"FINITE ELEMENT MODELLING"

of soft contact lenses on eye

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PURPOSE

When fitting soft contact lenses, it is impossible to visualise the tear layer below the lens in white light. In addition, being permeable, soft lenses absorbs normal fluorescein and use of high molecular fluorescein is not sensitive enough to identify subtle changes in fit.

This study provides a software tool based on a Finite Element Model of the human eye, developed over a period of more than 15 years at both Dundee University and Liverpool University, that can demonstrate the fit of a known contact lens design on a particular subject's eye through computer simulation.

Using this new technique, thickness maps for the tear layer under contact lenses can be created. These maps give important feedback to the contact lens fitting and design process and have the potential to enable the full customisation of contact lenses.

In addition, the model itself can demonstrate how the lens settles onto the eye during the blink process, together with rebound from the corneal surface directly after the blink.

METHODS

Topography data from more than 100 normal eyes were collected by the Eye Surface Profiler (Eaglet Eye, Netherlands) which provides anterior corneal and scleral surface data up to 20 mm diameter and can supply up to 250,000 data points for analysis.

The data thus collected was used to fit a finite element model mesh for each eye under investigation. Material characteristics of an "average eye", including axial length and IOP, were obtained from previous Finite Element modelling of the human eye (Elsheikh, Geraghty et al. 2010, Whitford, Studer et al. 2015).

Data were taken directly from contact lens design minifiles and fitted to the model, including such information as modulus. In this way, the exact lens shape using the required material properties was fitted to the simulated cornea of the subject.

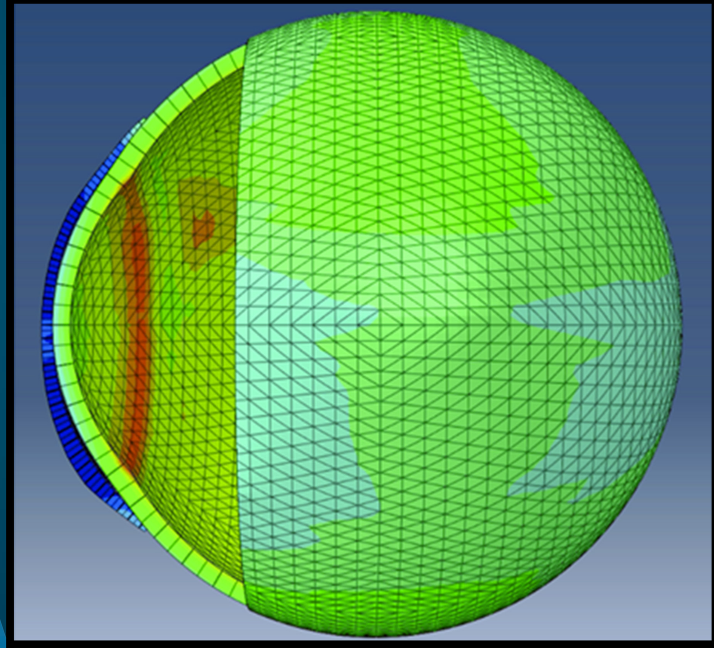


Fig 1 FE model of normal eye with contact lens in place. The shape of the prismatic area can be seen inferiorly and the stresses on the lens towards the edges can be seen by the paler blue colour.

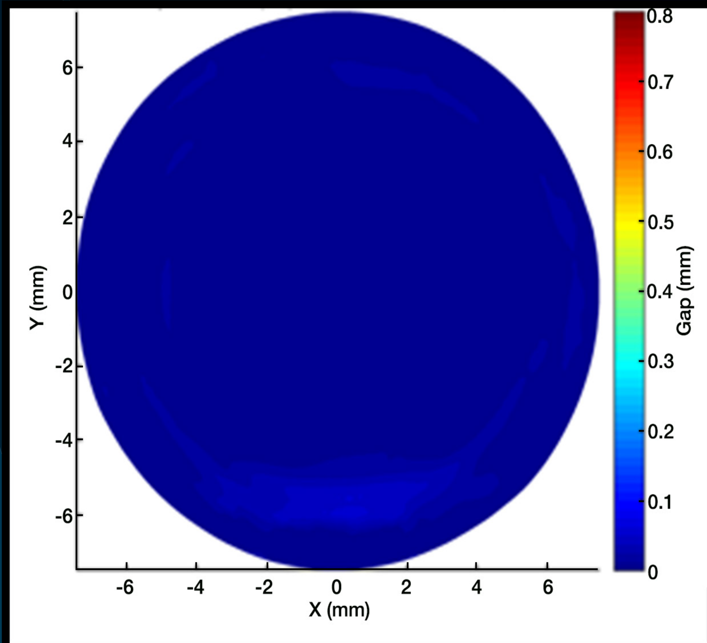


Fig 2 Tear layer map under the same lens showing a generally uniform tear layer with slight pooling under prismatic area. The FE model showed that this area was the last to settle during the blink cycle.

METHODS

The negative pressure produced by the surface tension of the tear layer between the eye lid and the anterior surface of the eye was applied, along with the eyelid pressure. The contact lens model was allowed to react to these forces and the final shape of the contact lens was exported to be analysed.

From this process, the final lens back surface shape could be directly compared to the anterior corneal shape and a thickness difference map produced. This, then represented the tear layer thickness under the lens.

Videos were produced to show fluctuation of the tear film under the lens which could be used to assess soft contact lens fitting.

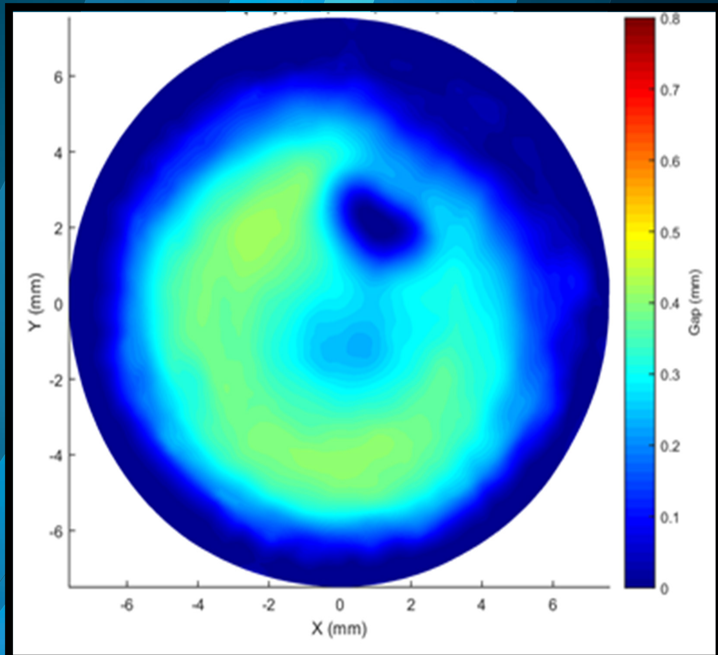
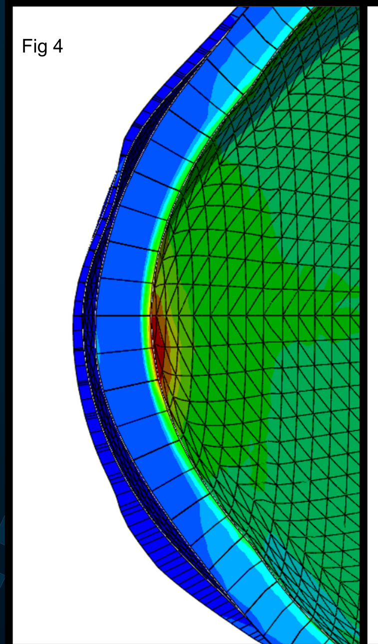


Fig 3 A keratoconic patient was experiencing visual variablility with his soft lens.

The tear layer map produced by the above described method showed a possible area of touch which represented the lens buckling at this position.

Tears can be seen to encroach down into the central area which would interfere with vision.



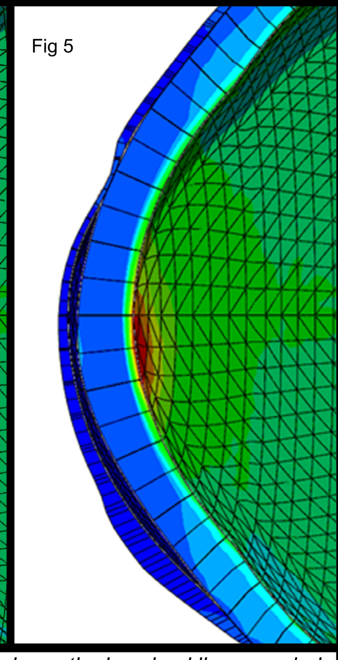


Fig 4 Profile view of the FE model shows the lens buckling superiorly due to pressure from the lid during eye closure.

Fig 5 Shows the rebound of the inferior portion of the lens off the cornea as the eye re-opens. The superior section is still aligned with the cornea and corresponds with teh area of "touch" seen in Fig. 3.

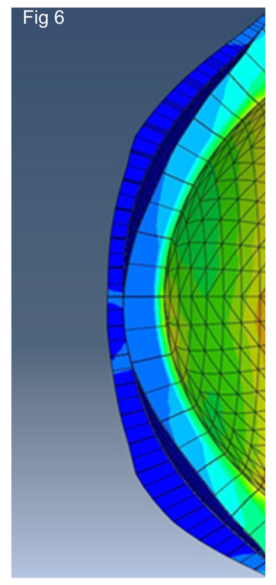
The FE modelling successfull explained the patients's visual issues.

RESULTS

This study showed that the fitting process of a soft contact lens is sensitive to several parameters: the shape of the eye, the geometrical design of the lens, the stiffness of the contact lens material, thickness of the lens and the eye lid pressure.

It was possible to match issues with fit and vision to the model's performance in terms of lens behaviour and tear film thickness under the lens. The tear layer mapping in particular gave imformation very similar to that obtained by using fluorescein in RGP lens fittings.

Additionally, issues such as lens buckling, could be identified and rectified using this modelling technique.



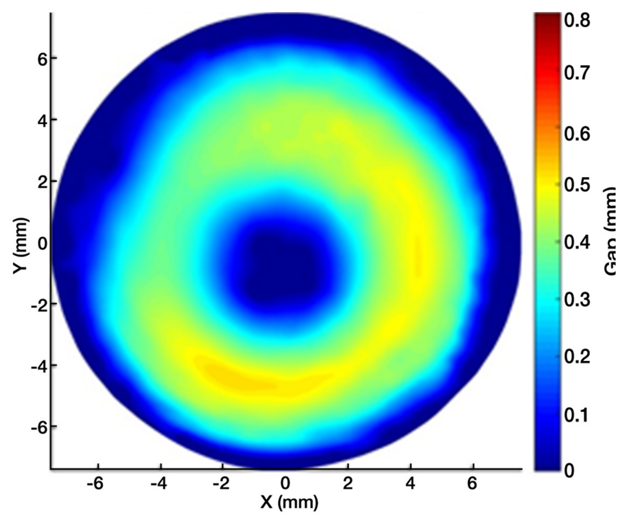


Fig 7 Tear Layer Map (corresponding to Fig 6) showing high tear volume under the lens similar to an RGP keratoconic fits

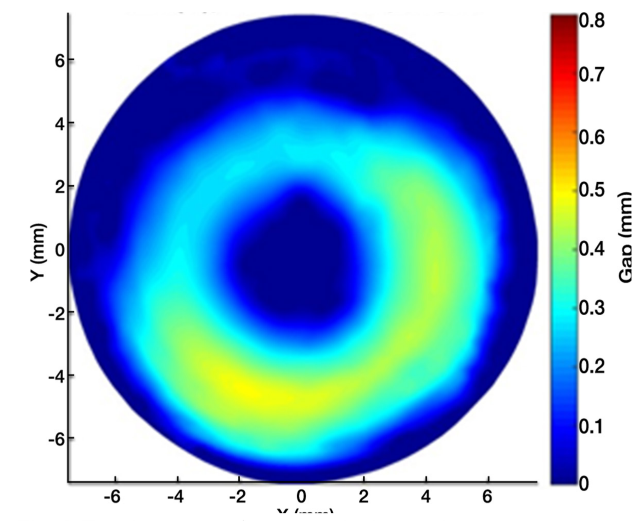


Fig 8 Tear layer map for same design and power with centre thickness reduced by half.

Fig 6 Thick soft lens fitted to keratoconic subject (actual anterior corneal shape only) demonstrating poor contact superiorly and inferiorly

CONCLUSIONS

Through the use of Finite Element Modelling, it is now possible to predict the fit of a particular soft contact lens design on a specific, individual eye shape and examine the effects of changes in fit and overall contact lens design. Going forward, this could provide a valuable tool for fitting complex irregular corneas as well as improving contact lens design in general.

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