Permanent Vision Correction Via Laser-Induced Collagen Crosslinking

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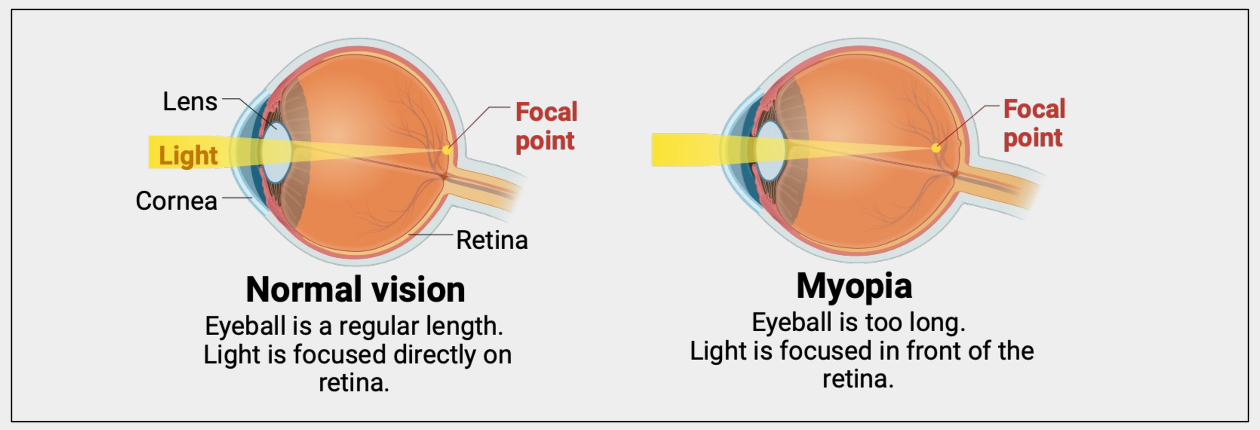
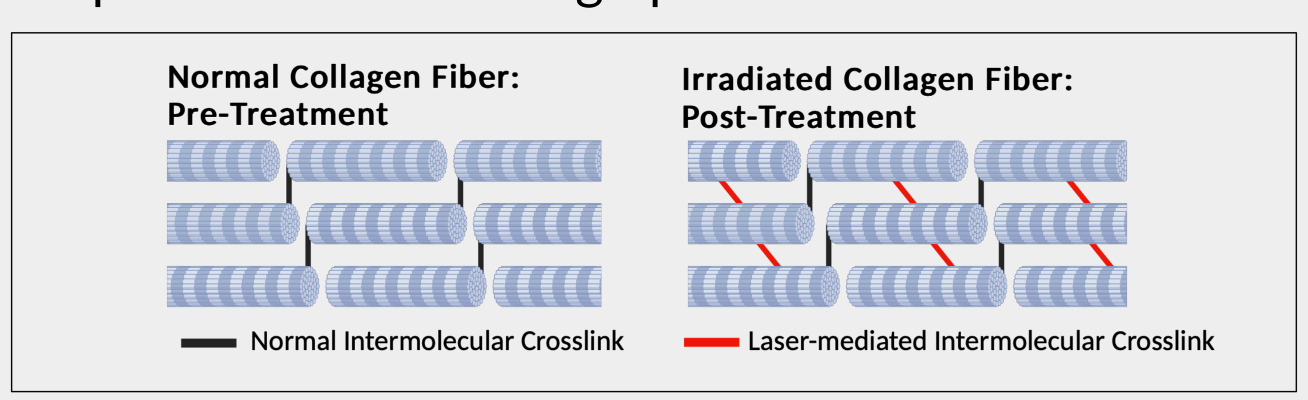
Introduction

- Myopia, or nearsightedness, is a common refractive error caused excessive curving of the cornea, resulting in blurred vision [1].



- Refractive surgeries, such as laser-assisted in situ keratomileusis (LASIK), are effective in improving visual acuity, but these invasive procedures can lead to postoperative complications [2].
- We implemented a noninvasive method for permanent vision correction using femtosecond lasers. This technique generates low-density plasma within the cornea, inducing chemical crosslinking (CxL) in corneal collagen.
- The increased CxL alters the cornea's biomechanical rigidity and curvature, resulting in a decrease in myopic diopter while minimizing operative trauma.



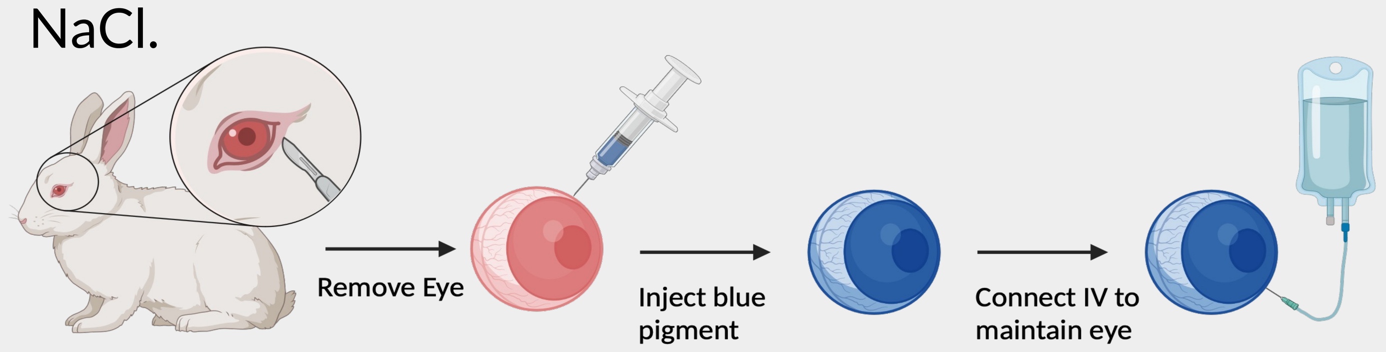
Objective:

- Achieve increased levels of CxL and demonstrate a significant decrease in effective refractive power (ERP) in laser treated eyes.

Methods

Ex Vivo Rabbit Eye Preparation:

- 3 pairs of fresh rabbit eyes were used. For each pair, one served as a control and one underwent laser treatment.
- Albino eyes were injected with Trypan Blue dye.
- Each eye was connected to an IV drip containing 0.9% NaCl.



Eye Deformation:

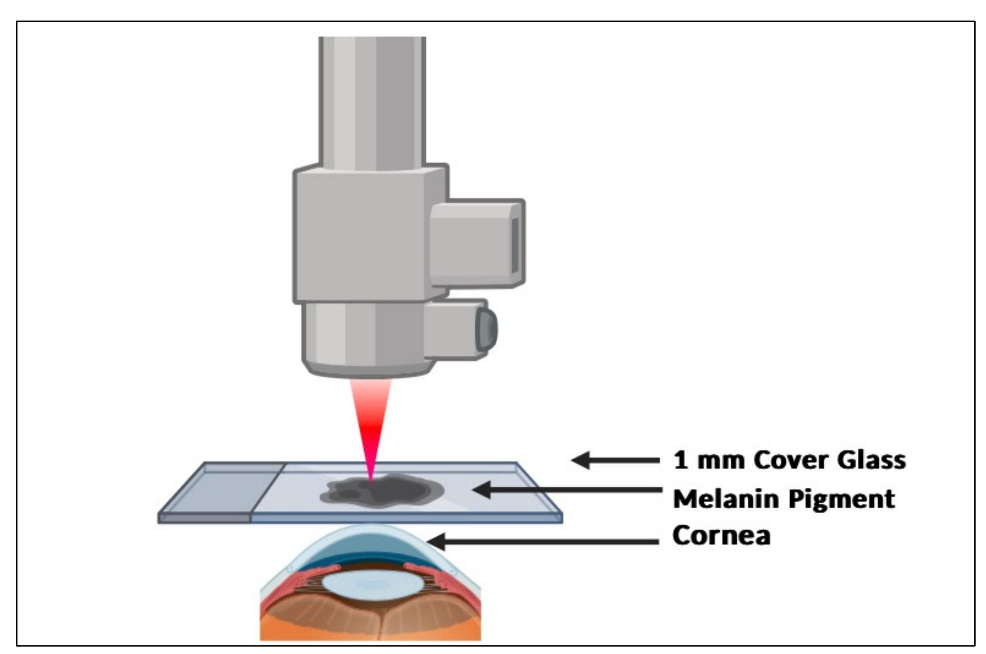
- A microscope cover glass was applied to the surface of the eye to flatten the cornea and ensure uniform exposure of the cornea during laser irradiation.
- Melanin pigment was placed below the cover glass to enhance plasma generation during laser treatment.

Crosslinking Treatment:

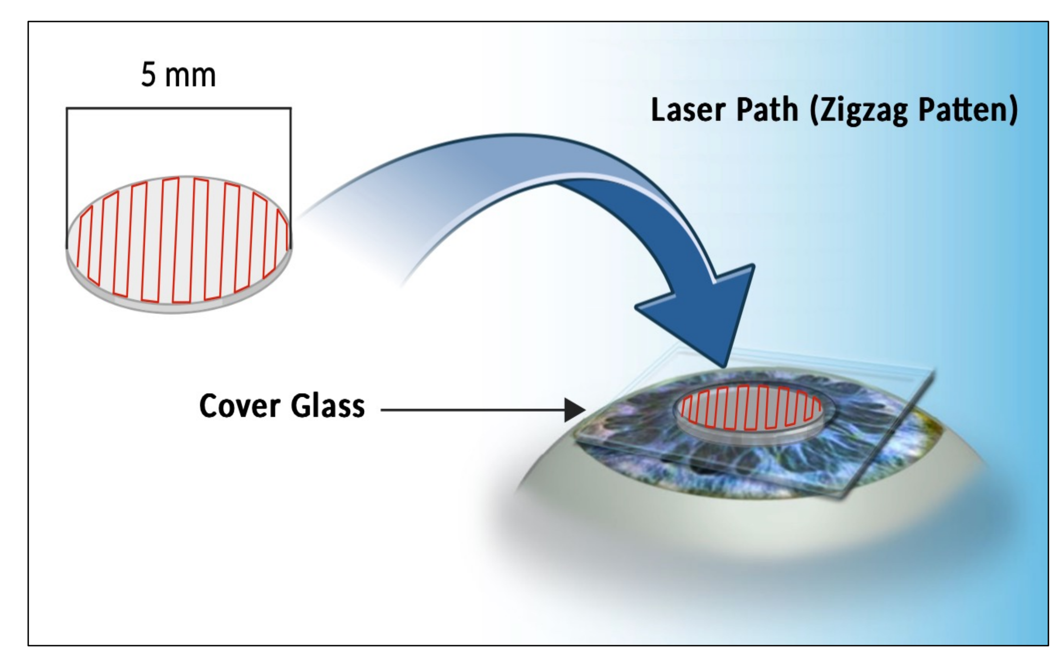
- A femtosecond laser was used for treatment at a power of 185 mW.
- Laser followed a zigzag trajectory and targeted a 5 mm diameter circle on the corneal surface.
- Treated 5 layers of the cornea with a distance of 20 µm between each layer, resulting in a total treatment depth of 100 µm.
- The cover glass was removed immediately after treatment.

Corneal Topography:

- Topography exams were conducted once before treatment and hourly for 6 hours post-treatment to assess ERP changes.

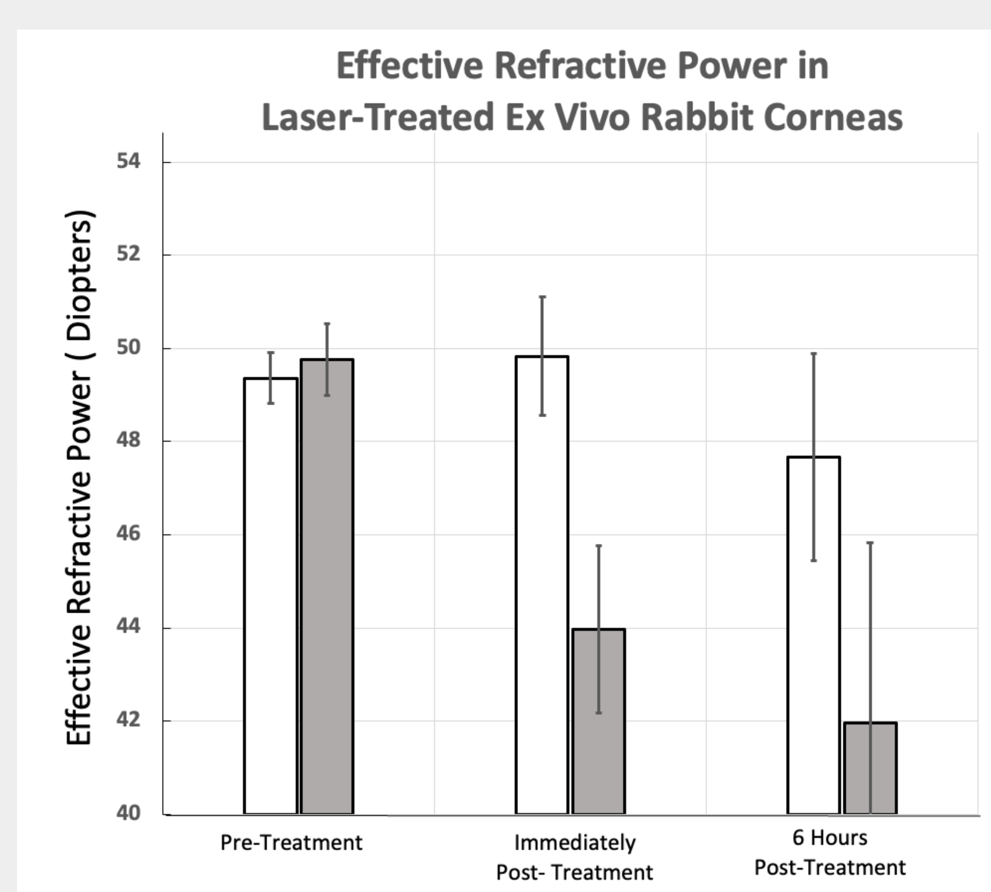


Laser Treatment Set-Up

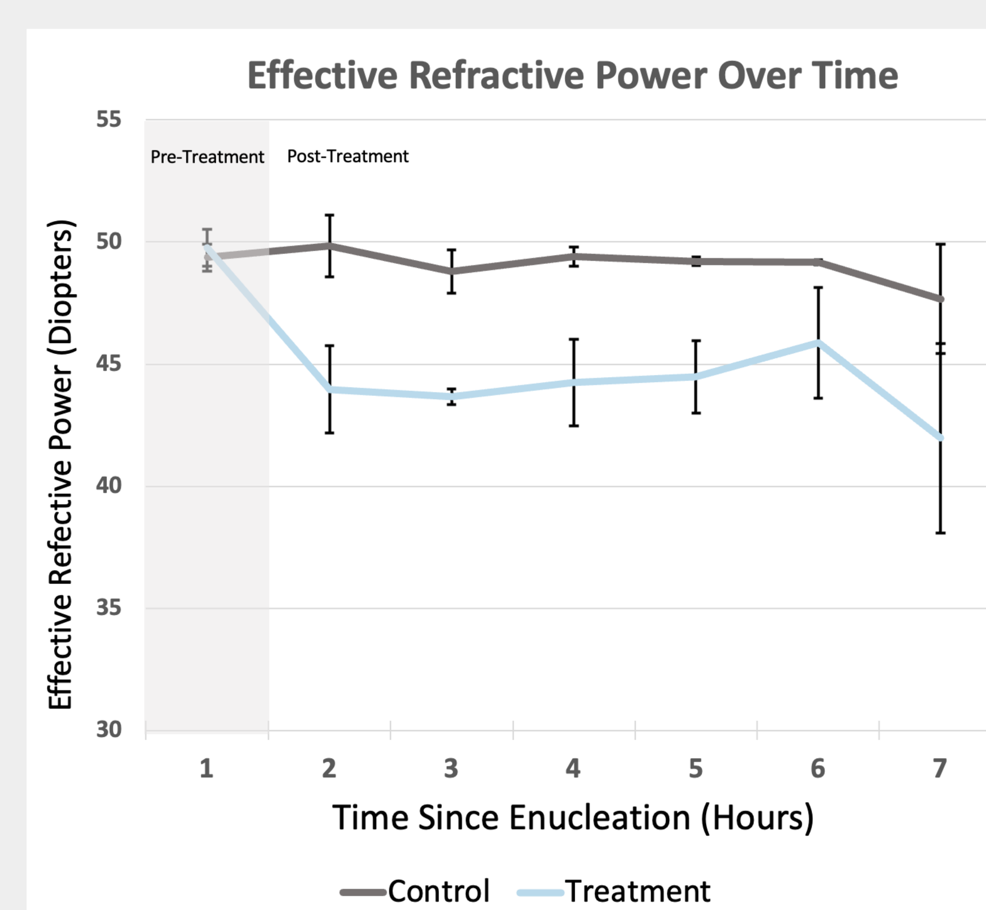


Laser Zigzag Path on Corneal Surface [3]

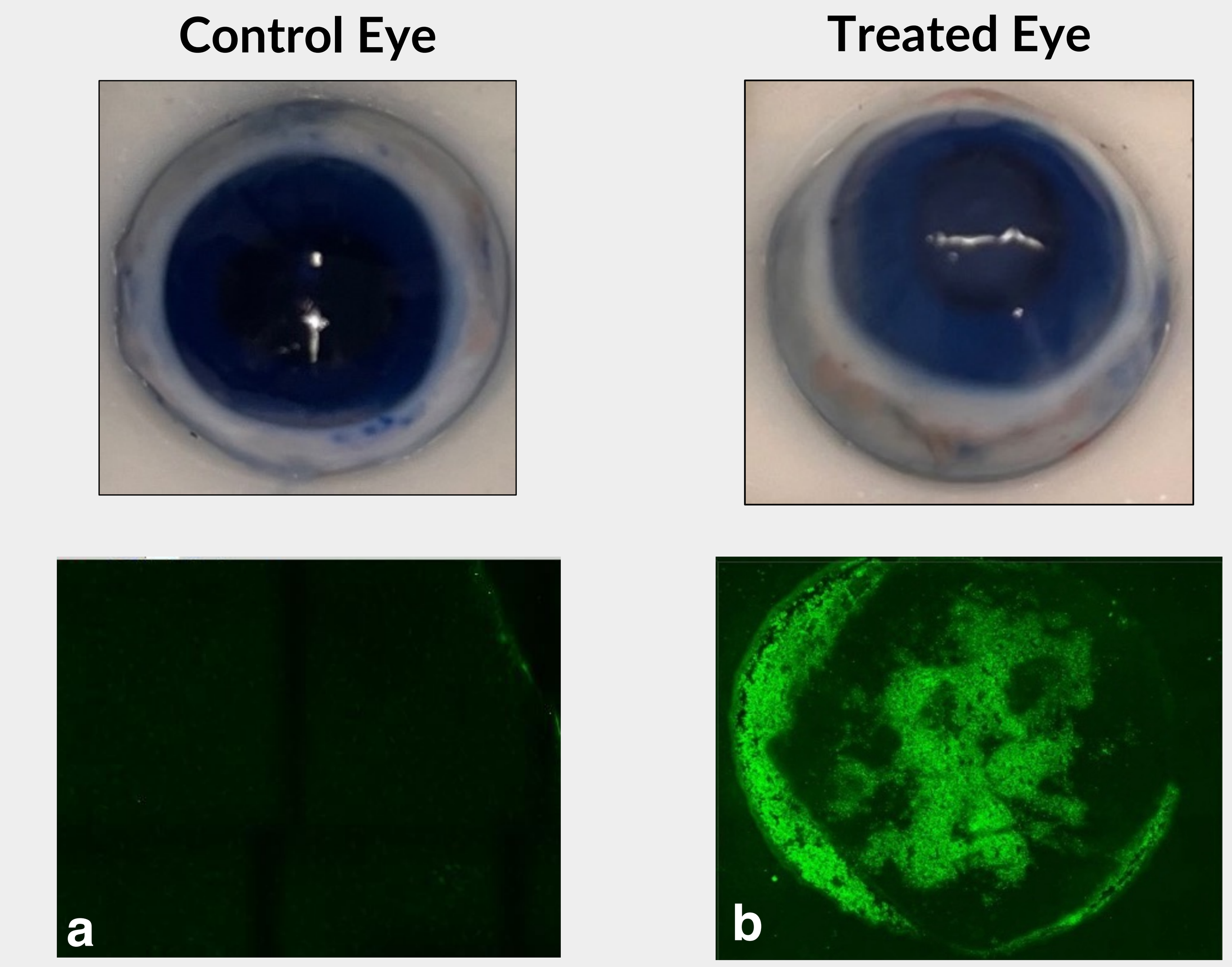
Results



ERP changes in ex vivo rabbit eyes (n=3). Error bars represent standard deviation.



EFP changes in ex vivo rabbit eyes over 7 hours (n=3). Error bars represent standard deviation.



Second-Harmonic Generation (SHG) Imaging of Laser-Treated Rabbit Cornea. (**a**) untreated portion of cornea (**b**) treated portion of cornea.

- Increased CxL results in a greater density of collagen, indicated by green segments of SHG image.

Discussion

- SHG imaging showed increased crosslinks in laser-treated corneal segments.
- Sustained ERP decrease post-treatment.
- Data trend indicates potential treatment efficacy.
- Experiments were a part of a power study to determine sample size required for statistical significance.
- Large standard deviation is likely due to topography exams conducted by inexperienced users

Future Direction

- **Sample Size:** Greater sample size for statistically significant results.
- **Induce Greater Deformation:** Increase the deformation to further flatten the eye during treatment in order to cause greater sustained ERP change.
- **Laser Power:** Determine the optimal laser power setting that achieves CxL while minimizing optical damage.

References

[1] Singh, H. et al. (2022). Indian Journal of Ophthalmology, 70(8), 2788-2799.
[2] Sahay, P. at al. (2021). Indian Journal of Ophthalmology, 69(7). 1658-1669.
[3] Wang, C. et al. (2018). *Nature Photonics*, 12(7), 416–422.