• Clinical Research •

Transpalpebral intraocular pressure measurement by Diaton compared to Goldman applanation tonometer in myopic eyes before and after transepithelial photorefractive keratectomy in Saudi Arabia

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Abstract

● **AIM:** To compare intraocular pressure (IOP) measured *via* the trans palpebral IOP (tpIOP) method using a Diaton or with a Goldman applanation tonometer (GAT) and study the determinants of IOP difference in eyes undergoing transepithelial photorefractive keratectomy (TPRK) for myopia.

● **METHODS:** This cross-sectional validation study was held in 2020 in an eye hospital in Saudi Arabia. IOP was measured by Diaton and GAT before treatment, after one week, and one month of TPRK. It is considered if IOP difference by Diaton and GAT was less than ±2 mm Hg acceptable. The IOP difference was tested if correlated to spherical equivalent (SE), central corneal thickness (CCT), age, gender, or tpIOP.

● **RESULTS:** Totolly 200 myopic eyes of 100 patients were included in the study. The mean difference of IOP measured by two methods before TPRK, 1wk, and 1mo after TPRK were 0.790, -0.790, and -0.920 mm Hg, respectively (P<0.001). Diaton could measure IOP effectively 89.5% eyes before TPRK and 82% and 84% at 1wk and 1mo after TPTK, respectively. At week 1, IOP differences were significantly correlated to baseline CCT (P=0.02) and tpIOP at week 1 (P<0.001). One month after TPRK, only tpIOP was significantly correlated to the difference in IOP (P<0.001).

● **CONCLUSION:** Diaton is a good screening tool for IOP before TPRK. It helps in monitoring IOP after surgery. Although more practical, it is less efficient than GAT. In eyes with high myopia and low tpIOP before surgery, IOP post-TPRK by Diaton and GAT could differ.

● **KEYWORDS:** intraocular pressure; Goldman applanation tonometry; trans palpebral tonometry; myopia; transepithelial photorefractive keratectomy

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INTRODUCTION

Intraocular pressure (IOP) is the most significant risk factor for glaucoma[1]. It should therefore be evaluated for screening high-risk groups and monitoring the damage to intraocular structures from IOP changes following medication, surgery, or trauma[2]. Since many years, measuring IOP by Goldman applanation tonometry (GAT) was considered the gold standard[3]. However, GAT has limitations for IOP measurement in eyes with abnormal corneal biomechanical properties, pathologies, and uneven counters[3-4]. Research enabled caregivers to find alternative tonometry tools[5]. One tool is the transscleral transpalpebral measurement of IOP. Diaton, a trans palpebral IOP (tpIOP) measuring tonometer, is claimed to be an efficient, patient-friendly, and validated tool[6]. The Diaton tonometer estimates IOP by rebound tonometry through the upper eyelid. A metal rod is released within the instrument and rebounds off the eyelid, superior tarsus, and superior sclera. The deceleration of the metal rod is used to estimate IOP[7]. In eyes with corneal surgeries like keratoplasties, refractive surgeries, and ocular trauma, its efficiency in comparison with GAT is debatable. It is claimed to be a useful screening tool, especially for young populations[8]. However, it may give different IOP measurements than GAT in eyes after corneal surgeries[9]. GAT is influenced by central corneal thickness (CCT), the severity of myopia before surgery, and existing glaucoma before refractive surgery[2,10-11]. Similarly, tpIOP is influenced to a lesser extent by corneal characteristics[2].

tpIOP is widely used before and after transepithelial

photorefractive keratectomy (TPRK). However, studies that compare tpIOP to GAT and factors affecting the IOP differences in patients treated with refractive surgery are limited in the literature[12-14]. Rozhdestvenskaya *et al*[12] noted that tpIOP were not affected by corneal biomechanical properties while IOP measured by GAT need to be adjusted by CCT. Hemida *et al*[13] noted reduction of IOP and corneal biomechanical factors after laser-assisted *in situ* keratomileusis (LASIK) and are much influenced when measured by GAT. Lanza *et al*[14] used different tonometer to measure IOP after photorefractive keratectomy (PRK) for myopia and noted that there was significant underestimation of IOP by GAT and therefore alternative tonometry was proposed after refractive surgery.

We present validation of Diaton-measured tpIOP compared to GAT and the determinants of difference in IOP measured by these two methods before, one week, and one month after TPRK in myopic Saudi patients.

SUBJECTS AND METHODS

Ethical Approval We obtained approval from our hospital's ethical and research committee. We adhered to the tenants of the Helsinki Declaration. All myopic patients to be operated on with TPRK between June 2020 and May 2021 were included in the study. This was a cross-sectional validity study.

To calculate the sample size for a cross-sectional study, we assumed IOP measured by Diaton would be within ±2 mm Hg of that measured by GAT in the same eye[15]. To achieve a 95% confidence interval and acceptable error margin of 5% in a study with a 10 000-person population, we need to examine 196 eyes *via* both tonometry methods. We used open Epi software to calculate the sample size for a cross-sectional study[16].

One cornea surgeon and one glaucoma surgeon were the investigators of the present study. The demographic information included age at surgery and gender. tpIOP was measured with the help of Diaton (Bicom Inc, New York, USA) while the patient closed their eyes in a sitting position, and the probe was held in the upper region of the sclera. The GAT (S4Optik Goldman R900, Innova, Advancing eyecare, Toronto, Canada) was mounted on a slit-lamp biomicroscope (Topcon, USA). To minimize selection bias, a randomly-selected eye was first subjected to tpIOP and GAT. The next eye scheduled for TPRK had IOP measured by GAT first, followed by Diaton after 5min. The CCT and corneal epithelial thickness were measured by anterior optical coherent tomography (Pentacam AXL, Oculus, Germany)[17]. Based on CCT, eyes were grouped into Gr I (CCT<530 μm), Gr II (CCT between 530 and 560 μm), and Gr III (CCT>560 μm)[10]. The refractive status in the dioptric value of each eye was documented as spherical, cylinder, and its axis. To calculate the spherical equivalent (SE), we used the formula (spherical refractive error + cylinder/2). The refractive status was further graded as mild (>-3.0 D SE), moderate (-3.0 to -6.0 D SE), and severe myopia (<-6.0 D SE) as well as astigmatism of more than 1 D[18]. The steps of the TPRK we adopted in the present study are already described in detail[19-20].

The IOP of each eye was measured again at week 1 and month 1 after TPRK. The CCT was once again measured at a week 1 follow-up visit. If IOP was 22 mm Hg or more, we considered it high pressure. IOP of less than 22 mm Hg was labeled a normal IOP.

The data was collected from hospital records using Microsoft XL®. The data was checked for consistency and duplication, and information on the eyes as a unit was compiled. Then, it was transferred into the Statistical Package for Social Sciences (SPSS 25; IBM, Chicago, USA) spreadsheet. The qualitative data were presented in number and percentage proportions. The quantitative data, if distributed normally, were presented as mean and standard deviation. If the distribution was skewed, they were presented as median and interquartile values. The difference in IOP by GAT–Diaton of each eye was the primary outcome at baseline, week 1, and month 1 follow-up. To study the efficiency of tpIOP, we used the Bland-Altman plot graph of SPSS. We considered eyes with a difference of IOP by two methods being less than ±2 mm Hg as an acceptable difference. If the IOP differed more than 2 mm Hg, we considered it an overestimation or underestimation. We correlated qualitative variables of IOP measured by Diaton and GAT by matched-pair analysis to estimate the two-sided *P* value of correlation. To compare quantitative variables to the difference in IOP by two methods, we used the nonparametric method and presented Spearman coefficient (*r*) and *P* values.

RESULTS

We evaluated 200 eyes in 100 patients. The mean age of participants was 25.7±5.8y. There were 47 males and 53 females. The mean CCT before surgery was 544.5±37.8 μm. The mean SE was -3.2±1.92 D.

The tpIOP measurement by Diaton in comparison with GAT was graded as similar (±2 mm Hg), overestimation (>+2 mm Hg), and underestimation (<-2 mm Hg). Figure 1 shows the agreement of IOP by Diaton to GAT. It was 89.5% before TPRK and 82% and 84% at one week and one month after TPTK, respectively.

The IOP by GAT and tpIOP by different variables are given in Table 1. The mean difference of IOP by two methods before TPRK was 0.790 mm Hg. This difference in IOP with 2 mm Hg was statistically significant (*P*<0.001). At week 1 and month 1 follow-ups, the mean differences were -0.790 mm Hg (*P*<0.001) and -0.920 mm Hg (*P*<0.001) respectively.

The Bland-Altman plot shows the difference in IOP by tpIOP and GAT before, one week, and one month after TPRK (Figures 2-4).

Table 1 IOP measured by GAT–trans palpebral transscleral tonometry by Diaton in myopic eyes before and after TPRK

Items	Number	IOP by GAT		tpIOP by Diaton		Validation
		Mean	SDV	Mean	SDV	
Before TPRK						
Gender						*P*=0.496
Male	94	14.33	2.95	15.03	2.81	
Female	106	14.09	2.77	14.96	2.75	
Myopia grade						*P*=0.046
Mild	93	14.3	2.7	15.0	2.7	
Moderate	79	14.1	3.0	15.0	2.76	
Severe	21	13.7	2.9	15.2	2.7	
Astigmatism	9	15.0	3.4	14.8	3.8	
CCT grade (μm)						*P*=0.345
<530	68	13.6	2.8	14.5	2.79	
530 to 560	71	13.9	2.67	14.86	2.62	
>560	61	15.2	2.9	15.7	2.84	
One week after surgery						
Gender						*P*=0.054
Male	94	14.5	2.36	15.6	2.2	
Female	106	14.44	2.39	16.06	2.57	
Myopia grade						*P*=0.495
Mild	93	14.64	2.21	16.0	2.17	
Moderate	79	14.6	2.19	15.95	2.51	
Severe	21	13.3	3.23	14.71	3.02	
Astigmatism	9	13.9	2.67	16.1	2.15	
CCT grade before surgery (μm)						*P*=0.114
<530	68	13.7	2.11	15.4	1.9	
530 to 560	71	14.7	2.46	16.0	2.9	
>560	61	15.1	2.34	16.2	2.27	
CCT grade at week 1 post TPRK (μm)						*P*=0.604
<530	168	14.4	3.7	15.7	2.5	
530 to 560	26	14.8	2.1	16.5	1.9	
>560	6	15.0	3.9	16.8	1.94	
High IOP at week 1						*P*=0.325
≥22 mm Hg	3	21.7	1.53	24.0	1.0	
<22 mm Hg	197	14.3	2.2	15.7	2.2	
One month after TPRK						
Gender						*P*=0.102
Male	94	14.4	3.34	15.0	3.2	
Female	106	15.0	4.0	16.2	4.67	
Myopia grade						*P*=0.016
Mild	93	15.5	4.36	16.3	5.1	
Moderate	79	14.0	2.93	14.9	2.82	
Severe	21	13.1	2.26	14.7	1.91	
Astigmatism	9	16.0	3.35	17.3	3.84	
CCT grade before surgery (μm)						*P*=0.044
<530	68	14.0	4.35	14.9	5.0	
530 to 560	71	14.7	3.32	15.5	3.4	
>560	61	15.5	3.25	16.6	3.48	
CCT grade at week 1 post TPRK (μm)						*P*=0.021
<530	168	14.3	3.7	15.4	4.22	
530 to 560	26	16.6	3.2	16.5	2.8	
>560	6	17.0	3.2	18.7	3.1	
High IOP at week 1						*P*=0.08
≥22 mm Hg	3	17.3	5.9	14.3	1.1	
<22 mm Hg	197	14.5	2.37	15.8	2.42	
High IOP at month 1						*P*<0.001
≥22 mm Hg	9	23.7	5.8	28.4	7.1	
<22 mm Hg	191	14.3	3.0	15.0	2.7	

IOP: Intraocular pressure; GAT: Goldman applanation tonometer; TPRK: Transepithelial photorefractive keratectomy; CCT: Central corneal thickness; SDV: Standard deviation.

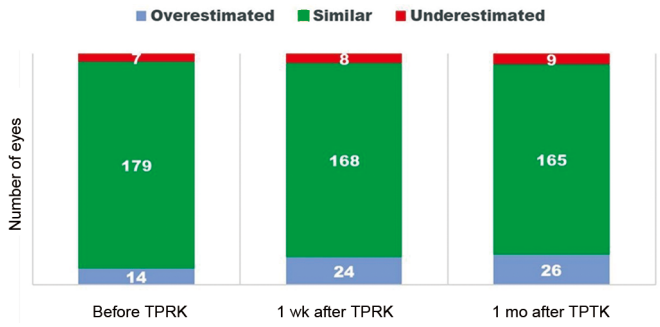

Figure 1 Ability of Diaton (trans-palpebral tonometry) to accurately measure IOP compared to GAT before and after TPRK for myopia Overestimation suggests IOP by Diaton>2 mm Hg than GAT; Similar means ±2 mm Hg IOP difference between tpIOP and GAT; Underestimation suggests IOP by GAT>2 mm Hg than Diaton. IOP: Intraocular pressure; tpIOP: Trans-palpebral intraocular pressure; GAT: Goldman applanation tonometer; TPRK: Transepithelial photorefractive keratectomy.

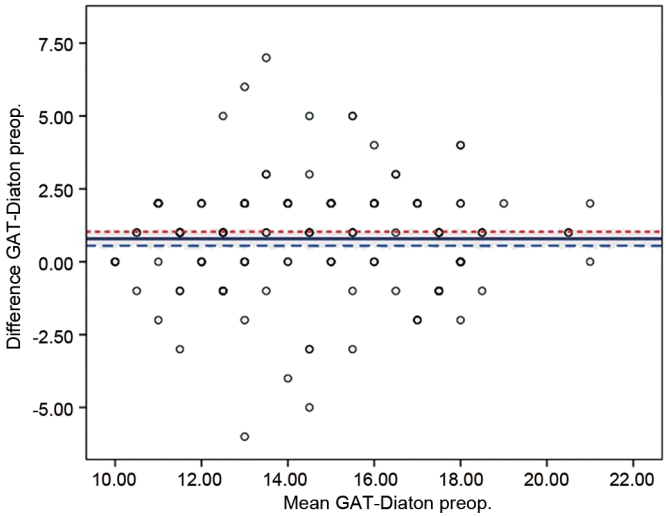

Figure 2 Bland-Altman plot showing comparison of Diaton and GAT measured IOP before TPRK for myopia IOP: Intraocular pressure; GAT: Goldman applanation tonometer; TPRK: Transepithelial photorefractive keratectomy.

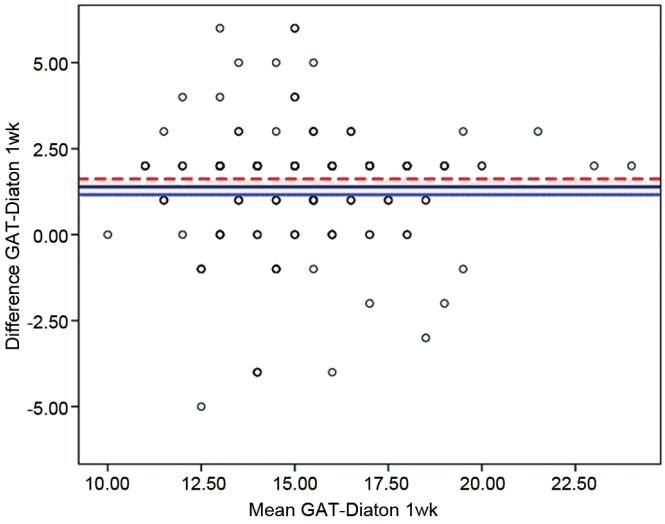

Figure 3 Bland-Altman plot showing comparison of Diaton and GAT measured IOP one week after TPRK for myopia IOP: Intraocular pressure; GAT: Goldman applanation tonometer; TPRK: Transepithelial photorefractive keratectomy.

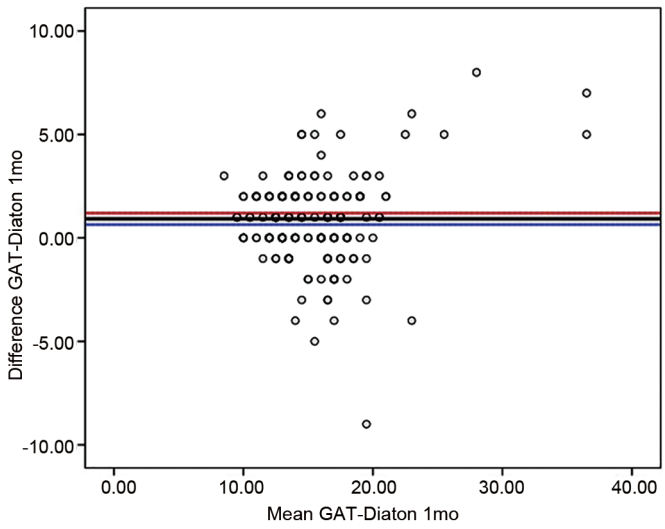

Figure 4 Bland-Altman plot showing comparison of Diaton and GAT measured IOP one month after TPRK for myopia IOP: Intraocular pressure; GAT: Goldman applanation tonometer; TPRK: Transepithelial photorefractive keratectomy.

The factors influencing the IOP measured by GAT and Diaton are given in Table 2. Before TPRK, myopia grades were significantly associated with the difference in IOP by two methods (P=0.05). The female gender had significantly higher tpIOP than GAT one week after TPRK (P=0.05). One month after TPRK, myopia grade (P=0.02), CCT before surgery (P=0.04), CCT post-TPRK (P=0.02), and high IOP at month 1 (P<0.001) were significant associated factors.

The quantitative variables were correlated to a difference in IOP measured by GAT and Diaton. In Table 3, tpIOP (P=0.006) and SE myopia (P=0.006) before surgery were significantly correlated to a difference in IOP by both methods.

At week 1, the difference in IOP measured in both methods was significantly correlated to baseline CCT (P=0.02) and tpIOP at week 1 (P<0.001). At one month after TPRK, only tpIOP was significantly correlated to the difference in IOP measured by the two methods (P<0.001).

DISCUSSION

tpIOP measured by Diaton seems to be a good screening tool in a young myopic population but monitoring IOP using Diaton after TPRK may be less reliable and is influenced by factors like tpIOP, myopia severity, CCT before surgery, and tpIOP after refractive surgery. tpIOL measurement was useful and promising for screening young populations with myopia undergoing refractive surgery. It also helped caregivers to monitor IOP changes following TPRK. One in 16 myopic eyes managed by TPRK showed high IOP after surgery. Although

Table 2 Factors correlated to difference of IOP measured by GAT–trans palpebral transscleral tonometry by Diaton in myopic eyes before and after transepithelial photorefractive keratectomy

IOP by GAT–IOP by tpIOP	Before TPRK		1wk after TPRK		1mo after TPRK	
	Spearman *r*	Spearman *P*	Spearman *r*	Spearman *P*	Spearman *r*	Spearman *P*
Age	-0.027	0.707	0.01	0.887	0.129	0.068
CCT pre TPRK	-0.08	0.261	-0.165	0.02	0.028	0.696
CCT post TPRK	-0.193	0.006	0.061	0.39	-0.038	0.588
Pre TPRK SE	-0.193	0.006	-0.09	0.203	-0.108	0.127
Pre TPRK tpIOP			0.351	<0.001	-0.015	0.834
tpIOP at week 1			-0.054	0.449	0.084	0.239
tpIOP at month 1					0.256	<0.001

IOP: Intraocular pressure; GAT: Goldman applanation tonometer; TPRK: Transepithelial photorefractive keratectomy; CCT: Central corneal thickness; SE: Spherical equivalent.

Table 3 Changes in parameters after transepithelial photorefractive keratectomy for myopia compared to before surgery

Parameters	Median	Inter quartile range	Minimum-maximum	*P*
All	0.00	-1.0; +2.0	-7.0; +11.0	
Pre CCT				K-W *P*=0.15
<530 μm	1.0	-2.0; +3.0	-5.0; + 8.0	
530 to 560 μm	1.0	-1.0: +3.0	-7.0; +11.0	
>560 μm	0.0	-1.0; +2.0	-4.0; +8.0	
Pre myopia				K-W *P*=0.237
Mild	1.0	-1.0; +3.0	-3.0; 11.0	
Moderate	0.0	-1.0; + 3.0	-5.0; +9.0	
Severe	0.0	-3.5; 2.0	-7.0; +5.0	
Gender				Mann-Wintney *U P*=0.05
Male	0.0	-2.0; +2.0	-4.0; +11.0	
Female	1.0	-1.0; +3.0	-7.0; +9.0	
Age				*R*=-0.07, Pearson *P*=0.304

CCT: Central corneal thickness.

none of the eyes had glaucoma before surgery, eyes with IOP>22 mm Hg post-TPRK were significantly associated with tpIOP>15 mm Hg before surgery and a mild grade of myopia prior to TPRK. This agreement declined from 90% before TPRK to 82% and 84% one week and one month after TPRK, respectively.

Myopia is prevalent among the teenage Saudi population[21-22]. Refractive surgery is continuously evolving, and an increasing number of Arabs are surgically treated for myopia[23]. IOP measurement is essential for patient selection for surgery and monitoring for increased IOP induced by steroids or precipitation of glaucoma postoperatively. In addition to the conventional GAT, many ophthalmologists in Saudi Arabia have adopted newer technologies. Still, this may be the first study showing the reliability of Diaton over the conventional GAT to screen myopic eyes before and monitor IOP after TPRK among the Arab population. The study favors procuring this patient-friendly and reliable tool and using it to monitor IOP, especially in conditions where conventional IOP measurement is difficult.

The difference in IOP measured by Diaton and GAT in the same eye after TPRK was substantial compared to measurements taken before surgery in our study. The IOP difference in diatom compared to GAT one month after TPRK was significantly more in group of eyes with CCT more than 560 μm than in group of eyes with CCT<530 μm noted before surgery. Thus, in eyes with thinner corneas, Diaton should be preferred over GAT to monitor IOP after TPRK. The reduction of CCT post-TPRK could have been responsible for this difference. The eyes with thin corneas had more IOP measured by GAT than by Diaton; in eyes with thick corneas, the mean IOP measured by GAT was more than that of Diaton in a study by Toker *et al*[10]. The differences in IOP measured by two method before TPRK and at one week after TPRK did not vary by groups of CCT. However, the difference in IOP in the two methods was significantly correlated to CCT grades one month after TPRK in our study. Rozhdestvenskaya *et al*[12] also noted this. This difference of IOP by two methods post TPRK is logical because there will be a significant reduction of CCT after TPRK. GAT is influenced by corneal properties,

including CCT, but tpIOP is less affected by corneal changes. The influence of CCT on tpIOP remains debatable. Toker *et al*[10] concluded that Diaton tonometry is affected by CCT in thin corneas. In contrast, Chakraborty *et al*[24] noted that tpIOP measurement is more reliable than GAT in eyes with thinned cornea. Further studies with an adequate sample of different CCT grades are recommended to confirm our observation.

With increasing myopia severity noted before TPRK, tpIOP decreased more than GAT measured before and after TPRK. Females had a more significant difference in IOP measured by GAT and tpIOP one week after TPRK than males with myopic eyes in our study. However, this difference was not significant before and one month after TPRK. Myopia prevalence and severity were higher in female college students than male college students in Saudi Arabia[25]. The myopia grade could be a confounding factor to the association we noted to IOP measurement.

We noted that the efficiency of tpIOP declined from before TPRK to one week and one month after TPRK, changing the efficiency of tpIOP before and after TPRK at week 1 and month 1. This justifies the Rozhdestvenskaya *et al*[12] proposal to use CCT corrected GAT IOP for comparison with tpIOP after surgery.

The SE before TPRK was negatively correlated to the difference in IOP by two methods. Caregivers should be more vigilant when treating eyes with mild myopia than with severe myopia because the former are likely to mislead about IOP after surgery if measured by Diaton rather than GAT.

IOP level before surgery was an independent risk factor for the difference in IOP by two methods. Those with IOP between 15 to 21 mm Hg are more likely to show a high-pressure difference in Diaton than GAT. With small numbers of eyes in both groups with >22 mm Hg, this could be a chance observation and need more studies with adequate sample of eyes with >22 mm Hg to confirm our observation.

This study had a few inherent limitations. Because it was cross-sectional, the time-related relationship between outcome and variables could not be established. Although the selection of the IOP measurement tool for each eye was random, the possibility of change in IOP due to the first measurement method on subsequent methods cannot be ruled out. The sample size of subgroups, like those with high IOP, was small and showed trends only. Further studies with a suitable study design and larger sample are recommended to confirm subgroup trends.

Mid-level eye care professionals are increasingly involved in the initial workup and follow-up of eye patients, especially in developing countries and large hospitals[26]. tpIOP by Diaton, which can be nontraumatic and used without anesthesia, is favored over GAT. The present study supports task transfer of IOP measurement even in refractive surgeries.

Diatom tonometry is a good screening tool to determine IOP among patients planned for refractive surgery. It is an efficient screening tool. However, one should be careful while monitoring tpIOP after TPRK because the conventional measurement of IOP by GAT differs from tpIOP and is influenced by many corneal properties.

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Conflicts of Interest: Alzuhairy S, None.

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