ARVO Annual Meeting Abstract | June 2013

OCT-Vibrography: A Novel Non-Contact Method to Estimate Corneal Biomechanical Properties

Sabine Kling; Ernest Chang; Giuliano Scarcelli; Nandor Bekesi; Seok Yun; Susana Marcos

— Author Affiliations & Notes

Sabine Kling
Instituto de Optica, Consejo Superior de Invest Cientificas, Madrid, Spain

Ernest Chang
Wellman Center, Massachusetts General Hospital, Boston, MA

Giuliano Scarcelli
Wellman Center, Massachusetts General Hospital, Boston, MA

Nandor Bekesi
Instituto de Optica, Consejo Superior de Invest Cientificas, Madrid, Spain

Seok Yun
Wellman Center, Massachusetts General Hospital, Boston, MA

Susana Marcos
Instituto de Optica, Consejo Superior de Invest Cientificas, Madrid, Spain

Footnotes

Commercial Relationships**Sabine Kling**, None; **Ernest Chang**, None; **Giuliano Scarcelli**, massachusetts general hospital (P); **Nandor Bekesi**, None; **Seok Yun**, Massachusetts General Hospital (P); **Susana Marcos**, Essilor (F), PCT/ES2012/070185 (P)

SupportNone

Investigative Ophthalmology & Visual Science June 2013, Vol.54, 1630. doi:

Abstract

Purpose

Corneal biomechanics are key for diagnosing corneal pathologies and evaluating treatments that alter corneal geometry or stiffness. Most methods to measure corneal biomechanics are destructive, while in-vivo techniques (e.g. air-puff imaging) are biased by corneal geometry and IOP. We developed a new technique to determine corneal material parameters, while reducing current prevalent restrictions.

Methods

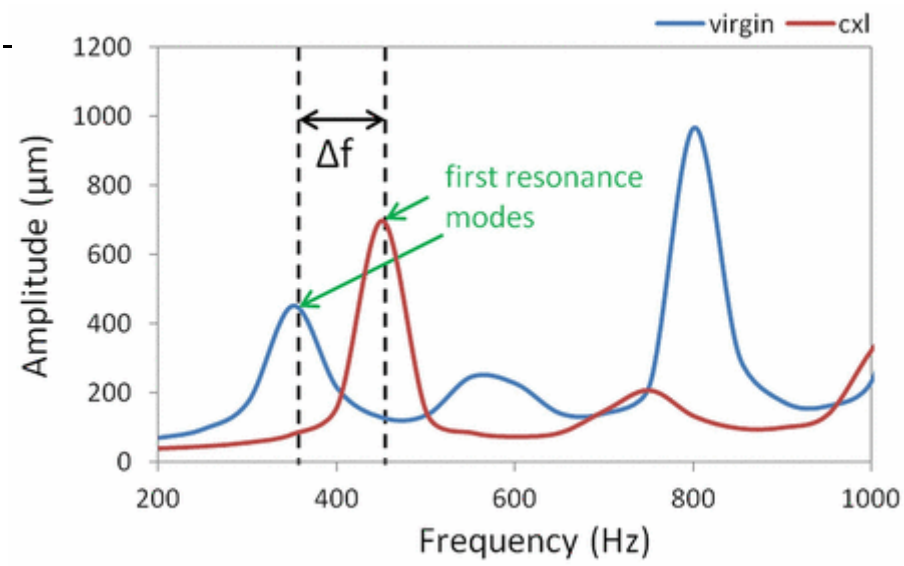
Sound excitation (100-110 db) together with phase sensitive OCT was used to measure the profile of the natural frequencies (range 200-1000 Hz) in corneal tissue. The technique was tested in-vitro on 6 freshly enucleated pig and bovine eyes, using corneal flaps, corneal buttons and whole eyes. Different conditions were tested (virgin, riboflavin-dextran instillation, cross-linking CXL) to determine the effect of corneal rigidity and hydration. Changes in corneal stiffness were determined by the shift of natural frequencies and viscoelastic behavior by the phase lag between sound wave and corneal oscillation. Finite element (FE) models were built to simulate the experimental observations.

Results

We found an experimental shift in the first natural frequency of 101.25±67.1 Hz between the anterior flaps of virgin and CXL corneas; no significant shift was observed for posterior flaps (-12.5±32.0 Hz). Corneal buttons and globes confirmed a frequency shift after cross-linking. The phase lag was sensitive to the tested frequency and to corneal fixation (δ(flap)=4.06, δ (button)=6.19 and δ(globe)= 5.93 at 355Hz). FE-models predicted the first natural frequency to be strongly correlated with corneal stiffness (ΔE=+1.4MPa, Δf(globe)=+100Hz, Δf(button)=+250Hz, Δf(flap)=+150Hz). Natural frequencies of higher modes were also sensitive to IOP, corneal curvature, thickness and density.

Conclusions

OCT vibrography is a promising non-invasive technique for the estimation of corneal biomechanical properties, allowing the separation of corneal stiffness from other parameters.



View Original Download Slide

Shift of the first resonance frequency with increased corneal rigidity.

Keywords: 552 imaging methods (CT, FA, ICG, MRI, OCT, RTA, SLO, ultrasound) • 473 computational modeling • 551 imaging/image analysis: non-clinical