Iris color matters in ocular health assessment

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Abstract

Corneal transparency, quantified by corneal densitometry (CD), is used in ocular health assessment. This study found that iris color influences CD measurements. Light-colored irises are associated with higher CD values (i.e., lower transparency), suggesting that iris color may introduce bias in CD and affect clinical accuracy.

Introduction

Corneal densitometry (CD) is a widely used objective method for assessing corneal transparency by analyzing the amount of light backscattered from the cornea. [1] This metric is often expressed as the mean pixel intensity (MPI) obtained from Scheimpflug imaging systems. Given that corneal clarity is essential for optimal visual performance, CD has gained relevance in clinical practice, where it is used to track the progression of eye diseases, evaluate outcomes following ocular surgeries, such as refractive procedures, and detect early signs of corneal disorders like keratoconus.

With CD becoming more prominent in ophthalmic diagnostics, it is crucial to identify factors that may influence its precision and reproducibility. Prior research has shown that CD values can be affected by various elements, including patient age, anatomical differences like pupil size and anterior chamber depth, characteristics of the corneal epithelium, and even the positioning or tilt of the eye during image acquisition. Recent studies conducted by our group have also shown that brightness artefacts inherent to the Scheimpflug imaging technique can introduce variability in CD measurements. [2] These artefacts often stem from light reflections off neighboring ocular structures, notably the sclera and iris.

Initial findings have hinted at a potential link between iris color and the level of reflected light, which could, in turn, influence MPI values and CD outcomes. Lighter-colored irises appear to reflect more light, possibly contributing to artificially elevated densitometry readings. (Fig. 1.)

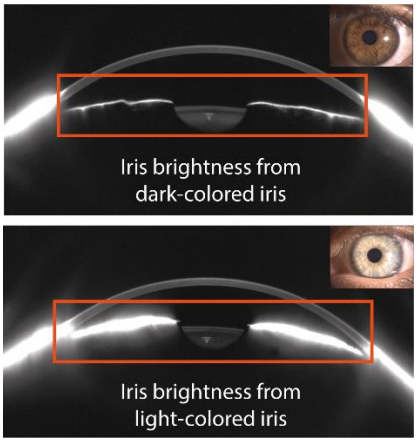

Fig. 1. Increased brightness artefacts are visible in Scheimpflug images of light-colored irises (bottom) compared to dark-colored irises (top).

To explore this further, the present study proposes a quantitative approach for assessing iris color and examines whether variations in iris pigmentation impact CD measurements. The aim is to determine if iris color acts as a confounding variable that should be taken into account in both clinical evaluations and research studies using CD.

Methods

Fifty-six healthy eyes from individuals aged 21 to 41 years, including 29 with light-colored irises and 27 with dark-colored irises, were examined under standardized ambient lighting. CD was measured using a Pentacam HR Scheimpflug tomographer, capturing 25 images per eye at different meridians. Each image was automatically segmented using median filtering and edge detection to identify the main structures: cornea, iris, and lateral regions of the image. MPI of the corneal region was calculated for each image, and the overall MPI per eye was obtained by averaging across all 25 images. Brightness artefacts were quantified using an adaptive threshold defined as the corneal MPI plus three times its standard deviation, by calculating the proportion of pixels exceeding this threshold in the iris, lateral regions, and overall.

Iris color was objectively quantified from slit lamp photographs by converting RGB images into the CIELAB color space, extracting lightness (L*), green-red (a*), and blue-yellow (b*) components. Each component was robustly normalized using its median and interquartile range to reduce bias and outlier effects. Statistical differences between iris color groups were assessed via the Mann–Whitney U test, and resulting p-values were transformed into weights to emphasize the most discriminative components. These weighted and normalized components were combined through a weighted root mean square calculation, yielding a single scalar metric (*IrisColor*) used for subsequent correlation analyses with corneal MPI.

Results

A moderate positive correlation was observed between CD, calculated as MPI, and iris-related brightness artefacts ($r = 0.40$, $p = 0.003$), as shown in Figure 2a. A strong negative correlation was also found between *IrisColor* and iris brightness artefacts ($r = –0.75$, $p < 0.001$), indicating that lighter irises reflect more light (Figure 2b). Likewise, *IrisColor* correlated negatively with CD ($r = –0.36$, $p = 0.006$), confirming that pigmentation influences MPI values: lighter irises result in higher MPI readings.

Group-wise analysis revealed that eyes with light-colored irises exhibited significantly higher CD (50.3 ± 3.3) compared to dark-colored irises (47.3 ± 2.8, $p < 0.001$), as well as increased iris brightness artefacts (2.2% vs. 0.5%, $p < 0.001$). No significant difference was observed in lateral (scleral) brightness, suggesting that the iris is the main contributor to artefactual increases in CD.

Conclusions

This study confirms that iris color, quantified through an objective imaging metric, significantly affects CD. Since CD is the primary objective metric for corneal transparency in ocular health assessment, iris pigmentation can introduce bias into transparency evaluation. Lighter irises backscatter more light, leading to higher apparent MPI values. These findings emphasize the need for considering iris pigmentation in CD analysis and support the development of correction protocols or stratification strategies in both clinical and research contexts.

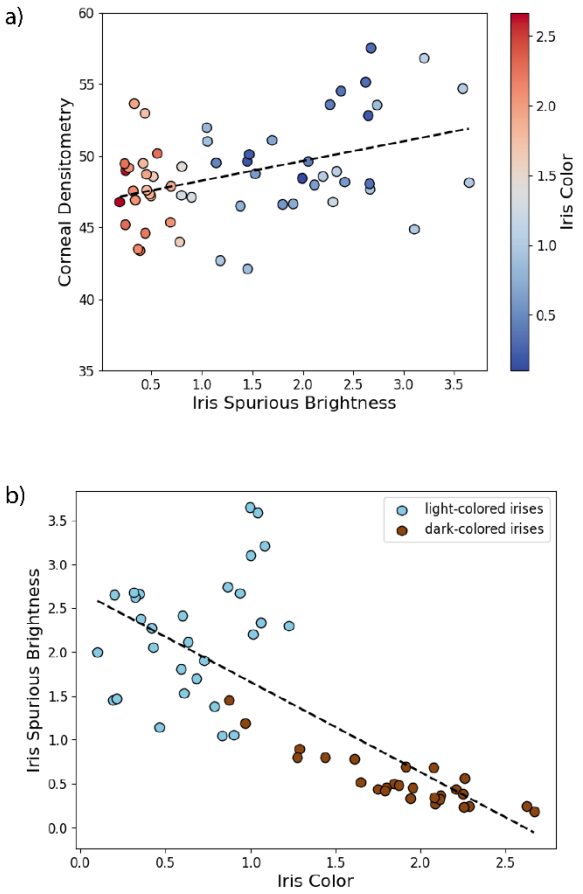

Fig. 2. (a) Shows the correlation between corneal densitometry, computed as corneal MPI, and iris brightness artefacts. (b) Shows the correlation between iris brightness and iris pigmentation (*IrisColor*).

Acknowledgments

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