Comparison of the ocular response analyzer and the Goldmann applanation tonometer for measuring intraocular pressure after penetrating keratoplasty
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Introduction
Penetrating keratoplasty (PKP) is a full-thickness transplant procedure, in which a trephine of an appropriate diameter is used to make a full-thickness resection of the patient’s cornea, followed by placement of a full-thickness donor corneal graft. Interrupted and/or running sutures are placed in a radial manner at equal tension to minimize postoperative astigmatism.

The main aim of corneal transplantation of any kind is to restore the optical properties of the eye. However, it is of particular importance to understand the nature of the change in biomechanical properties of the graft when refractive surgery of the transplanted cornea is anticipated.

Further, monitoring intraocular pressure (IOP) after corneal transplantation is very important, as a high IOP (21 mmHg) is encountered in transplanted eyes at a high incidence, ranging from 10 to 42\% [1].

Although Goldmann applanation tonometry (GAT) is considered the gold standard for measuring IOP, high astigmatism and surface irregularities after corneal transplantation can decrease its accuracy, and therefore other tonometers can alternatively be used [2].

Further, decreased rigidity of the ocular wall in some conditions such as keratoconus, which may require corneal transplantation, can result in underestimating IOP measured with GAT.

Objectives
To compare intraocular pressure (IOP) readings measured by the ocular response analyzer (ORA) with those measured by the Goldmann applanation tonometer (GAT) following penetrating keratoplasty (PKP) and evaluate the influence of biomechanical properties of the grafts on IOP measurements.

Background
The ORA (Reichert Technologies) is a device that shows the biomechanical properties of the cornea. It reflects certain biomechanical properties of the cornea such as corneal hysteresis (CH) and corneal resistance factor (CRF).

Patients and methods
IOP using the GAT (IOP (GAT)), CH, CRF, Goldmann-correlated IOP (IOPg), cornea-compensated IOP (IOPcc) using the ORA, and central graft thickness (CGT) were measured in 30 eyes undergoing PKP. Bland–Altman plots were used to evaluate agreement between the tonometers. The correlation between refraction, graft curvature, astigmatism, CH, CRF, and CGT with IOP readings was investigated using multivariate regression analysis.

Results
The mean CGT, CH, and CRF were 532.43 ± 30 µm, 8.52 ± 1.81 mmHg, and 8.56 ± 1.59 mmHg, respectively. Mean IOP (GAT), IOPg, and IOPcc were 11.88 ± 3.66, 14.64 ± 4.08, and 17.27 ± 4.80 mmHg, respectively. The 95\% limit of agreement between IOP (GAT) and IOPg ranged from 2.39 to 3.29 mmHg, and for IOPcc and IOP (GAT) it ranged from 4.7 to 6.2 mmHg.

No significant association was found between CGT and IOP readings. According to IOP (GAT), there was significant negative association with CH. According to IOPcc, there was significant negative association with CH and mean keratometry. According to IOPg, there was significant positive association with CRF.

Conclusion
Following PKP, graft biomechanics had more influence on IOP values than anatomical features. In comparison to the GAT, the ORA yielded higher IOP values.

Keywords:
corneal biomechanics, corneal hysteresis, corneal resistance factor, ocular response analyzer

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In an attempt to circumvent the aforementioned problems with GAT in grafted eyes, several tonometers have been tried and compared to find an ideal instrument [3].

Recently, Reichert Ophthalmic Instruments introduced a new technology noncontact tonometer that measures IOP as well as new metrics called corneal hysteresis (CH) and corneal resistance factor (CRF) [4].

The ocular response analyzer (ORA) has an infrared electro‑optical system that monitors corneal deformations. It delivers a precisely metered collimated air pulse to the eye. The cornea suffers an inward movement, passing a first applanation state before assuming a concave shape. The air pressure progressively declines after this first applanation and the cornea passes through a second applanation state while returning to its normal convex curvature. The examination generates a waveform that contains two peaks, corresponding to the inward and outward applanation events.

Using this bidirectional applanation measurement, the ORA is able to present the four original parameters. CH is the difference between these two pressure values, which represents the corneal viscoelastic damping. The mean of these two pressures is the Goldmann‑correlated IOP (IOPg). The corneal‑compensated IOP (IOPcc) is a pressure measurement that uses the CH to determine an IOP value that is less affected by corneal properties, such as the central corneal thickness (CCT). CRF is calculated using a proprietary algorithm and is an indicator of the overall cornea resistance [4].

The main aim of this study was to find the best way to follow up the IOP after PKP.

**Patients and methods**

After receiving the approval of the institute ethics committee, all patients received a thorough explanation of the study design and aims; the study was conducted in compliance with informed consent regulations.

This study is a prospective, comparative study which was carried out on patients attending the ‘Ophthalmology Department of Menoufia University Hospitals and Memorial Institute of Ophthalmology in Giza’ from December 2016 to February 2018.

In this cross‑sectional comparative study, a total of 33 consecutive eyes having undergone penetrating keratoplasty (PK) were recruited for this study. Of these eyes, 25 eyes had suffered from keratoconus, and approximately five of the eyes had herpes simplex and corneal scars from burns or trauma. Three eyes were excluded, because the parameters measured with the ORA were out of scale.

All participant names were hidden and replaced by code numbers to maintain privacy of the patients.

**Inclusion criteria**

Inclusion criteria were as follows: age from 20 to 65 years, all patients who had undergone PKP, and the participants had a clear graft and all sutures were removed at least 8 months before entering the study.

**Exclusion criteria**

Exclusion criteria were as follows: previous ocular surgery, corneal scars or opacities, chronic use of topical medications, and systemic collagen diseases, for example, Marfan and Ehler‑Danlos syndromes.

Each participant had a comprehensive ophthalmologic examination, including a review of their medical history, best corrected visual acuity, slit‑lamp biomicroscopy fundus examination, manifest refraction, and keratometry.

As measuring IOP by one tonometer may influence the following measurement, the tonometers were used in random order with a 5‑min interval between readings to minimize the effect of IOP fluctuation. To avoid the effect of sleeping and diurnal variation on corneal properties such as central graft thickness (CGT), CH, CRF, and IOP as well, the measurements were obtained in the morning at least 3 h after awakening, when postawakening decline had already occurred. All measurements were performed by a single qualified ophthalmologist.

In each eye, IOP was measured twice using GAT (AT‑900; Haag‑Streit AG, Koniz, Switzerland) and averaged, after anesthetizing the cornea with a drop of benoxinate (benoxinate hydrochloride 0.4%).

To reduce the effect of corneal astigmatism on the measurement, the tonometer head was rotated 43° to the least‑curved meridian. Additionally, to consider the effect of CGT on IOP readings, for every 10 µm above 520 µm, 0.7 mmHg was reduced from IOP (GAT) [5].

The ORA (Reichert, Buffalo, New York, USA) was used to measure CH, CRF, IOPg, and IOPcc. Briefly, the patients were seated and asked to keep their eyes wide open while fixating on a green target light at the center of red lights. After releasing an air puff, the measured parameters were displayed on the monitor. For each patient, four readings were obtained immediately and consecutively at the same session and averaged after
excluding the outliers (defined as irreproducible values not having good quality or two distinct peaks).

Manifest refraction and keratometry were measured using Auto Ref/Keratometer (ARK 510 A; NIDEK, Gamagori, Japan).

The last examination performed was central graft pachymetry using specular microscopy (SP-2000P; Topcon, Tokyo, Japan).

Statistical analysis

Data were statistically described in terms of mean ± SD, median and range, or frequencies and percentages when appropriate. Paired *t* test was used to compare mean IOP readings by the ORA and GAT. Repeated measurement comparison analysis adjusted for multiple comparisons by the Bonferroni method was used to compare mean IOP readings by the ORA and GAT. The agreement between the two tonometers was evaluated with Bland–Altman plots. The correlation of CGT, refractive status (mean keratometry and graft astigmatism), and graft biomechanical properties (CH and CRF) with the IOP readings by both tonometers were investigated using multivariate regression analysis. A *P* value less than of 0.05 was considered statistically significant.

All statistical calculations were done using the computer program Statistical Package for the Social Sciences (IBM Corp., New York, New York, USA), version 21, for Microsoft Windows.

Results

In our study patients, the mean age of these patients was 33.1 ± 10.13 years, majority of the patients were women (53.3%), while 46.7% were men, as shown in Table 1. Postoperative spherical equivalent refractive error (SRE), mean keratometry, and keratometric astigmatism were −4.325 ± 2.16, 44.71 ± 2.03, and −6.97 ± 3.21 D, respectively.

As demonstrated in Table 2, there was a highly significant difference between three IOP measurements as the highest one was IOPcc (17.27 ± 4.61 mmHg) followed by IOPg (14.64 ± 4.12 mmHg) while the least one was IOP (GAT) (11.80 ± 3.66 mmHg), and that difference was statistically significant. Pairwise comparison using the Bonferroni test was used to assess significance within three measurements; first, there was a statistically significant difference between IOP (GAT) and IOPcc. Second, there was a statistically significant difference between IOPcc and IOPg as well. Lastly, that difference was obvious also between IOP (GAT) and IOPg.

The Bland–Altman plots show the agreement between pressure measurements obtained with ORA and GAT as the dots lie within the limits of confidence interval (CI) of agreement (Figs. 1 and 2) as the mean difference between IOPcc and IOP (GAT) was 5.5 ± 2.02 mmHg (95% CI = 4.7–6.2 mmHg), while between IOPg and IOP (GAT) it was 2.85 ± 1.21 mmHg (95% CI = 2.39–3.29 mmHg). As indicated, the mean differences remained relatively stable at two extremes of IOP measurements.

Using simple linear regression to predict pressure measurement of ORA from GAT and to assess the association between them; first, there was a significant association found between IOP (GAT) and IOPcc expressed by the equation

\[
\text{IOP GAT} = -0.624 + 0.719 \times \text{IOPcc}
\]

Second, there was a significant association found between IOP (GAT) and IOPg expressed by the equation

\[
\text{IOP GAT} = -0.769 + 0.858 \times \text{IOPg}
\]

Correlations of biometric characteristics (CCT, mean keratometry, astigmatism, SRE, CH, and CRF) with IOP measurements obtained with the ORA and GAT: there was only significant negative association between

![Figure 1](http://www.mmj.eg.net)
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Table 3 Correlations of biometric characteristics (central corneal thickness, mean keratometry, astigmatism, spherical equivalent error refractive, corneal hysteresis, and corneal resistance factor) with intraocular pressure measurements obtained with the ocular response analyzer and Goldmann applanation tonometer

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Pearson’s correlation coefficient (r)</th>
<th>Statistical significance (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH vs.</td>
<td>IOP (GAT)</td>
<td>−0.413</td>
</tr>
<tr>
<td></td>
<td>IOPcc</td>
<td>−0.702</td>
</tr>
<tr>
<td></td>
<td>IOPg</td>
<td>−0.357</td>
</tr>
<tr>
<td>CRF vs.</td>
<td>IOP (GAT)</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>IOPcc</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>IOPg</td>
<td>0.446</td>
</tr>
<tr>
<td>SRE vs.</td>
<td>IOP (GAT)</td>
<td>−0.094</td>
</tr>
<tr>
<td></td>
<td>IOPcc</td>
<td>−0.168</td>
</tr>
<tr>
<td></td>
<td>IOPg</td>
<td>−0.082</td>
</tr>
<tr>
<td>Astigmatism vs.</td>
<td>IOP (GAT)</td>
<td>−0.157</td>
</tr>
<tr>
<td></td>
<td>IOPcc</td>
<td>−0.220</td>
</tr>
<tr>
<td></td>
<td>IOPg</td>
<td>−0.069</td>
</tr>
<tr>
<td>Central corneal thickness vs.</td>
<td>IOP (GAT)</td>
<td>0.249</td>
</tr>
<tr>
<td></td>
<td>IOPcc</td>
<td>0.044</td>
</tr>
<tr>
<td></td>
<td>IOPg</td>
<td>0.281</td>
</tr>
<tr>
<td>Mean keratometry vs.</td>
<td>IOP (GAT)</td>
<td>−0.110</td>
</tr>
<tr>
<td></td>
<td>IOPcc</td>
<td>−0.418</td>
</tr>
<tr>
<td></td>
<td>IOPg</td>
<td>−0.09</td>
</tr>
</tbody>
</table>

CH, corneal hysteresis; CRF, corneal resistance factor; IOP (GAT), intraocular pressure (Goldmann applanation tonometer); IOPcc, intraocular pressure (cornea compensated); IOPg, intraocular pressure (Goldmann related); SRE, spherical equivalent error refractive. *Statistical significance.

Table 2 Comparison between intraocular pressure measurements obtained with the ocular response analyzer and Goldmann applanation tonometer

<table>
<thead>
<tr>
<th>IOP measurements (mmHg)</th>
<th>IOP (GAT) (n=30)</th>
<th>IOPcc (n=30)</th>
<th>IOPg (n=30)</th>
<th>Test of significance F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean±SD</td>
<td>11.80±3.66</td>
<td>17.27±4.61</td>
<td>14.64±4.12</td>
<td>149.04</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>P1</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001*</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001*</td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001*</td>
<td></td>
</tr>
</tbody>
</table>

F, one-way repeated analysis of variance. IOP (GAT), intraocular pressure (Goldmann applanation tonometer); IOPcc, intraocular pressure (cornea compensated); IOPg, intraocular pressure (Goldmann related). P, significance within three IOP measurements. P1, significance between IOP (GAT) and IOPcc. P2, significance between IOPcc and IOPg. P3, significance between IOP (GAT) and IOPg. Significance between measurements assessed by Bonferroni post-hoc test. *Statistical significance.

Discussion
The human cornea is a viscoelastic tissue that can be described by two principal properties: (a) a static resistance component (characterized by the CRF), for which deformation is proportional to the applied force and (b) a dynamic resistance component (characterized by CH), for which the relationship between deformation and applied force depends on time. Both CH and the CRF are measured by a dynamic bidirectional applanation process using the ORA [6].

By using the two-way mixed model to assess the agreement between pressure measurements obtained with ORA and GAT [IOP (GAT), IOPcc, and IOPg], there was statistically significant reliability between three measurements as shown in Table 4.

Figure 2
Bland–Altman plots representing the difference between IOPg and IOP (GAT) versus the mean of both; the red dotted lines represent the upper and lower borders of the 95% limits of agreement. IOPg, intraocular pressure (Goldmann related); IOP (GAT), intraocular pressure (Goldmann applanation tonometer).

IOP (GAT) and CH as illustrated in Table 3, while there was no association with CCT, mean keratometry, astigmatism, SRE, and CRF.

There was significant negative association between IOPcc and CH and mean keratometry, while there was no association with CCT, astigmatism, SRE, and CRF as illustrated in Table 3.

There was significant positive association with CRF as illustrated in Table 3, while there was no association with CCT, mean keratometry, astigmatism, SRE, and CH.

By using the two-way mixed model to assess the agreement between pressure measurements obtained with ORA and GAT [IOP (GAT), IOPcc, and IOPg], there was statistically significant reliability between three measurements as shown in Table 4.

Discussion
The human cornea is a viscoelastic tissue that can be described by two principal properties: (a) a static resistance component (characterized by the CRF), for which deformation is proportional to the applied force and (b) a dynamic resistance component (characterized by CH), for which the relationship between deformation and applied force depends on time. Both CH and the CRF are measured by a dynamic bidirectional applanation process using the ORA [6].

In a simplistic approximation, the eye can be thought of as a uniform sphere filled with fluid under pressure.
Table 4 Agreement between pressure measurements obtained with ocular response analyzer and Goldmann applanation tonometer [intraocular pressure (Goldmann applanation tonometer), intraocular pressure (cornea compensated), and intraocular pressure (Goldmann related)]

<table>
<thead>
<tr>
<th>Average measures</th>
<th>Intraclass correlation coefficient</th>
<th>95% confidence interval</th>
<th>( P )</th>
</tr>
</thead>
</table>

|                    | 0.97                              | 0.94-0.98               | <0.001 |

If the walls are thin enough, when a small force is applied on the outside, the sphere pushes back with a force related to the internal pressure only. This principle as it relates to the eye is known as the Imbert–Fick law [7]. Most methods of measuring IOP are based on the relationship between the applied force and the response from the internal pressure.

Applanation tonometry estimates IOP either by measuring the external pressure required to obtain a known quantity of corneal flattening or by measuring the area flattened by a standard force for a given size of plunger.

The accuracy of the Imbert–Fick law, on which both techniques are based, depends on several simplifying assumptions: (a) the corneal tissue is completely elastic and will offer no resistance to the applied force (the resistance to the applied force comes only from the internal pressure); (b) the tear film surface tension (which pulls on the plunger) is negligible; (c) the change in globe volume due to applanation or indentation is very small and will not artificially increase IOP; and (d) the sclera, limbus, and the cornea are homogeneous and have similar elastic properties. Although one cannot ignore these effects, some of these cancel each other out by design.

The Imbert–Fick law on which GAT is based does not take account of corneal thickness as it assumes measurements are made on a cornea of standard thickness (500 mm) [8].

Corneal rigidity, the measurement of the ability of the corneal tissue to change shape in response to pressure, also plays an important role in the accuracy of all tonometers, especially applanation tonometers [9]. The mechanical rigidity of the normal cornea is provided principally by the lamellae of collagen fibrils within the stroma, which comprises 70% of the corneal dry weight and 90% of the thickness of the cornea [10]. If a cornea is not of average thickness (calibration) or has abnormal rigidity, IOP measurements become less accurate and/or reliable. This is clearly demonstrated in the published literature on the relationship between IOP and CCT in normal and abnormal corneas, well summarized in a recent meta-analysis by Doughty and Zaman [11].

Corneal irregularity in the graft after PKP is usually due to a combination of edema, scarring, and astigmatism that may lead to inaccuracies in Goldmann IOP measurements after surgery.

Any surgical intervention on corneal tissue results in substantial changes in the tissue structure, and thus, can alter corneal biomechanical properties [12], and the cornea may never regain its original mechanical strength after these interventions [13].

Studies have found that when the corneal tissue is weakened because of a corneal wound (e.g., refractive surgery or surgical interventions [12]), or because of disease processes (such as keratoconus [14] or osteogenesis imperfecta [15]) corneal biomechanics and IOP read lower than would be expected. For this study, it is hypothesized that an altered structure in the cornea in post-PKP eyes may also result in a variation in corneal biomechanics and hence in IOP readings.

IOP measurement in eyes with a PK is fraught with problems. The accuracy of IOP measurement with the GAT in these patients could be compromised because of various factors like corneal thickness, the biomechanical properties of the graft–host interface, and the high degree of corneal astigmatism in such cases. It is important to be able to assess the IOP of these patients as they are often on long-term steroids and may be steroid responders (the incidence of secondary glaucoma after PK ranges from 12 to 30% [16]).

The most accurate method for measuring IOP is to insert a manometric probe into the anterior chamber and directly measure the pressure, but this method is not feasible in the clinical setting [17].

Different studies have examined different tonometers to find a reliable alternative that can circumvent the problems encountered with IOP measurements by GAT after keratoplasty [3,18]. These studies found either no difference [18] or considerable variations between values obtained by GAT and other tonometers [3].

Comparing IOP measurements after PKP using four different tonometers including GAT, TonoPen XL, Pascal Dynamic Contour tonometer, and ORA, Chou et al. [19] found the least agreement between the ORA and GAT. Fabian et al. [20] found that IOP (GAT) was significantly lower than IOPcc but, comparable to IOPg after PK.

The present study compares the ORA with the GAT after PKP and the results of this study should be interpreted in this context, because the abnormal recipient corneas remaining after trephination may have an influence on graft metrics and IOP readings.
When significant astigmatism is present, the mires in the Goldmann tonometer are elliptical rather than circular, resulting in an area of contact with the cornea that is different in different meridians. In the usual horizontal split position of the mires, the IOP is underestimated when the eye shows with-the-rule astigmatism and overestimated with against-the-rule astigmatism [21]. Holladay et al. [5] suggested that IOP was underestimated by as much as 1 mmHg for every 4 D of with-the-rule astigmatism and overestimated by an equal amount for against-the-rule astigmatism. In patients with irregular astigmatism, the semicircles are irregular and the area of contact of the tonometer tip with the cornea is unpredictable, resulting in higher variability of IOP measurements [22].

In the present study, no correlation was found between astigmatism and IOP readings obtained using the two tonometers. To reduce the effect of corneal astigmatism on readings by GAT, the tonometer tip was rotated 43° to the least-curved meridian. There are other ways to compensate for underestimation or overestimation of IOP resulting from high astigmatism, which includes taking an average of values measured at two axes of 90° apart or reducing or adding 1 mmHg for every 4 D against-the-rule or with-the-rule astigmatism, respectively [5].

Among the different corneal parameters, CH showed a significant negative correlation with IOP (GAT) while there is no association with (CCT, mean keratometry, astigmatism, SRE, and CRF). Judging from these observations, it can be concluded that although CH, CRF, and CGT are related, they represent different physical/biomechanical properties. The dependence of IOP measurements by GAT on various anatomical (central thickness) and biomechanical (CH and CRF) graft properties was also investigated in the present study.

CCT measurements are indicative of the structural composition as well as the hydration and metabolic status of the cornea. Thickness is most commonly measured by an optical method or by ultrasound [17]. Within a healthy population of normal corneas, CCT follows a normal distribution with a large SD (530 ± 29 μm for optical pachymetry and 544 ± 34 μm for ultrasonic pachymetry) [17]. CCT appears to be independent of age and ocular biometric dimensions, and correlates with IOP and ocular rigidity [23]. There are reported differences in CCT between sexes and among races, but such data are limited and needed to be confirmed with further investigations. In particular, a study recently showed that African-Americans had a relatively thinner cornea than whites, which may be responsible for the reduced mean IOP readings reported for these patients [24]. It is well documented that CCT has an effect on IOP readings, being overestimated in eyes with thick corneas and underestimated in those with thin corneas [25].

Studies have shown a relation between CCT and IOP in eyes with normal and abnormal corneas, when measured by GAT [11]. This has led to the association of increased corneal thickness and falsely elevated tonometer readings. In previous studies an increase of between 0.11 and 0.71 mmHg has been reported for every 10 mm of deviation from a normal CCT measurement, albeit in structurally normal corneas [23]. As demonstrated by Young [26], CCT has an effect on IOP readings, it is overestimated in eyes with thick corneas and underestimated in those with thin corneas [25].

However, this study failed to show any association between CGT and IOP (GAT) readings, which is not surprising given the additional influence of other factors including surgical wound scar. This observation is in line with other studies evaluating the correlation between CGT and IOP [3].

It was previously observed that the influence of corneal thickness on IOP measurement is reduced in soft corneas. Therefore, the thin recipient rims retained after corneal transplantation can be one explanation for the lack of correlation [27]. It is possible that corneal transplantation alters the normal relationship between central thickness as well as material properties (Young’s modulus and Poisson’s ratio) and IOP observed in nongrafted eyes [26].

Corneal curvature is another variable that can affect the accuracy of IOP measurement, possibly because of the difference in the volume of the displaced fluid after a given area is flattened. Young previously described the relationship between corneal deformation under IOP and corneal curvature as well as thickness [26]. According to him:

\[ \Delta R = \frac{1}{2E} \times R(1 - \nu) \times (2R \times \Delta R - t) \]

Where \( \Delta R \) is the corneal deformation along the radial direction; IOP is the true IOP; \( R \) is the radius of the corneal curvature; \( t \) is the corneal thickness; \( E \) is Young’s modulus (defined as the ratio of the stress and the strain); and \( \nu \) is Poisson’s ratio (characterizing the deformation perpendicular to the direction of the load) of the cornea. This equation, which indicates the corneal radius of curvature has a relationship with IOP readings, does not support the present study as there is no association between the graft curvature and IOP (GAT). It is possible that the scar that develops between recipient and donor corneas can contribute to the biomechanical properties of a host–donor cornea as a whole, dominating other influential factors like CGT and corneal curvature.
In the current study, both IOPg and IOPcc were significantly higher than IOP (GAT), although the values were all correlated. Additionally, IOPcc was significantly higher than IOPg.

Using the information provided by CH, IOPcc is intended to compensate for corneal thickness and provide a value independent of the corneal factors [4]. This is likely the reason for the results in the current study demonstrating IOPcc values higher than IOP (GAT) and IOPg values.

**Conclusion**

To summarize, the results of this study are in agreement with previous studies, which have reported that the corneal tissue becomes weaker after surgical intervention. After a PK the normal corneal elasticity and rigidity must be altered because of scar tissue formation at the graft–host junction. It can be postulated that in post-PK eyes, the cornea may not achieve the same tensile strength even 1 year after surgical intervention and thus all of its biomechanical measures are compromised. This has particular importance in a group with a potentially higher risk of glaucoma and may explain some of the difficulties managing glaucoma in this group of patients.

In contrast to the manufacturer’s guidelines, this study shows that the ORA can be safely used in transplanted corneas because no wound dehiscence was observed as a result of measurements. This means after complete suture removal, the PKP wound is strong enough to provide a value independent of the corneal factors. This is likely the reason for the results in the current study demonstrating IOPcc values higher than IOP (GAT) and IOPg values.

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**Conflicts of interest**

There are no conflicts of interest.

**References**


