Electrical Impedance Profiling of Corneas With Keratoconus and Post–Penetrating KeratoplastyUsing a Multifrequency Prototype Device

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Presentation Number: 5469

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INTRODUCTION

Keratoconus and post-penetrating keratoplasty represent distinct corneal structural states with different biomechanical properties. Current diagnostic tools do not directly measure the electrical characteristics of corneal tissue, which may reflect underlying structural organization. Impedance-based sensing offers a potential method to characterize these differences in vivo.

PURPOSE

To evaluate whether a multifrequency impedance device can differentiate corneal profiles in keratoconus and post-penetrating keratoplasty eyes.

Electrical impedance reveals corneal structural signatures

METHODS

A pilot study was conducted using a second-generation impedance device (IMPEL).

Measurements were obtained in 7 eyes: 4 with keratoconus and 3 with stable post-penetrating keratoplasty.

Resistance (R) and capacitance (C) were recorded across 500 Hz to 64 kHz.

Data were normalized and analyzed using:

- Principal Component Analysis (PCA)
- Supervised machine-learning models (LDA)

Phase-space representations (C/C_mean vs R/R_mean) and frequency-response plots were used for visualization.

Electrical signatures encode tissue architecture

RESULTS

Keratoconus and post-keratoplasty corneas exhibited distinct impedance behaviors across frequencies.

Differences were more evident in phase-space representation, where keratoconus showed wider dispersion patterns compared to the more compact trajectories of post-keratoplasty eyes.

Machine-learning analysis demonstrated separability between groups, consistent with the observed clustering patterns.

Figure 1. Phase-space representation of normalized capacitance versus resistance.

Keratoconus shows broader dispersion patterns, while post-keratoplasty exhibits more compact trajectories.

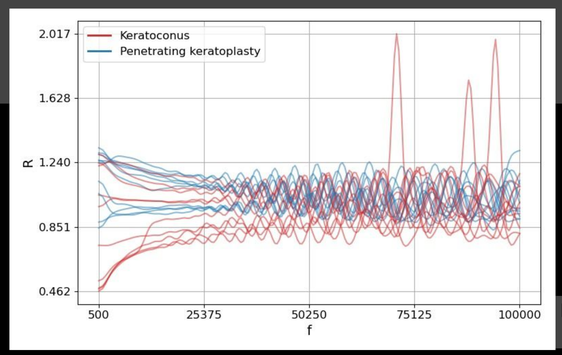

Figure 2. Imp Frequency-response curves of corneal resistance showing distinct impedance behavior between keratoconus and post-keratoplasty eyes.

CONCLUSIONS

The IMPEL prototype was able to detect distinct corneal impedance signatures associated with different structural states.

These findings support the feasibility of impedance-based corneal characterization beyond conventional diagnostic parameters.

Larger studies are required to validate these preliminary observations.

Disclosures for Bonetto, Bellotti, Saravia: Code P (Patent):US Patent: US 12,402,801 B2

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