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Flow behaviour of vitreous humour biofluid during saccadic eye movements

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20\textsuperscript{th} of May 2016
Outline

- Background;
- Motivation;
- Experimental part:
  - Experimental methodology;
  - Experimental results;
- Numerical part:
  - Numerical methodology;
  - Numerical results;
- Conclusions.

Flow behaviour of vitreous humour during saccadic eye movements
Background

Saccadic: a rapid movement of the eye between fixation points.
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Flow behaviour of vitreous humour during saccadic eye movements
Saccadic: a rapid movement of the eye between fixation points.

Flow behaviour of vitreous humour during saccadic eye movements

- Duration: Until 200 msec
- Amplitude: 10° < α < 50°
- Angular velocity up to 900°/s
Background

Flow behaviour of vitreous humour during saccadic eye movements

1. Vitreous Humour is only produced during the embryonic stage, and becomes progressively liquefied with age.

2. Just a few experimental and numerical studies about the rheology and the flow properties of the biofluid have been reported.
Motivation

Some of the eye diseases are related with changes in VH:
• Posterior vitreous detachment;
• Retinal detachment;
• Retinal tears;
• Floaters.

http://www.retinaeye.com/retinaldetachment.html

http://retinagallery.com/displayimage.php?album=475&pid=4790#top_display_media
Motivation

Some of the eye diseases are related with changes in VH:
- Posterior vitreous detachment;
- Retinal detachment;
- Retinal tears;
- Floaters.

To treat some of the diseases:
- Silicone Oils;
- Densiron 68.
Some of the eye diseases are related with changes in VH:

- Posterior vitreous detachment;
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To treat some of the diseases:

- Silicone Oils;
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Better understanding of the VH and pharmaceutical substitutes:

- Rheology;
- Flow dynamics.

Flow behaviour of vitreous humour during saccadic eye movements
Experimental methodology

**Pharmacological fluids samples**

- Silicone oils
- Densiron 68
Flow behaviour of vitreous humour during saccadic eye movements

Experimental methodology

Pharmacological fluids samples

- Silicone oils
- Densiron 68

Vitreous Humour samples

**Specimen:** healthy New Zealand white rabbit;
**Age:** 18 ± 3 weeks;
**Weight:** between 2.8 and 3 kg.
Experimental methodology

Pharmacological fluids samples

Silicone oils  Densiron 68

Vitreous Humour samples

**Specimen:** healthy New Zealand white rabbit;
**Age:** 18 ± 3 weeks;
**Weight:** between 2.8 and 3 kg.

Temperature: 37°
Experimental results

Pharmacological fluids

All the fluids behave as Newtonian fluids under steady shear, with constant viscosity.
Experimental results

Pharmacological fluids

Flow behaviour of vitreous humour during saccadic eye movements

All the fluids behave as Newtonian fluids under steady shear, with constant viscosity.
Experimental results

Vitreous humour

Gel vitreous

Liquefied vitreous

Flow behaviour of vitreous humour during saccadic eye movements
**Experimental results**

**Vitreous humour**

**Flow behaviour of vitreous humour during saccadic eye movements**

\[ \eta = \eta_s + \eta_p (1 - f)^2 \frac{1}{1 + (l - 2\alpha) f} \]

**Viscosity**

\[ G' = \frac{\eta_p \lambda \omega^2}{1 + (\lambda \omega)^2} \]

**Elastic modulus**

\[ G'' = \eta_s \omega \frac{\eta_p \omega}{1 + (\lambda \omega)^2} \]

**Viscous modulus**

**Giesekus model**

**Liquefied vitreous**

**Gel vitreous**
Numerical methodology

Saccadic movements

\[ \theta(t) = c_0 + c_1 t + c_2 t^2 + c_3 t^3 + c_4 t^4 + c_5 t^5 \]

1 David et al. [Physics in Medicine and Biology, 1998, 43, 1385-99 ]
2 Repetto et al. [Physics in Medicine and Biology, 2006, 50,4729–43]
Numerical methodology

Saccadic movements

\[ \theta(t) = c_0 + c_1 t + c_2 t^2 + c_3 t^3 + c_4 t^4 + c_5 t^5 \]

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Numerical methodology

Eye Shape
Numerical methodology

Eye Shape

Solidworks model

Main dimensions

24 mm

19 mm
Numerical methodology

Eye Shape

Solidworks model

Main dimensions

24 mm

19 mm

OpenFOAM

Newtonian:
pimpleDyMFoam

Viscoelastic:
modified viscoelastic solver

Dynamic meshes
Numerical results

Applied velocity

$T = 0.05D = 0.0062\ s$

$T = t_p = 0.0375\ s$

$T = D = 0.1250\ s$

Flow behaviour of vitreous humour during saccadic eye movements
Flow behaviour of vitreous humour during saccadic eye movements

**Numerical results**

**Applied velocity**

- $T = 0.05D = 0.0062 \text{ s}$
- $T = D = 0.1250 \text{ s}$
- $T = t_p = 0.0375 \text{ s}$

![Graph](image_url)
Flow behaviour of vitreous humour during saccadic eye movements
Numerical results

40°: T=t_p

Flow behaviour of vitreous humour during saccadic eye movements
Numerical results

40°: T=D

Flow behaviour of vitreous humour during saccadic eye movements
Conclusions

- The pharmacological fluids used in eye surgery exhibit a constant viscosity;
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• Vitreous humour, both gel and the liquefied phase behave as viscoelastic fluids;
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• Vitreous humour, both gel and the liquefied phase behave as viscoelastic fluids;

• The flow dynamics of the biofluid in the eye cavity is strongly related with the viscosity of the fluid;
Conclusions

• The pharmacological fluids used in eye surgery exhibit a constant viscosity;

• Vitreous humour, both gel and the liquefied phase behave as viscoelastic fluids;

• The flow dynamics of the biofluid in the eye cavity is strongly related with the viscosity of the fluid;

• Vitreous humour flow dynamic plays an important role to keep a stable biological structure of the major components of the fluid.
Thanks for your attention