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Obtaining biomechanical properties of corneal tissue in-vivo using a non-contact method

Ahmed Elsheikh[1,2], Kai-Jung Chen[1], Ashkan Eliasy[1], Riccardo Vinciguerra[3]
[1]School of Engineering, Liverpool, United Kingdom. [2]NIHR Biomedical Research Centre for Ophthalmology, Moorfields Eye Hospital NHS Foundation Trust and UCL Institute of Ophthalmology, London, United Kingdom. [3]St Paul's Eye Unit, Royal Liverpool and Broadgreen University Hospital, Liverpool, United Kingdom

Abstract

Introduction: The current inability to characterise the material properties of corneal tissue in vivo has led to inability to optimise several treatment procedures that either interact or interfere mechanically with the eye. Example applications that stand to benefit from knowledge of material properties include planning of refractive surgeries [1], selection of contact lenses, optimisation of collagen cross-linking [2], and use of corneal implants. This study aims to determine biomechanical properties of corneal tissue based on the corneal response parameters obtained using the CorVis-ST.

Methods: A material parameter (β) was developed to enable in vivo estimation of the stress-strain behaviour of corneal tissue. To validate β in healthy eyes, numerical models were built of 158 (randomly-selected) eyes of 158 participants. The models simulated the eye's specific geometry, measured intraocular pressure (IOP) and the air pressure produced by the CorVis ST. For each eye, an inverse analysis procedure was conducted resulting in estimating the corneal tissue's stress-strain behaviour, which was then used to provide a value for the material parameter, β. These values were compared with those obtained using the β algorithm to validate the algorithm.

Results: In this dataset, the mean value of participants's age was 40±17 years (range 7-81), central corneal thickness (CCT) 544± 29 µm (454-621), CorVis IOP 15±2.6 mmHg (9.5-29) and biomechanically-corrected IOP (bIOP) 14.5±2.2 mmHg (9.8-24.3). The β parameter obtained from inverse analysis of numerical models simulating the 158 eyes included in the study had a mean of 0.93±0.21 (0.47-1.55) and the β algorithm provided a β mean of 0.93±0.19 (0.56-1.67). There were no significant differences between the two sets of β values (p=0.99), Figure 1.

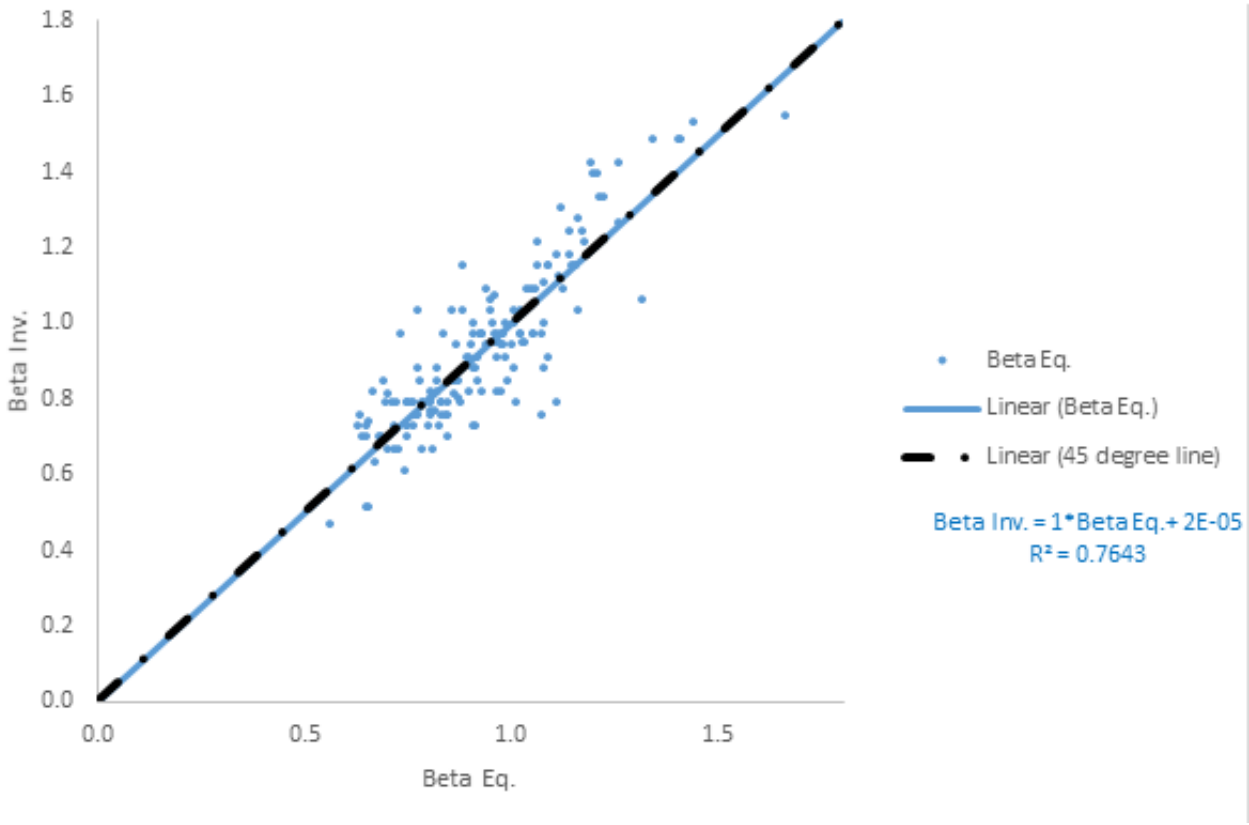

Figure 1, the results of β algorithm against β inverse analysis for 158 healthy eyes are shown where the linear trend line is compared with 45 degree line.

Conclusions: The new β material algorithm has been able to successfully predict the in-vivo material behaviour of corneal tissue as estimated using an inverse analysis procedure. With this success, the algorithm can be used to optimize several procedures that interact or interfere mechanically with the eye, such as refractive surgery. The next step will be to develop a similar material algorithm for eyes with abnormal tomography, such as those with keratoconus.

References

1. Bryant and McDonnell. Journal of biomechanical engineering 1996;118(4):473-81.
2. Goldich et al. Cornea 2012;31(6):609-14.