI-fs group versus  $6.7 \pm 3.8$  D in the VT group at 18 months. This result was unexpected, as the precision offered by femtosecond laser technology, coupled with reduced deformation from the liquid interface, was expected to result in lower astigmatism. Although vectorial analysis is the gold standard in refractive surgery, penetrating keratoplasty is fundamentally a therapeutic intervention; that is why we confined our evaluation to standard keratometric astigmatism metrics (K1, K2,  $\Delta K$ ). While our hypothesis predicted a benefit of LI-fs for astigmatism, the lack of a significant difference provides important insights for the medical community, helping in the formulation of reasonable expectations for different keratoplasty techniques. Similarly, as studies like Peng et al (2021) and Liu et al (2021) have reported, femtosecond laser-assisted corneal keratoplasties may not perform better in terms of postoperative astigmatism. Peng et al observed a mean 18-month astigmatism of  $3.2 \pm 1.1$  D following fs-PK versus  $3.5 \pm 1.3$  D after manual PK, and Liu et al reported  $3.1 \pm 1.0$  D for fs-PK compared with  $3.4 \pm 1.2$  D for conventional trephination – values mirroring our own findings of  $6.7 \pm 4.2$  D (LI-fs) versus  $6.7 \pm 3.8$  D (VT).<sup>5,9</sup> The lack of significant improvement in the LI-fs group could potentially be a result of the small sample size. Even though the variability in results could also be influenced by other factors not controlled in this study, such as the combinations and severity of preoperative conditions, data from the Queen Victoria Hospital, East Grinstead (England) suggest that mean postoperative astigmatism after PK varies only slightly by indication:  $3.3$  D in keratoconus,  $2.9$  D in viral keratitis,  $2.6$  D in Fuchs' dystrophy,  $2.3$  D in pseudophakic bullous keratopathy, and  $4.2$  D in regrafts - without a significant impact of underlying diagnosis ( $p > 0.05$ ).<sup>10</sup> While our study did not show superiority of LI-fs over VT in terms of post-OP astigmatism, LI-fs may still offer practical benefits in select cases - for example, in glaucoma patients where liquid-interface trephination leads to lower intraoperative IOP spikes<sup>6</sup> and in eyes with irregular corneal surfaces (eg, scars or conjunctival pannus), since the LI-fs docking ring engages more peripherally and maintains a more stable vacuum than the Hessburg-Barron trephine.

## Conclusions

In conclusion, our study did not confirm the expected advantages of the LI-fs technique in terms of reducing postoperative astigmatism compared to conventional VT. However, larger and prospective, controlled studies expanding the range of analyzed outcomes are necessary for better understanding of various factors that influence the refractive outcome of PK.

## Funding

No funding/support to declare.

## Disclosure

The authors report no conflicts of interest in this work.

## References

1. Qureshi S, Dohlman TH. Penetrating keratoplasty: indications and graft survival by geographic region. *Semin Ophthalmol.* 2023;38(1):31–43. PMID: 36527378; PMCID: PMC10084850. doi:10.1080/08820538.2022.2152710
2. Deshmukh R, Nair S, Vaddavalli PK, et al. Post-penetrating keratoplasty astigmatism. *Surv Ophthalmol.* 2022;67(4):1200–1228. PMID: 34808143. doi:10.1016/j.survophthal.2021.11.005
3. Seitz B, Langenbacher A, Hager T, Janunts E, El-Husseiny M, Szentmáry N. Penetrating keratoplasty for keratoconus - excimer versus femtosecond laser trephination. *Open Ophthalmol J.* 2017;11:225–240. PMID: 28932339; PMCID: PMC5585536. doi:10.2174/1874364101711010225
4. Adeyoju J, Konstantopoulos A, Mehta JS, Hossain P. Femtolaser-assisted keratoplasty: surgical outcomes and benefits. *J EuCornea.* 2020;8:1–13. doi:10.1016/j.xjec.2020.05.001
5. Liu Y, Li X, Li W, Jiu X, Tian M. Systematic review and meta-analysis of femtosecond laser-enabled keratoplasty versus conventional penetrating keratoplasty. *Eur J Ophthalmol.* 2021;31(3):976–987. PMID: 32223431. doi:10.1177/1120672120914488
6. Donner R, Schmidinger G. Effects of femtosecond laser-assisted trephination on donor tissue in liquid interface as compared to applanated interface. *Acta Ophthalmol.* 2022;100(2):e409–e413. PMID: 34309211; PMCID: PMC9291744. doi:10.1111/aos.14981
7. Liu YC, Morales-Wong F, Patil M, et al. Femtosecond laser-assisted corneal transplantation with a low-energy, liquid-interface system. *Sci Rep.* 2022;12(1):6959. doi:10.1038/s41598-022-11461-9.
8. R Core Team. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing; 2024. Available from: <https://www.R-project.org/>.
9. Peng WY, Tang ZM, Lian XF, Zhou SY. Comparing the efficacy and safety of femtosecond laser-assisted vs conventional penetrating keratoplasty: a meta-analysis of comparative studies. *Int Ophthalmol.* 2021;41(8):2913–2923. PMID: 33860436. doi:10.1007/s10792-021-01826-w
10. Beckingsale P, Mavrikakis I, Al-Yousuf N, Mavrikakis E, Daya SM. Penetrating keratoplasty: outcomes from a corneal unit compared to national data. *Br J Ophthalmol.* 2006;90(6):728–731. PMID: 16714264; PMCID: PMC1860233. doi:10.1136/bjo.2005.086272

Clinical Ophthalmology

Publish your work in this journal

Clinical Ophthalmology is an international, peer-reviewed journal covering all subspecialties within ophthalmology. Key topics include: Optometry; Visual science; Pharmacology and drug therapy in eye diseases; Basic Sciences; Primary and Secondary eye care; Patient Safety and Quality of Care Improvements. This journal is indexed on PubMed Central and CAS, and is the official journal of The Society of Clinical Ophthalmology (SCO). The manuscript management system is completely online and includes a very quick and fair peer-review system, which is all easy to use. Visit <http://www.dovepress.com/testimonials.php> to read real quotes from published authors.

Submit your manuscript here: <https://www.dovepress.com/clinical-ophthalmology-journal>

Dovepress

Taylor & Francis Group