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Visual functions and anterior ocular surface changes post trans-PRK

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Background: Corneal refractive surgery is rapidly evolving, and several surgical techniques have been developed, including transepithelial photorefractive keratectomy (trans-PRK).

Aim: To assess the impact of trans-PRK on visual acuity (VA), contrast sensitivity, spherical aberration, tear stability, corneal surface and thickness.

Setting: The study was conducted in Saudia Arabia, Al Madinah Almunwrah, Eye Specialist Center.

Methods: A quantitative, comparative, and prospective case study was conducted. Eighty-six consenting volunteers aged between 18 years and 40 years, including both genders, were enrolled in the study. Participants were grouped according to the time they presented after surgery. The Statistical Package for Social Sciences (SPSS) software version 27 (IBM Corporation) was used for descriptive and comparative data analysis by applying one-way analysis of variance (ANOVA) and paired *t*-tests.

Results: There was a significant increase in contrast sensitivity ($P < 0.005$) and VA, with the post-operative mean best corrected visual acuity (BCVA) being 0.00 Log MAR for all groups. Central corneal thickness (CCT) was significantly thinner ($P = 0.000$), and significant corneal flattening occurred ($P < 0.005$) in all study groups. Spherical aberration improved significantly only in participants returning after 1 year ($P = 0.000$). Tear break-up time (TBUT) remained stable in all groups and tear volume decreased significantly in groups 1 ($P = 0.000$) and group 3 ($P = 0.013$) only.

Conclusion: The trans-PRK improves VA and contrast sensitivity and causes significant thinning and flattening of the cornea. Although tear volume decreases after trans-PRK, the TBUT does not change and patients will experience improvement in spherical aberration only after 1-year post-surgery.

Contribution: The study will benefit both clinicians and patients who intend to undergo trans-PRK, by providing information on expected post-surgical outcomes.

Keywords: trans-PRK; contrast sensitivity; Pelli-Robson test chart; spherical aberration; tear stability.

Introduction

The cornea is a complicated transparent structure that, in addition to playing a defensive role,[1] contributes approximately two-thirds of the eye's optical power,[2] therefore contributing to the refractive status. Across all age categories, the most prevalent ocular anomaly is refractive errors, which has been identified by the World Health Organization (WHO) as a public health concern, given that 43% of the global visual impairments (VIs) are caused by refractive error. In addition to refractive error being the primary cause of VI, it is also the second cause of vision loss globally.[3] Myopia (near sightedness), hyperopia (long-sightedness), and astigmatism are different types of refractive errors and can be corrected with spectacles, contact lenses, orthokeratology and refractive surgery, which includes laser vision correction.

Cornea-based refractive surgery is fast evolving with impactful scientific and technological advancements.[1] It involves several procedures intended to change the corneal curvature profile and the eye's optics to improve the refractive status.[2] Several surgical procedures have been developed to treat refractive errors, including laser-assisted in situ keratomileusis (LASIK) and transepithelial photorefractive keratectomy (trans-PRK).[4] Mild, moderate and high myopia, as well as myopic astigmatism, can be treated with trans-PRK, which is principally safe with mostly good patient satisfaction because of it being effective with predictable outcomes.[5,6]

When performing surface ablation procedures, laser energy may be delivered to the Bowman's layer on the corneal stromal surface or further into the stroma using lamellar surgery.[7] A flap is created and the stromal bed is abraded with an excimer laser, as performed in LASIK. The LASIK flap is created by using a mechanical microkeratome or femtosecond laser, thought to result in better clinical outcomes.[8] Trans-PRK was developed as an alternative to conventional PRK because it does not require mechanical or alcohol epithelial removal.[9] A board beam laser, mechanical debridement, and a 4.5 mm to 5.0 mm optic zone without transition zones are used in this no-touch laser vision correction procedure.[10] The epithelium and stroma are removed in a single step with no instrument contact to the cornea, resulting in a procedure that is quicker to perform, and the cornea heals faster with swift vision recovery and less post-surgical pain.[11]

Aberrations of the eye, defined as small optical irregularities, are described as imperfections of refraction caused by light not focussing onto the retina perfectly, resulting visual image defects.[12] They may be further classified as either high-order (often 3rd and 4th orders) or low-order (1st and 2nd orders) aberrations.[13] High-order aberrations (HOAs), which include coma, spherical aberrations, and trefoil cannot be corrected by cylinder or spherical corrections.[14] Spherical aberrations reduce contrast sensitivity and cause halos surrounding point light sources.[15] Lower-order aberrations include astigmatism, positive defocus (myopia) and negative defocus (hyperopia).[12]

The cornea is responsible for approximately 90% of eye aberrations and that may explain why HOAs are often viewed as responsible for patients' complaints of glare, haloes, and decreased responsiveness following corneal refractive surgery procedures.[16] To differentiate between the aberrations of the cornea and lens, current studies have concentrated on spherical aberration, indirectly measured the aberrations of the internal surfaces, or used data from in vitro tests of crystalline lenses.[17]

Corneal topography maps the varying degrees of curvature and power of the anterior surface.[18] According to the typical map, the average adult cornea has an ellipsoidal shape, progressively flattening from the centre and being generally steeper in the vertical than in the horizontal meridian.[19] In refractive surgery, corneal topography is used to preoperatively rule out suspicious or keratoconus patterns and post surgically to assess the dioptric change produced at the corneal level, decentred or insufficient ablation, post-excimer ectasia, or other changes.[20]

The tear film is a lubricating liquid comprised of lipids, water and mucin that covers the outer surface of the eye, serving as a boundary between the eye and the environment. Studies have revealed that there are changes in the tear film post refractive surgery.[21] Most studies on laser vision correction focus on VA outcomes only, with little information being available in the scholarly literature on the effects of the procedures on the other aspects of visual function, such as contrast sensitivity, which may also be affected by corneal reshaping. In addition, more information is also required on pre- and post-aberrometry findings. In this article, the participants' VAs, contrast sensitivity, spherical aberration and anterior ocular surface changes from the pre- and post-trans-PRK consultations will be presented. The study is expected to benefit both clinicians and patients who intend to undergo trans-PRK laser vision correction surgery by providing empirical information on expected post-surgical outcomes.

Research methods and design

Study design and sampling

A quantitative, comparative, prospective, case study was conducted at the Eye Specialist Center (ESC) in Almadinah Almnwarh, Saudia Arabia (KSA) from March 2021 to March 2023. Applying Equation 1:

$$n = \frac{\left(\sigma^2\right)\left(Z\left(\alpha/2\right)+Z\left(\beta\right)\right)^2}{\Delta^2} \qquad \text{[Eqn 1]}$$

where Z is the upper point of the standard normal distribution, σ^2 is expected standard deviation (s.d.) of corrected distance visual acuity (VA), which is 0.07, Δ is the expected mean corrected distance VA between preoperative and 6 months postoperative, which is 0.02 and α = Type I error; and β = Type II error, the minimum representative calculated sample size determined was 85, with a final number of 86 consenting patients participating in the study. The sample included participants of both genders, aged 18 to 40 years, who met the inclusion criteria and underwent trans-PRK.

Study process

All participants were examined pre-trans-PRK and, depending on the period that they presented for post-surgery follow-up consultation, were divided into three study groups. There were 28 patients re-examined after 3 months, 29 after 6 months and 29 after 1-year post-surgery. Clinical tests conducted were VA, subjective refraction, corneal topography, tear assessment (Schirmer 2 and tear break-up time [TBUT]), contrast sensitivity test, and spherical aberration measurement.

A Pelli-Robson test chart, which has 48 letters arranged in eight rows of six letters each, was used to measure contrast sensitivity. Each line consists of two triplets, each containing letters of equal contrast. The contrast of each triplet decreases by a factor of 0.15 log contrast sensitivity units. Each letter subtended 2.8° at the test distance of 1 meter.[22] The manufacturers advise a working distance of 1 m, eye level with the centre of the test chart, and room illumination levels between 480 and 600 lux. Participants were instructed to read all letters on the chart beginning with the highest contrast, allowed up to 30 s to read a single letter if needed, and forced to guess until they failed to correctly identify at least two of three letters in a triplet. The right eye was tested first, followed by the left, and finally both eyes and results were recorded on a standard scoring sheet. A contrast sensitivity evaluation was carried out with spectacle corrections at the baseline visit and post-surgery for right and left eye separately. Distance VA was measured monocularly with a Logarithm of the Minimum Angle of Resolution (LogMAR) chart in the TOMEY TCP2000A chart panel, set for a 3 m distance, and under suitable room lighting.

The SCHWIND SIRIUS was used for the corneal topography profile, corneal thickness and to obtain the degree of aberration. The device is made up of a 3-D rotating Scheimpflug camera combined with a Placido disc topographer and is able to measure pupil diameters, either in static or dynamic positions. Three images were taken for each eye separately for more accuracy, with the patient seated comfortably with wide-open eyes, no head movement and no blinking.

The Schirmer 2 and TBUT tests were used to assess the changes in the tear layer both before and after refractive surgery. All patients, both pre- and post-Trans PRK, underwent the Schirmer 2 test using Schirmer 5 mm – 35 mm test strips to measure the tear volume. After applying Benox (anaesthetic eye drops) and gently drying off the excess tears, the strip was folded 5 mm from the end and kept in the lower fornix at the junction of the lateral 1/3 and medial 2/3 without touching the cornea or lashes. The participant was asked to close his or her eyes. A stopwatch was used and after 5 min, the filter paper was removed, and results were recorded from the 35 mm filter scale. The grading used was: 0 mm to 5 mm of wetting = severe; 5 mm to 10 mm = moderate; 10 mm to 15 mm = mild dry eye, and normal tear function was assigned to strips with more than 15 mm of wetting.

For the qualitative tear evaluation, the tear film layers were assessed using the TOMEY RT 7000 with the integrated Tear Stability Analyzer System (TSAS) software program. After the program was set to TSAS and patients were seated in the same position as for the objective refraction, they were informed not to move their head or eyes (stay in position), blink twice and focus on the target while trying not to blink for 10 s. The device captured 10 images of the corneal surface in 10 s for analysis.

Data analysis

In tests where the right and left eye measurements were taken, the mean values were used in data analysis. Statistical Package for Social Sciences (SPSS) version 27 (Software from IBM Corporation, Armonk, New York, USA) was used to analyse the data. The paired *t*-test, post hoc and one-way analysis of variance (ANOVA) were applied and *P*-values less than 0.05 were considered statistically significant.

Ethical considerations

Ethical clearance to conduct this study was obtained from the University of KwaZulu-Nata Biomedical Research Ethics Committee (reference no. BREC/00003585/2021).

Results

Clinical profile of participants

A total of 86 participants were included and grouped based on the follow-up period, Group 1 included 28 participants (56 eyes), and Group 2 and Group 3 both included 29 participants (58 eyes) each. There were 27 males and 59 females with a mean age of 24.69 (s.d. = 4.97) years. The mean uncorrected visual acuity (UCVA) was 0.75, 0.83 and 0.67 LogMAR for groups one, two and three, respectively; while the mean best corrected visual acuity (BCVA) was 0.00 LogMAR (= 6/6 Snellen) for all groups post-operatively. The VA measurements in the right and left eyes, showed no significant differences with *P*-values of 0.64 and 0.16 pre- and post-surgery, respectively. Mean pre-trans-PRK subjective refraction spherical equivalent (SE) was −3.32 ± 2.39 DS, −3.91 ± 1.61DS and −3.17 ± 1.89 DS for the groups consecutively. Most participants (96.5%) were myopes with only two moderate and one simple hyperopes in Group 1 (Table 1).

Visual acuity

There was significant improvement (P = 0.000) in the mean VA post trans-PRK with the mean (BCVA) improving to 0.00 LogMAR for all groups (Figure 1). Eighty-five of the 86 participants across all the study groups had significant improvement in VA and refraction after trans-PRK. Apart from the one patient in Group 3, who had undergone a partial correction for one eye and achieved 0.5 LogMAR, all of the remaining participants achieved a full correction (Plano) with VA of 20/20 or 0.00 LogMAR.

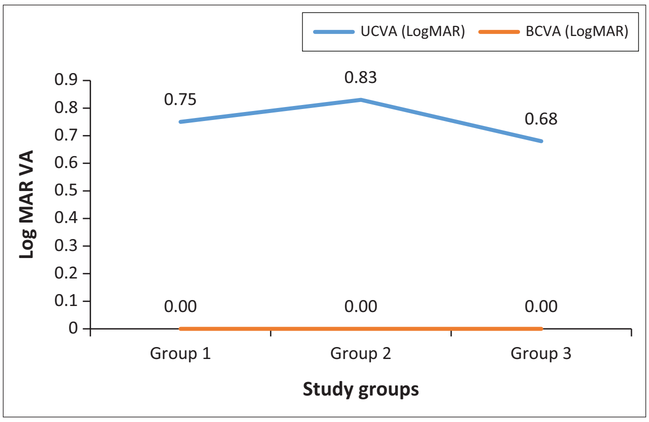
TABLE 1: Gender and refractive status profiles of the three study groups.

Study groups	Participants	Eyes	Gender		Refractive errors		
			Female	Male	Low myopes	Moderate myopes	High myopes
Group 1†	28	56	20	8	10	13	2
Group 2	29	58	18	11	12	15	2
Group 3	29	58	21	8	15	12	2
Total	**86**	**172**	**59**	**27**	**37**	**40**	**6**

Note: Low myopes: 0.25 D to 3.00 D; Moderate myopes: 3.00 D to 6.00 D; High myopes: > 6.00 D.

D, dioptre.

†, Group 1: 3 hyperopes, one with low hyperopia and two moderate hyperope.



BCVA, best-corrected visual acuity; UCVA, uncorrected visual acuity; VA, visual acuity.

FIGURE 1: Mean LogMAR UCVA (pre-trans-photorefractive keratectomy) and BCVA (post-trans photorefractive keratectomy) for each group.

Contrast sensitivity

Significant improvement in contrast sensitivity was revealed by the paired sample *t*-test in all study groups post-surgery with *P*-values of 0.002, 0.000 and 0.000 for Groups 1, 2 and 3, respectively (Table 2).

Spherical aberration

There were no significant changes in spherical aberrations noticed post-trans-PRK for two of the three groups. Paired samples *t*-tests resulted in *P*-values of 0.473 and 0.226 for Group 1 and Group 2, respectively, while for Group 3, there was a significant change ($P = 0.000$). Group 3 had the least mean spherical equivalent value pre-surgery, implying that they had the widest laser ablation zones, which was one 'millimetre or wider' than the scotopic pupil, improving post-surgery spherical aberration (Figure 2).

Keratometry

Prior to the surgery, Group 1 had the steepest mean-K (44.08 D) and Group 3, had the flattest mean-K (43.49 D). The difference between the flattest and steepest mean-K in each group was less than 0.60 D, revealing approximately spherical corneal profiles. The central corneal surfaces were significantly ($P < 0.005$) flatter post-trans-PRK than pre-trans-PRK for each group, with group 2 having the greatest mean central corneal topographical change of 3.23 D flatter than the pre-surgical value (Table 3).

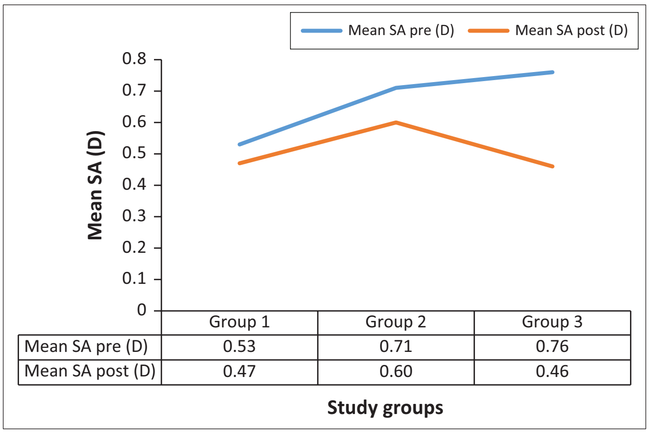
Corneal thickness

The mean pre-surgical central corneal thickness (CCT) for the entire sample was 556.89μm.

TABLE 2: Contrast sensitivity measurements pre- and post-trans-photorefractive keratectomy for all study groups.

Groups	Eyes (*n*)	Follow-up period (months)	Pre-operative (Log CS)		Post-operative (Log CS)		*P*
			Mean	s.d.	Mean	s.d.	
Group 1	56	3	2.04	0.14	2.12	0.12	0.002*
Group 2	58	6	2.02	0.18	2.14	0.13	0.000*
Group 3	58	12	2.00	0.18	2.07	0.15	0.000*

CS, contrast sensitivity; s.d., standard deviation; Log CS, CS units.
*, denotes statistical significance.



D, dioptre; SA, spherical aberration; trans-PRK, trans epithelial photorefractive keratectomy.

FIGURE 2: Spherical aberration pre- and post-trans-photorefractive keratectomy.

Post-operative CCT was found to be significantly thinner ($P = 0.000$) than prior to trans-PRK when the paired sample *t*-test was applied for all study groups. The mean ± s.d. pre-trans-PRK CCT was highest for Group 2 (Figure 3).

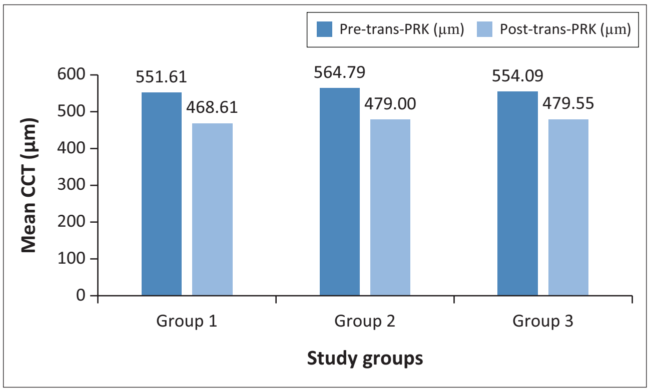
Tear volume

The mean tear volume pre-surgery was 21.59 mm/5 min for the total group, when analysing the total study sample ($n = 86$), tear volume changed significantly ($P = 0.000$) post-surgery, while TBUT remained stable. Further post-operative analysis, showed a significant decrease in tear volume for Group 1 ($P = 0.000$) and Group 3 ($P = 0.013$), with no significant change ($P = 0.441$) in Group 2 (Table 4).

TABLE 3: Means for mean-K for all groups pre- and post-trans-photorefractive keratectomy.

Groups	Follow-up period (months)	Eyes (*n*)	Pre-trans-PRK mean-K (D)		Post-trans-PRK mean-K (D)		*P*
			Mean	s.d.	Mean	s.d.	
Group 1	3	56	44.08	1.23	41.28	1.97	< 0.001*
Group 2	6	58	43.86	1.70	40.63	2.18	< 0.001*
Group 3	12	58	43.49	1.24	41.04	1.60	< 0.001*

s.d., standard deviation; mean-K, mean of K1 and K2; D, Dioptre; trans-PRK, trans-photorefractive keratectomy.
*, denotes statistical significance.



CCT, central corneal thickness; trans-PRK, trans epithelial photorefractive keratectomy; µm, millimicron.

FIGURE 3: Mean central corneal thickness pre- and post-trans-photorefractive keratectomy.

TABLE 4: Tear volume measurement and tear break-up time pre- and post-trans-photorefractive keratectomy for all study groups.

Group	Eyes (*n*)	Follow-up period (months)	Pre-surgery TV (mm/5 min)		Pre-surgery TBUT (s)	Post-surgery TV (mm/5 min)		Post-surgery TBUT (s)	*p*
			Mean	s.d.		Mean	s.d.		
Group 1	56	3	23.16	8.00	-	16.05	7.43	-	< 0.001*
			-	-	5.89	-	-	6.47	0.415
Group 2	58	6	19.17	9.47	-	17.74	10.43	-	0.441
			-	-	6.77	-	-	6.51	0.702
Group 3	58	12	22.50	8.63	-	18.67	7.68	-	0.013*
			-	-	6.99	-	-	6.88	0.870

Note: Tear function tests: TV and TBUT.
TV, tear volume; TBUT, tear break up time; s.d., standard deviation.
*, denotes statistical significance.

Tear break up time

The paired sample *t*-test indicated a stable tear film as there was no significant change in tear break-up time post-trans-PRK for Group 1 (P = 0.415), Group 2 (P = 0.702) and Group 3 (P = 0.870).

Discussion

Visual acuity

One of the major goals of laser vision correction is to achieve normal VA by correcting refractive errors so that the patient has normal VA without visual aids. Numerous studies on refractive surgery cited in this research have focussed on visual outcomes. The study highlights that post-surgery, within 3 months, patients can expect to have minimal refractive error and 0.00 LogMAR acuity. Once achieved, this refractive status remains stable over time, as those returning for their follow-up visits after 6 months and 1 year also had the same visual outcome. The findings of this study concur with that found in the study conducted by Xi et al., which showed effectiveness and consistency in adjusting basic and moderate myopia.[5] The studies differed in that their study, on 47 eyes, did not include hyperopes or high myopes, and the post-surgery assessment was limited to only 3 months after the procedures. Hence, the study alignment is applicable for the post-surgical follow-up period of 3 months in low and moderate myopes only.

Keratometry and central corneal thickness

All participants included in the study had normal corneal profiles pre-trans-PRK, which remained as normal corneal profiles post-trans-PRK, with slight central corneal flattening. Wu et al. in their comparative study of trans-PRK and FS-LASIK, also demonstrated significant post-surgery flattening of the anterior corneal surface.[23] Patients may be reassured that, although they will experience corneal reshaping with trans-PRK surgery, the cornea may remain normal up to the study period of 1 year, as there was no ectasia detected during the three study follow-up periods in this study.

The CCT, although significantly thinner, also remained within the normal range for all study groups independently analysed and in the total study sample. The findings of this study are comparable with a study conducted 2020 to investigate how myopia therapy with trans-PRK or FS-LASIK affects CCT and HOAs. The findings revealed a significant difference in CCT post-trans-PRK after 6 months of follow-up.[24] The demonstration that the resultant corneal thickness remained within normal limits helps to explain why the study found no corneal ectasia post-surgery. This will aid in alleviating anxiety among those contemplating undergoing the procedure about the possibility of developing post-surgery ectasia.

Tear stability (tear volume and tear quality)

The tear film, which coats the outside of the eye and acts as a barrier between the eye and its surroundings, is a lubricating fluid made of lipids, water, and mucin.[21] Therefore, tear film is very important for corneal health and protection, and forms a wet and smooth surface to help in corneal refractivity.[25] It is one of the ocular elements affected by laser vision correction, at least in the first few months post-surgery.[26] The study revealed that the tear volume decreased significantly in the groups that returned for their follow-up assessments after 3 months and 1 year, while in those who returned after 6 months, there were no noticeable changes. However, TBUT remained stable after the three follow-up periods in all groups. Although the differences among the three individual study cohorts were insignificant, when analysing the total study sample (n = 86), tear volume changed significantly (P = 0.000) post-surgery, while TBUT remained stable.

Iqbal et al.[27] evaluated pre- and post-trans-PRK qualitative and quantitative tear tests on 30 patients who returned after 1 week, 3 months, and 6 months. Results revealed that trans-PRK slightly decreased TBUT while tear volume, although initially decreasing, gradually returned to normal after 6 months.[27] The limitation in their study was that it was only conducted on 30 patients and ended after 6 months. Perhaps with the pattern of results improving at each subsequent visit, the changes may not be significant after 1 year, as found in this study. However, at the 6 months follow-up, both studies found no change in tear volume as compared to pre-surgery, but at 3 months' follow-up, it significantly decreased, highlighting a delay in the return to normal values.

According to a review article on the effect of corneal refractive surgery on the precorneal tear film, tear film abnormality was the most common side effect. The study covered most corneal refractive surgery techniques including LASIK, PRK, LASEK, SMILE, and femtosecond lenticule extraction (FLEX).[26] The review emphasised that tear stability was affected post-corneal refractive surgery and that patients should be advised to use preservative-free artificial tears to manage corneal dryness. Thus, it is advised that further research, with larger sample sizes and longer study periods, should be conducted to evaluate post-trans-PRK tear quality and quantity in order to determine reliable patterns. Clinicians should monitor tear functions and manage with tear supplements and other treatment modalities where indicated, as optimal trans-PRK outcomes should include good vision, good ocular health and comfort.

Contrast sensitivity

Contrast sensitivity is one of the visual functions needed to achieve high visual performance and accuracy. It helps detect and distinguish objects without a clear outline from their background contrast.[28] The contrast sensitivity of the total study sample (n = 86) improved significantly in this study, as did the contrast sensitivity of the three study groups over the various follow-up periods. Furthermore, the improvement of contrast sensitivity after trans-PRK found in all study groups demonstrates the predictability of performing trans-PRK surgery and the stability over the various post-surgery assessment periods. Although there was a statistically significant difference in contrast sensitivity, the appreciation of the difference clinically was not estimated and is recommended for future studies.

Although having only 30 participants, Khalil et al. also demonstrated a significant improvement in contrast sensitivity among their participants after trans-PRK surgery.[29] Contrary to the findings of this study, in 2022 researchers discovered no significant change in contrast sensitivity following trans-PRK and LASIK for high and moderate myopes.[11] Possible variation in results may be because of sample size and refractive status differences as their study only included 38 patients with high and moderate myopia who were followed up only once after 1 year, as opposed to this study, which examined 86 patients across multiple groups and over multiple follow-up periods without regard to the types or grades of refractive errors.

Spherical aberration

Spherical aberrations, defined as small optical irregularities in the eye,[15] have been known to be impacted by laser vision correction. The overall study sample displayed post-surgery spherical aberration that significantly changed (P = 0.001). Furthermore, results revealed no progression or regression in Groups 1 and 2, while Group 3, who returned after a year, showed significant changes in spherical aberration post-surgery (P = 0.000). The study's findings may suggest that post-surgical spherical aberration, in comparison to other clinical parameters, may take a longer period to reach optimal improvement.

In Seoul, South Korea, researchers evaluated the clinical outcomes, vector parameters and aberrations of mechanical PRK and trans-PRK in eyes with low myopia. They found that spherical aberration significantly decreased following trans-PRK, and both procedures significantly decreased the HOAs and coma.[30] These findings were consistent with the findings of this study in the total sample.

Conclusion

Considering the growing interest in trans-PRK as a means of correcting refractive errors, the objective of this study was to examine and compare the effects of the procedure on VA, refractive error, spherical aberrations, contrast sensitivity, tear film stability, CCT, and corneal topography. Based on empirical evidence, the study showed that trans-PRK was predictable and safe with good visual and tear function outcomes by comparing baseline findings for each of these parameters with those measured in the follow-up consultations over 1 year.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

E.H.E.M. and V.R.M. conceptualised the research, E.H.E.M. conducted the fieldwork and wrote the initial draft of article. V.R.M. supervised the research, reviewed and edited the article.

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Data availability

Derived data supporting the findings of this study are available from the corresponding author, E.H.E.M., on request.

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