Evolution of the epithelial thickness during orthokeratology treatment; invivo measurements & numerical simulations

Background Orthokeratology (Ortho-K) is a non-invasive and reversible refractive treatment that temporarily reshapes the cornea so that the patient’s visual acuity is normal without the need of contact lenses, glasses, or laser surgeries [1]. The effect of Ortho-K is achieved by wearing specially designed rigid contact lenses overnight. After this 6-8-hour period, lenses are removed, and the deformation of the cornea achieved by the rigid lens persists for the duration of the day. This technique allows patients to perform daily activities with perfect vision, even for strong pre-existing myopia. However, the effect is gradually lost towards the end of the day, resulting in glares and blurry vision. In clinics, the adaptation of these lenses is purely empirical, and no biophysical theory has been proposed to explain the underlying mechanisms that allow for the deformation and slow recovery of the cornea. Cornea is a viscoelastic material mainly composed of collagen fibres embedded in a ground substance, from which more the 80% is water. Experimental evidences suggest that Ortho-K primarily affects the shape of the corneal epithelium (see Fig.1) and induced a redistribution of the fluid in this epithelium.

Aim This project aims at evaluating the hypothesis suggesting that fluid redistribution in the epithelium is responsible for the optical correction. Moreover, we aim at determining if the poroelastic properties of the tissue are able to explain the optical correction observed clinically.

Materials and Methods In this project, the student will calibrate a numerical model describing the poroelastic behaviour of the corneal stroma and epithelium. First the student will analyze clinical data obtained on patients during Ortho-K wear; optical coherence tomography (OCT) images were collected before wearing the lens as well as after 1 day, 1 week, and one month of wear. OCT imaging provide accurate information on the thickness of the different corneal layers, which will be used to characterize the local evolution of the epithelium thickness over time. This clinical data will then be used to calibrate numerical models of the epithelium / stroma. The cornea tissues will be modeled as soft porous material and finite element simulations will be used to simulate the behaviour of overnight contact lenses, to calculate the deformation induced on the corneal tissue by the contact lens, and its relaxation after lens removal. Ultimately, the model will be assessed in patient requiring different amount of correction to assess whether the overall adaptation induced by Ortho-K can be accurately described.

Nature of the Thesis:
Analysis of clinical data: 20%
Biomechanical simulation: 80%

Requirements:
Knowledge in FE simulation

Skills acquired:
Python / Matlab, FEBio / Abaqus
Mechanical testing
Knowledge in optics and ophthalmology

Supervisors:
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Institute:
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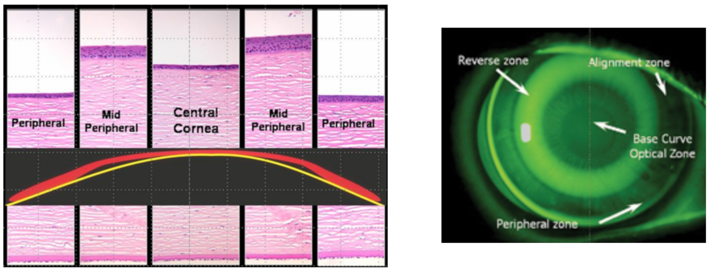

(a) (b)

Figure 1. Experimental effects of Ortho-K. (a) Thinning of epithelium in peripheral and central regions. Thickenning of mid-peripheral regions; (b) fluorogram with lens placed over cornea (black regions correspond to a gap of more than 50 microns)

References:
[1] Mountford J, Ruston D, Dave T. “Orthokeratology Principleas and Practice” (2004). Elsevier. ISBN 978-0-7506-4007-7 DOI https://doi.org/10.1016/B978-0-7506-4007-7.X5001-6

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