In response to the paper by Kim et al. (2020).

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Targeting manifest astigmatism with topography-guided LASIK is superior to topography-modified refraction (TMR), Layer Yolked Reduction of Astigmatism (LYRA), and Phorcides software protocols.

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Abstract

Dr. Kim et al. reported superior clinical outcomes in topography-guided LASIK eyes treated with the subjective manifest refractive astigmatism as input, compared to those treated on the topography-measured anterior corneal astigmatism using the topography-modified refraction (TMR) protocol. Their study design is admirable, and their results replicate the significantly inferior TMR outcomes that we previously reported, contributing to growing evidence that topography-guided protocols targeting the anterior corneal astigmatism, such as TMR and the Layer Yoked Reduction of Astigmatism (LYRA), are inferior to traditional manifest refraction targeted treatments. Using the anterior corneal astigmatism as treatment input results in inferior refractive accuracy outcomes, since such protocols ignore other significant sources of astigmatism such as posterior corneal astigmatism, lenticular astigmatism, and cortical perception. Conversely, targeting the subjective manifest refraction astigmatism equates to using the ideal summation of the entirety of ocular and cortical factors that contribute to astigmatism.

We read with interest "*Comparison of outcomes after topography-modified refraction versus wavefront-optimized versus manifest topography-guided LASIK*" [1]. The authors report superior refractive astigmatism accuracy outcomes in topography-guided LASIK eyes treated using the subjective manifest refractive astigmatism as input compared to eyes treated on the topography-measured anterior corneal astigmatism (ACA) with the topography-modified refraction (TMR) protocol [1]. The postoperative astigmatism magnitude in the TMR group was larger than that in the manifest targeted group, with a significant overcorrection [1].

Published data show that 87% of corneas have against-the-rule posterior corneal astigmatism [2], while more than 78% of corneas have with-the-rule ACA [3]. The posterior against-the-rule cylinder optically cancels much of the anterior with-the-rule cylinder with a net effect of reducing the impact of the ACA. [4]. As a result, the vast majority of eyes presenting for laser refractive surgery have a lower refractive astigmatism magnitude than ACA magnitude [4]. Treating the full ACA therefore overcorrects the refractive astigmatism, in keeping with data reported by Kim et al. [1].

It is encouraging to see that the study by Kim et al. complements our study findings, where we reported superior outcomes in topography-guided eyes treated on the manifest astigmatism axis, vs. the ACA axis, more notably in eyes with large axis differences between the two preoperatively [5].

Using vector analyses, we also found a significant relationship between the postoperative Angle of Error and the preoperative manifest vs. ACA axis difference, but only in eyes treated on

the ACA axis [5], and not on those treated on the refractive astigmatism axis. The larger the preoperative axis difference, the larger the postoperative Angle of Error in the ACA treated group.

Identically, in Kim et al. study's, the Magnitude of Error was shown to be significantly correlated with the preoperative manifest vs. ACA magnitude difference. This correlation was again only reported in the TMR group, and not in the Manifest group. Our combined findings validate that eyes having either a larger preoperative astigmatism magnitude or axis difference have a higher probability of inaccurate correction when treating on the topography-measured ACA.

In addition to these inferior TMR outcomes, a recent 432 eye comparative study reported that topography-guided LASIK targeting the ACA, with the TMR protocol, produces inferior postoperative astigmatism accuracy than wavefront-optimized (WFO) LASIK targeting the manifest refractive astigmatism [6]. Careful analysis reveals that the cause of the inferior refractive astigmatism accuracy in the topography-guided group was not the topography-guided technology itself, but rather having targeted the treatment on the ACA [7]. Had the manifest refractive astigmatism been the treatment input for the topography guided group as well, coupled with an accurate nomogram, the expected results would have produced superior or at least equivalent outcomes to WFO, as seen in several topography-guided studies.

In the Layer Yoked Reduction of Astigmatism (LYRA) protocol targeting the ACA, only 68.8% of eyes achieved a postoperative astigmatism of 0.50 D or less [8]. Kim et al. reported a similarly low rate of 71.8% in the TMR group vs. 87.5% Manifest group [1], while the published

literature shows between 86 and 96% for manifest topography-guided [9]. The above further confirms that targeting the ACA with TMR and LYRA results in significantly inferior refractive astigmatism outcomes.

In addition to Manifest, TMR and LYRA protocols, the current Alcon Contoura treatment guidelines recommend the ACA targeted correction to be reduced to the midpoint between ACA and refractive astigmatism in eyes where ACA is greater than refractive cylinder, with no evidence-based findings to suggest doing so [1]. Similar to this "in-between" treatment, Cao et al. introduced the mutual comparative analysis approach [10]. A manifest refraction is performed, followed with progressive phoropter cylinder addition aimed towards the ACA value. If full ACA presented on the phoropter is tolerated by the patient, then full ACA is treated, otherwise the astigmatism value at the point of subjective blur is used, somewhere between the manifest and ACA [10].

The "in-between" approaches do not appear to lead to superior refractive astigmatism accuracy vs. treating on the manifest [1, 10], although comparative studies are needed. Considering Kim et al.'s results show astigmatic overcorrection in eyes with TMR, any midpoint corrections between manifest and ACA could be speculated to also overcorrect astigmatism, as suggested by Kim et al. [1].

Finally, Phorcides topography-guided treatment planning software has also been proposed as an alternative treatment approach [11]. Phorcides attempts to combine objectively measured

information from the anterior corneal higher-order aberrations (HOA), the anterior corneal astigmatism, and the posterior corneal astigmatism to optimally modify the refractive treatment.

The Phorcides method assumes that anterior corneal HOAs play a significant contributory role in subjective refraction measurements, and the software attempts to compensate for their impact. However, a large 37,454 eyes study demonstrates that this assumption is flawed in healthy primary virgin eyes, where no clinically-meaningful correlation was found between anterior corneal HOAs and refractive cylinder [12]. Similarly, a study in 9,722 eyes indicates that the contribution of preoperative anterior corneal HOAs to topography-guided outcomes is negligible when treating on the manifest refraction, with excellent efficacy, accuracy, and safety in both low and high HOA eyes [13].

While Phorcides considers the posterior corneal astigmatism, it does so by incorporating individual patient data from the Pentacam or Galilei [14]. However, no single corneal imaging device has yet solved the riddle of accurately measuring posterior corneal astigmatism [15]. This is why several IOL calculators use the Baylor Nomogram, an algorithm that estimates posterior corneal astigmatism from the ACA based on population averages [15]. Published data shows those averages to be more accurate than using individual posterior corneal astigmatism values [15], as utilized by Phorcides.

With the erroneous assumption that anterior corneal HOA's impact cylinder in healthy eyes, and the use of questionable accuracy individualized posterior corneal astigmatism measurements, it is not surprising that early findings indicate Phorcides treatments do not lead to

improved postoperative astigmatism accuracy compared to treating on the manifest refractive astigmatism [11]. Phorcides may even lead to poorer outcomes than TMR or LYRA protocols, as recently published [14].

In summary, the reason why manifest topography-guided treatment works so well is that the manifest refractive astigmatism already includes all perceived sources of astigmatism, including the ACA, the posterior corneal astigmatism, and lenticular astigmatism. In addition, the manifest refractive cylinder also reflects the subjective cortical perception of astigmatism, something that neither TMR, LYRA, or Phorcides does. Prior to topography-guided technology, manifest refractive astigmatism was the gold standard target input, for good reasons. A review of over 150,000 of our own manifest topography-guided eyes using accurate manifest refraction data and an advanced big data nomogram demonstrates that refractive outcomes of manifest targeted eyes are superior to TMR, LYRA, and Phorcides treatment protocols [5, 16].

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and material

Not applicable.

Competing interests

The authors declare that they have no competing interests or no conflict to disclose.

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