*26 febbraio 2021*

# Lenti a Contatto: proprietà superficiali

COMiB
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Research Center
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# OUTLINE    Lenti a Contatto: proprietà superficiali

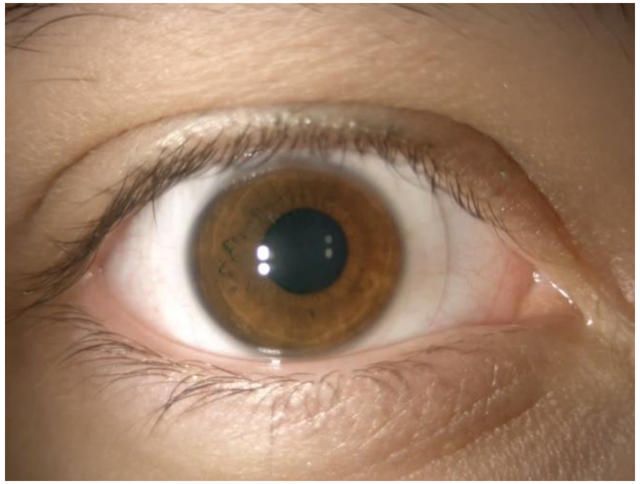
1. An introduction about comfort and CL surface properties

2. In-vitro measurements of wettability and friction

3. In-vivo measurements of wettability and friction

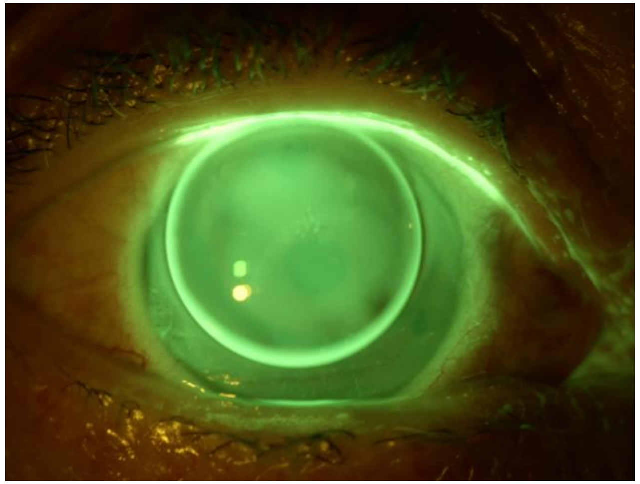
# Le Lenti a contatto

-Lac Sclerali



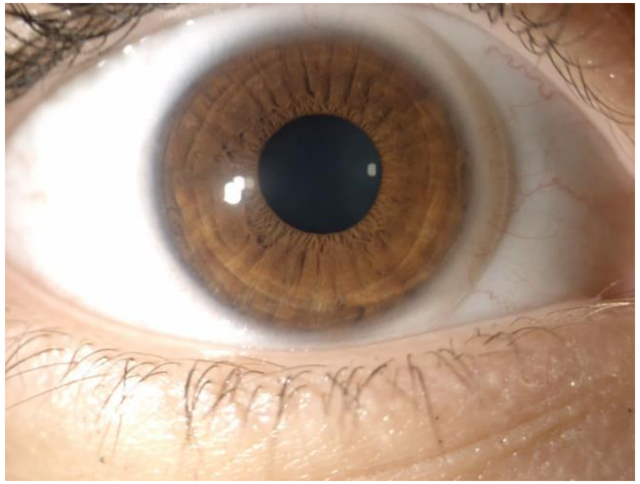
-Vetro1887-9
-Diametro tra 15:0-25.0 mm

-Lac Rigide GP



-Pmma 1948
-Diametro tra 8.0 e 12.0 mm

-Lac Morbide



-Hema 1971
-Idratazione: 24-74% di acqua
-Diametro tra 13.0 e 15.0 mm

# Le Lenti a contatto


Nichols and Starker 2020


Nichols and Starker 2020


Jones et al, 2020

# Le Lenti a contatto

AMERICAN ACADEMY™ OF OPHTHALMOLOGY

CrossMark

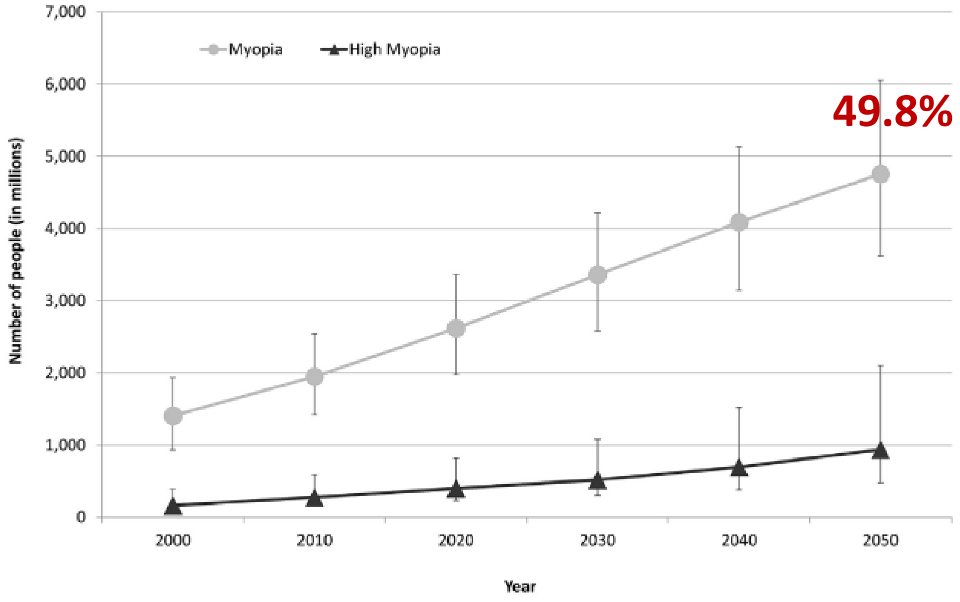
## Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050

Brien A. Holden, PhD, DSc,[1,2] Timothy R. Fricke, MSc,[1] David A. Wilson, PhD,[1,2,3] Monica Jong, PhD,[1] Kovin S. Naidoo, PhD,[1,2,3] Padmaja Sankaridurg, PhD,[1,2] Tien Y. Wong, MD,[4] Thomas J. Naduvilath, PhD,[1] Serge Resnikoff, MD[1,2]

EPIDEMIOLOGY

## Global Vision Impairment Due to Uncorrected Presbyopia

Brien A. Holden, PhD, DSc; Timothy R. Fricke, MScOptom; S. May Ho, PhD; Reg Wong, MBA; Gerhard Schlenther, MPH; Sonja Cronjé, MPhil(Optom); Anthea Burnett, BSc(Hons); Eric Papas, PhD; Kovin S. Naidoo, OD, MPH; Kevin D. Frick, PhD



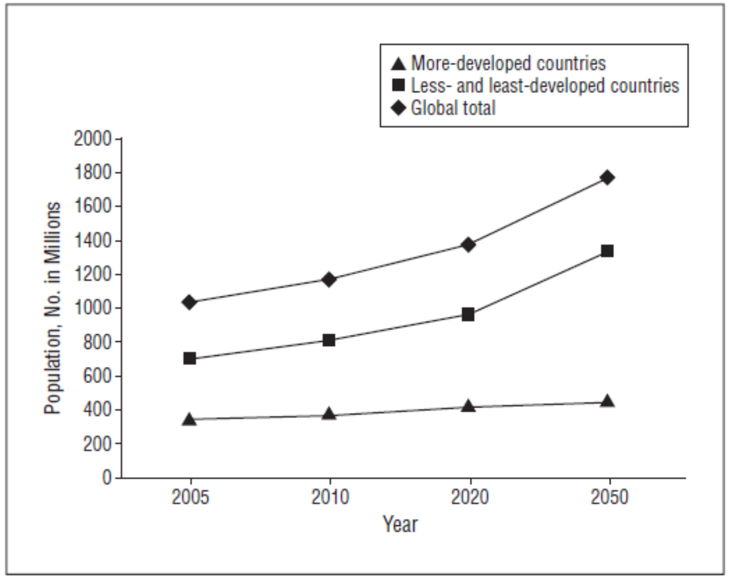




**Figure.** The predicted number of people with presbyopia from 2005 to 2050.

# Le Lenti a contatto

-Lac Morbide (80-90% del mercato)

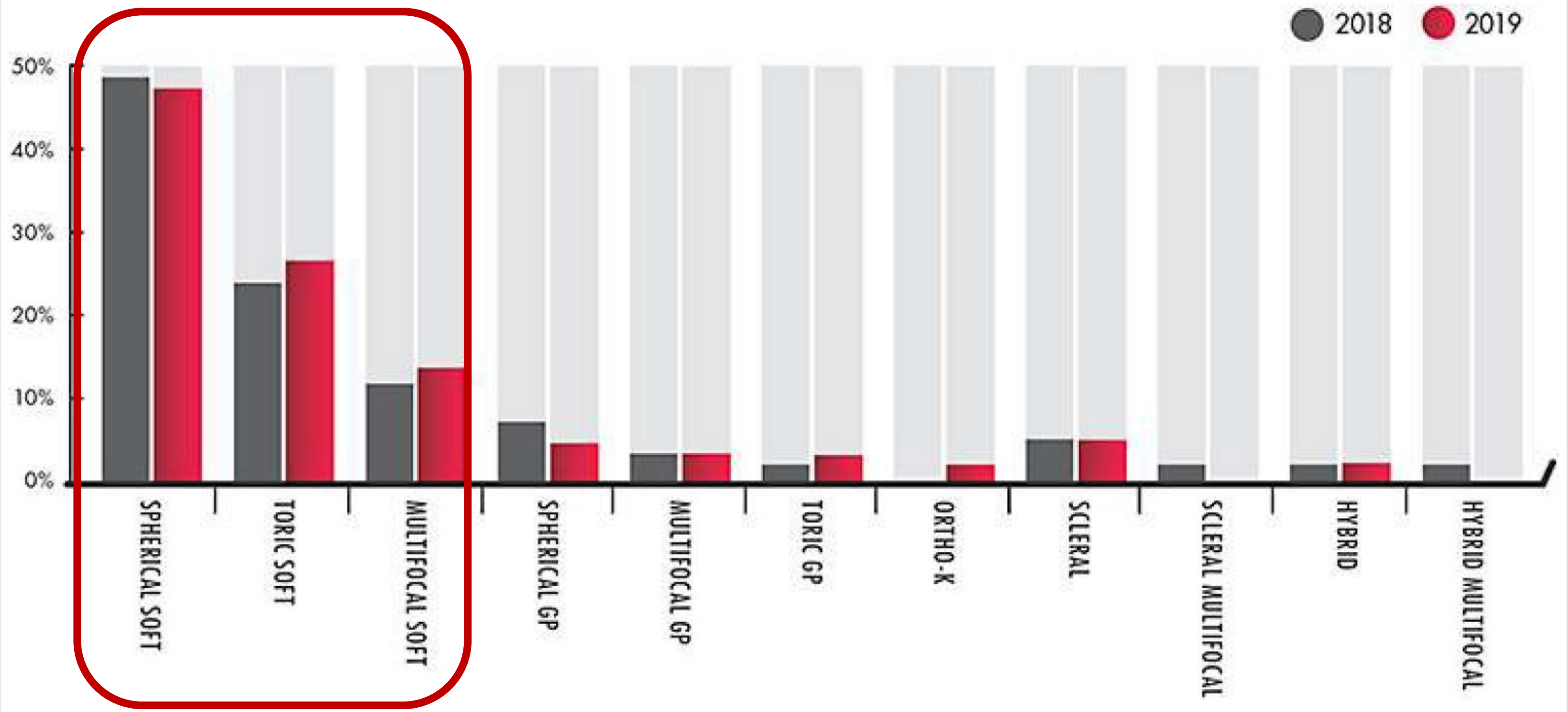



Figure 3. 2018 to 2019 contact lens fits & refits by lens designs.

Nichols and Starker 2020

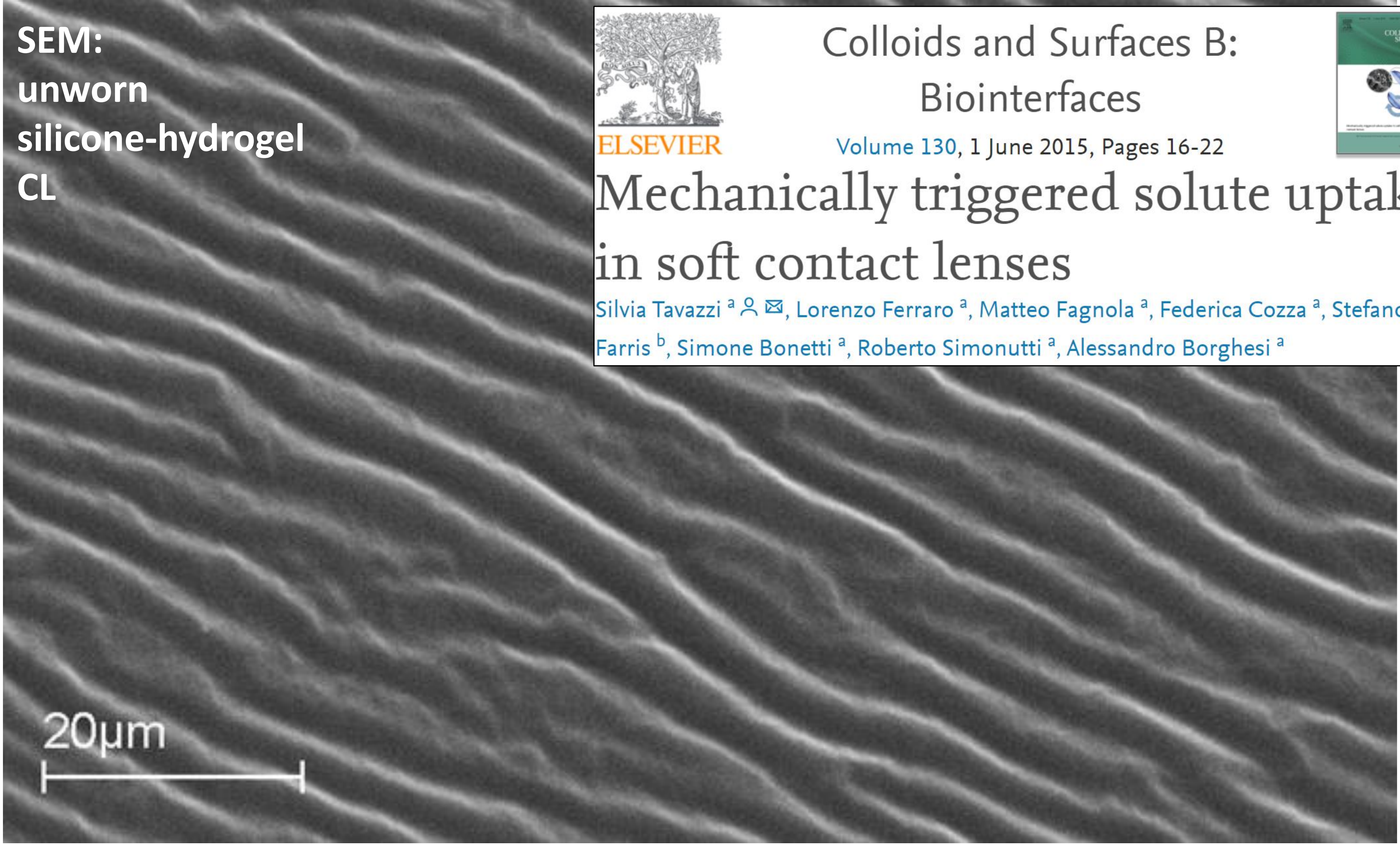
# SEM (unworn hydrogel CL + HA)


> J Biomed Mater Res B Appl Biomater. 2015 Jul;103(5):1092-8. doi: 10.1002/jbm.b.33278. Epub 2014 Sep 23.

**Wear effects on microscopic morphology and hyaluronan uptake in siloxane-hydrogel contact lenses**

Silvia Tavazzi [1], Martina Tonveronachi [1], Matteo Fagnola [1], Federica Cozza [1], Lorenzo Ferraro [1], Alessandro Borghesi [1], Miriam Ascagni [2], Stefano Farris [3]

**SEM: unworn silicone-hydrogel CL**




Colloids and Surfaces B: Biointerfaces

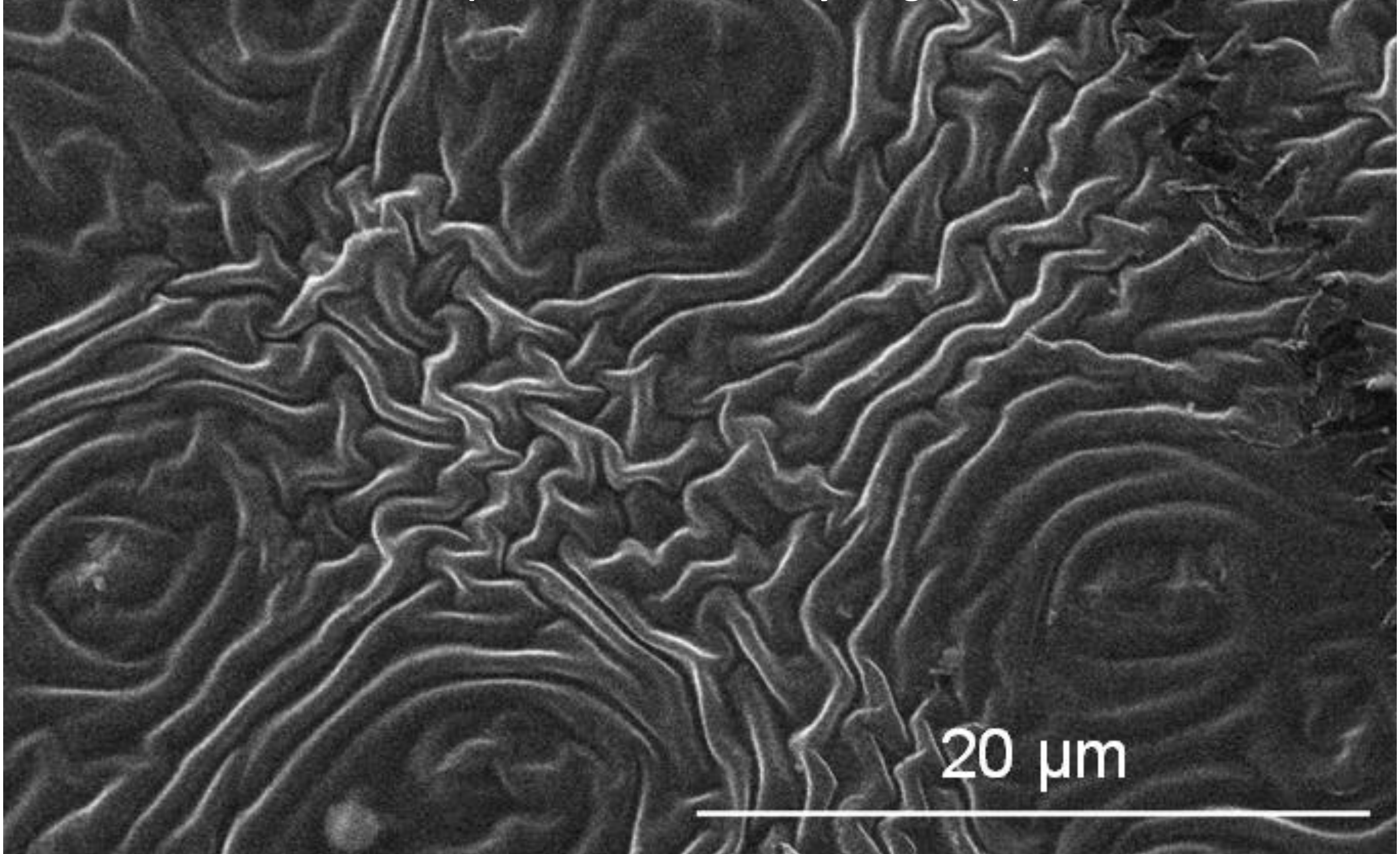
ELSEVIER

Volume 130, 1 June 2015, Pages 16-22

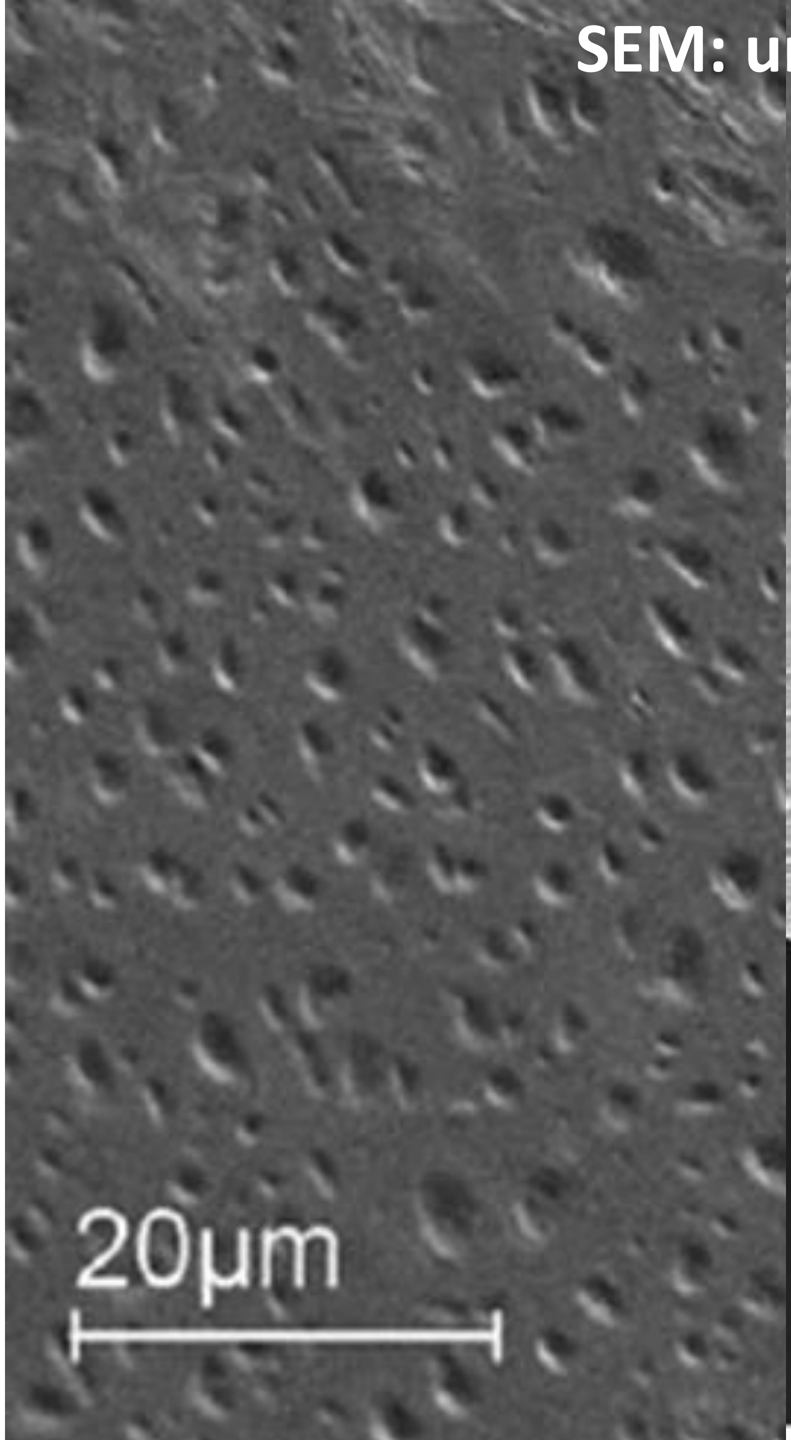
# Mechanically triggered solute uptake in soft contact lenses

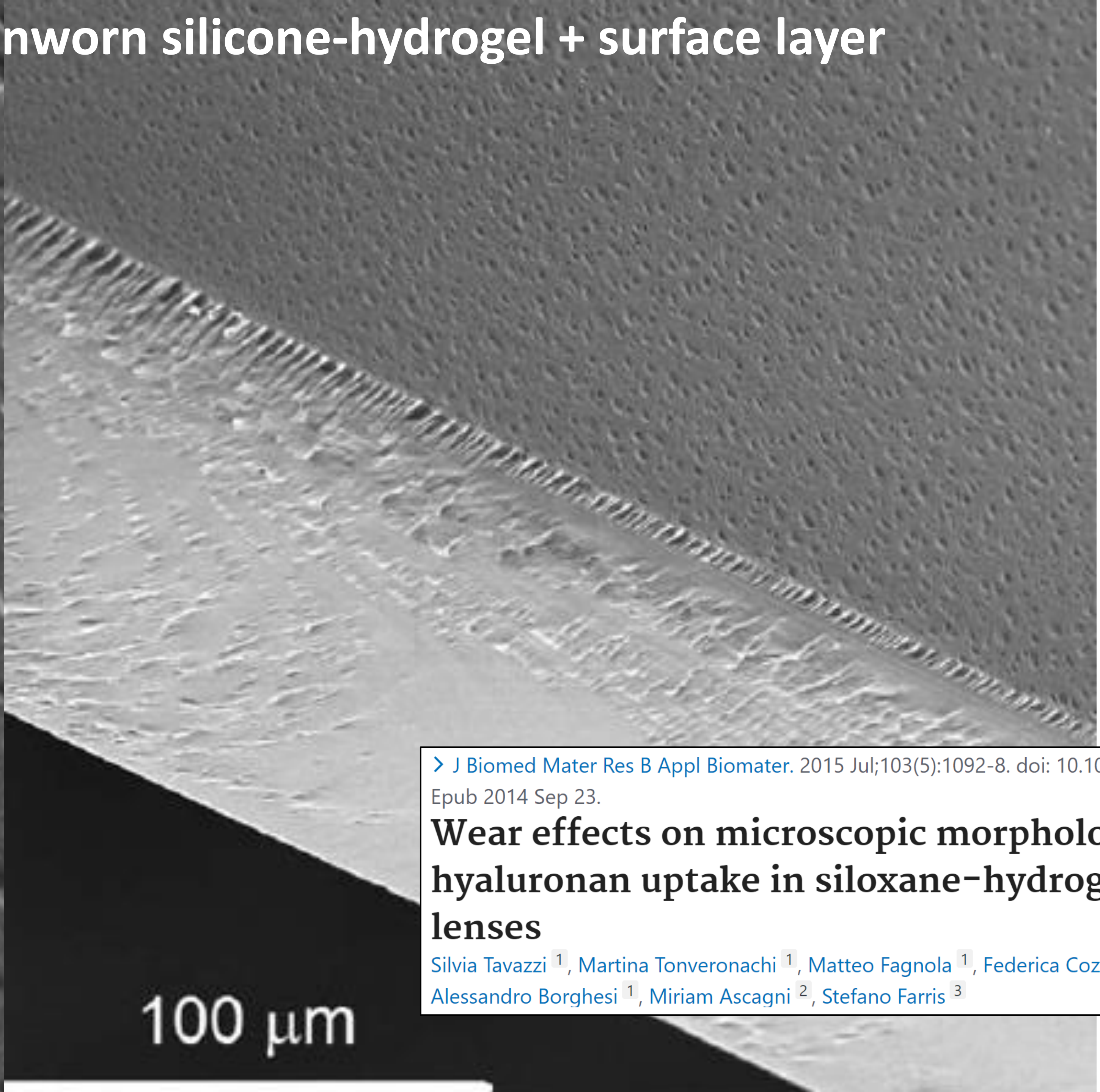
Silvia Tavazzi [a], Lorenzo Ferraro [a], Matteo Fagnola [a], Federica Cozza [a], Stefano Farris [b], Simone Bonetti [a], Roberto Simonutti [a], Alessandro Borghesi [a]

SEM (unworn silicone-hydrogel CL)



# SEM: unworn silicone-hydrogel + surface layer




> J Biomed Mater Res B Appl Biomater. 2015 Jul;103(5):1092-8. doi: 10.1002/jbm.b.33278. Epub 2014 Sep 23.

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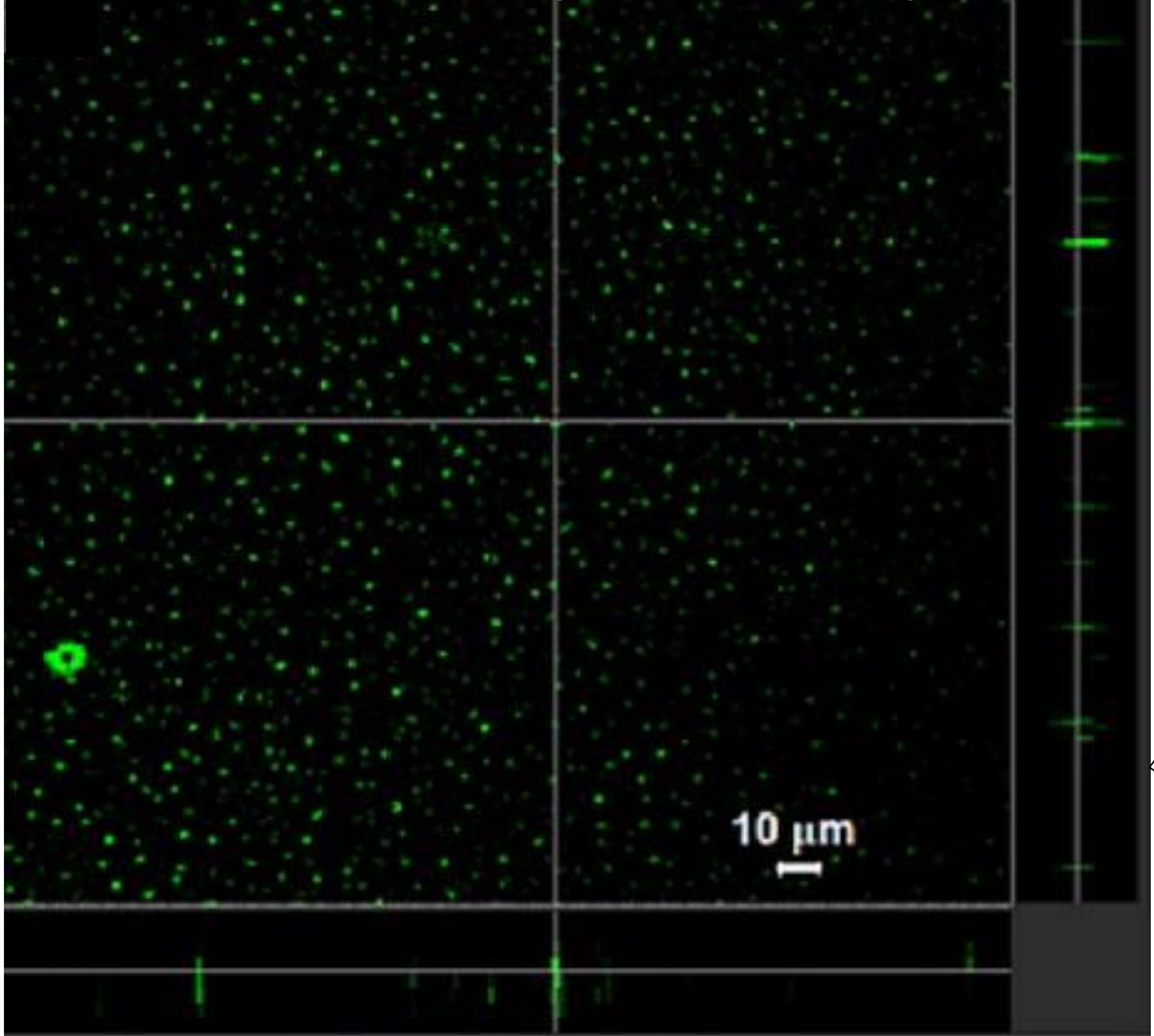
# confocal PL – HA penetration depth





J Biomed Mater Res B Appl Biomater. 2015 Jul;103(5):1092-8. doi: 10.1002/jbm.b.33278. Epub 2014 Sep 23.

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> J Biomed Mater Res B Appl Biomater. 2013 Nov;101(8):1585-93. doi: 10.1002/jbm.b.32901. Epub 2013 Apr 4.

# Surface properties and wear performances of siloxane-hydrogel contact lenses

Michela Bettuelli [1], Silvia Trabattoni, Matteo Fagnola, Silvia Tavazzi, Laura Introzzi, Stefano Farris

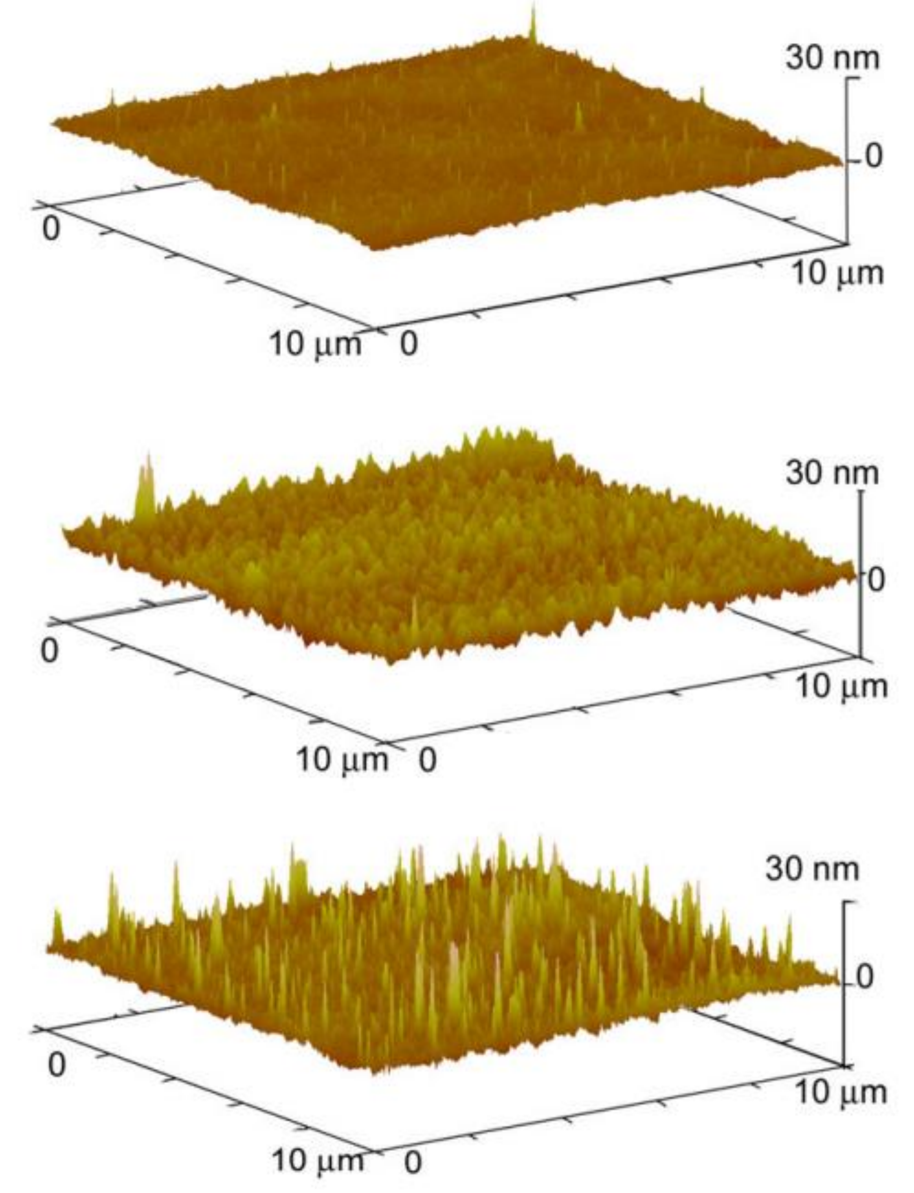



**FIGURE 5.** 3D AFM plots of lenses taken from the blister and rinsed in deionized water ($CL_{rins}$; first panel) and worn for 8 h, preserved for 12 h in saline solution, and rinsed in deionized water ($CL_{worn}$, second panel: smooth type and third panel: sharp type). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

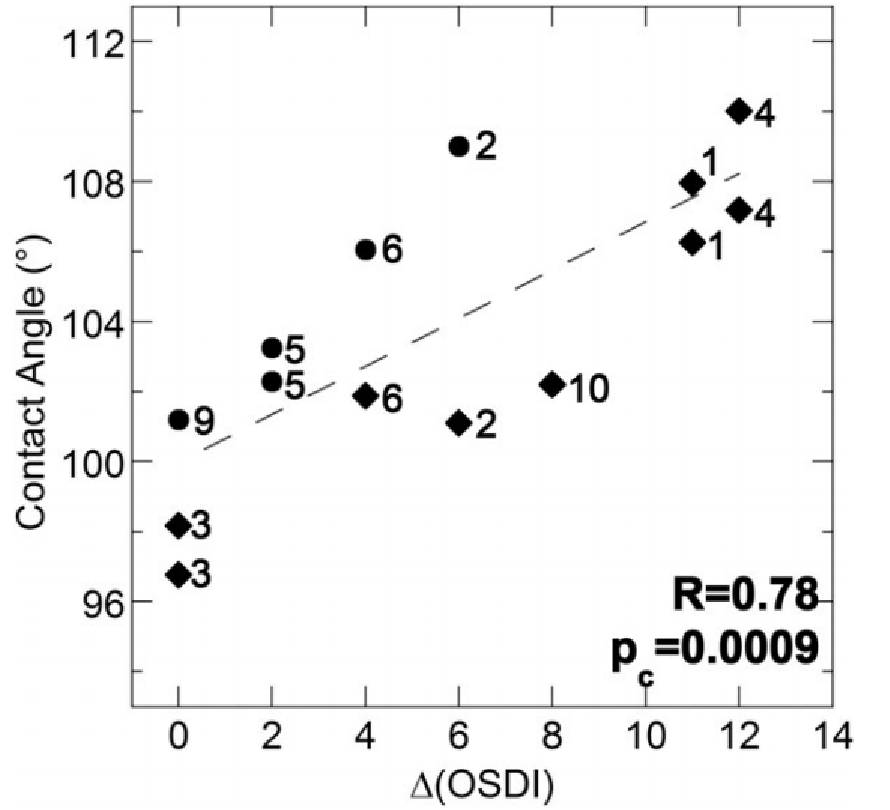



**FIGURE 8.** Measured contact angle of worn contact lenses as a function of the change of the OSDI. A continuous line indicates the result of the linear fitting of the data.

# OUTLINE Lenti a Contatto: proprietà superficiali

1. An introduction about comfort and CL surface properties
2. In-vitro measurements of wettability and friction
3. In-vivo measurements of wettability and friction

# The impact of comfort on CL market

Clinical Optometry
Dovepress
open access to scientific and medical research
Open Access Full Text Article
REVIEW

## A Review of Contact Lens Dropout

This article was published in the following Dove Press journal:
*Clinical Optometry*

Andrew D Pucker[1]
Anna A Tichenor[2]
[1]School of Optometry, University of Alabama at Birmingham, Birmingham, AL, USA; [2]School of Optometry, Indiana University, Bloomington, IN, USA

**Purpose:** Contact lens (CL) dropout is likely a major factor contributing to the near stagnant growth in the CL market. The purpose of this review is to summarize the current state of knowledge related to the frequency of CL dropout and the factors associated with it.
**Methods:** PubMed.gov was searched on or before March 22, 2020, with the terms "contact lens" with "dropout" or "cessation" or "disruption" or "discomfort". Pertinent articles were collected. The references from these articles were likewise searched to identify additional relevant articles. Only manuscripts written in English were included. No study design or date exclusions were imposed on this review.
**Results:** This literature review found that CL dropout was frequent across developed countries, with a CL dropout frequency that ranged between 12.0% and 27.4% (pooled mean = 21.7%). The top cited reason for CL dropout in established CL wearers was discomfort, while vision was the top reason in neophyte CL wearers. If given the chance, CL dropouts are often able to successfully resume CL wear up to 74% of the time. While the literature is mixed with regard to factors promoting CL dropout, meibomian gland dysfunction appears to promote CL dropout.
**Conclusion:** CL dropout is a frequently encountered condition that may be curtailed by early detection, patient education, alterative CL options, or early treatment of underlying ocular surface diseases such as meibomian gland dysfunction.
**Keywords:** contact lens dropout, contact lens cessation, contact lens dry eye, ocular surface

**Table 1** Summary of the Frequency of Contact Lens Dropout by Study and for All Studies

| Study | Study Design | Neophyte/ Established Wearer | Number of Subjects (n) | Dropout Frequency | Top Dropout Reason |
|---|---|---|---|---|---|
| Weed et al 1993[15] | Canadian/Survey | Established | 568 | 26.5% | Ocular Discomfort |
| Briggs 1996[12]~ | Saudi Arabia/Survey | Established | 200 | N/A | Ocular Discomfort |
| Pritchard et al 1999[8] | Canadian/Survey | Established | 1444 | 12% | Ocular Discomfort |
| Richdale et al 2007[25] | United States/Survey | Established | 730 | 24.1% | Ocular Symptoms |
| Rumpakis 2010[11] | International/Survey | Unknown | 372 | 15.9% United States<br>17.0% North America<br>31.0% Asia/Pacific Rim<br>30.4% Europe/Middle East/Africa | Ocular Discomfort |
| Dumbleton et al 2013[10] | Canadian/Survey | Established | 4207 | 23% | Ocular Discomfort |
| Sulley et al 2017[17] | United Kingdom/Retrospective Chart Review | Neophyte | 524 | 26% | Poor Vision |
| Sulley et al 2018[18] | United Kingdom/Prospective Cross-Sectional Study | Neophyte | 250 | 22.4% | Poor Vision |
| Macedo-de-Araújo et al 2019[19]* | Portugal/ Prospective Cross-Sectional Study | Neophyte | 95 | 27.4% | Difficulty with Scleral Lens Handling |
| Pooled Dropout Frequency# | N/A | N/A | 8190 | 21.7% | [illegible] |

**Notes:** *Subjects in this study were scleral lens wearers while the majority of the subjects in the other included studies were soft contact lens wearers. #The Rumpakis 2010 percentage used in the pooled dropout frequency was the mean of the four countries since the number of subjects in this study was not described by region. ~Briggs 1996 was excluded from the total number subjects in the pooled dropout frequency estimate because a frequency was not provided.

# The impact of comfort on CL market

Clinical Article

Discontinuation of Contact Lens Wear:
A Survey

Pritchard, N., Fonn, D., & Brazeau, D. (1999). Discontinuation of contact lens wear: a survey. *International Contact Lens Clinic*, *26*(6), 157-162.

ARTICLE

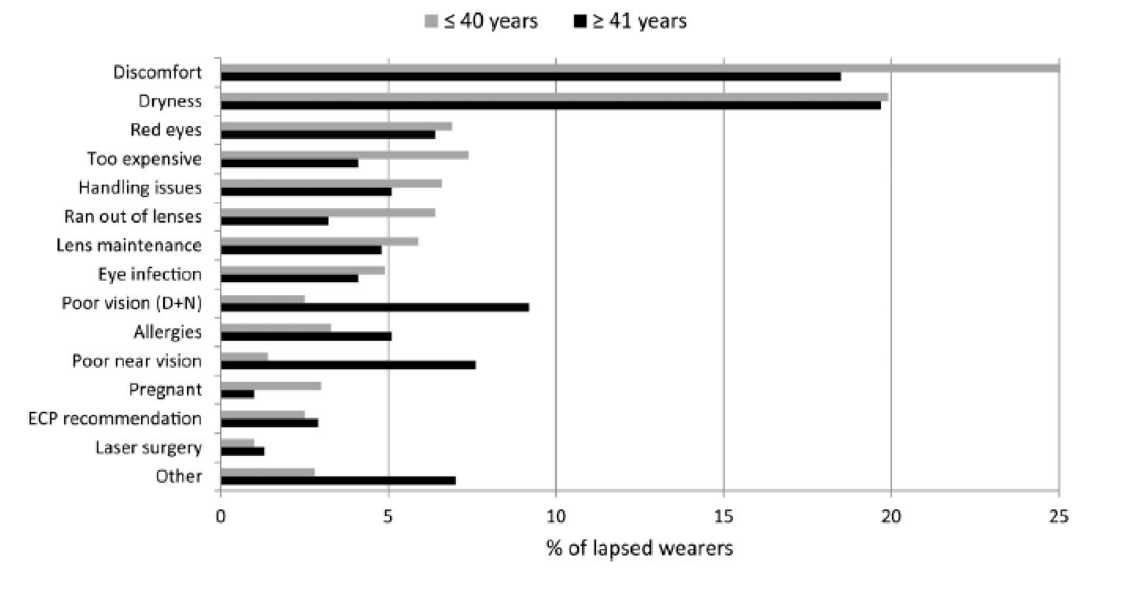
The Impact of Contemporary Contact Lenses on Contact Lens Discontinuation

*Kathy Dumbleton, M.Sc., Craig A. Woods, Ph.D., Lyndon W. Jones, Ph.D., and Desmond Fonn, M.Optom.*

Dumbleton, K., Woods, C. A., Jones, L. W., & Fonn, D. (2013). The impact of contemporary contact lenses on contact lens discontinuation. *Eye & contact lens*, *39*(1), 93-99.

Table 1. Top Ten Reasons for Discontinuing and Resuming Contact Lens

| Discontinuing Contact Lens Wear (n = 488) | Percentage |
|---|---|
| 1. Discomfort/irritation | 49 |
| 2. Experienced dry eye | 9 |
| 3. Needed to replace lenses | 6 |
| 4. Lens cleaning too much bother | 5 |
| 5. Experienced red eye | 5 |
| 6. Poor vision | 4 |
| 7. Advised so by eyecare practitioner | 4 |
| 8. Insertion/removal too much bother | 3 |
| 9. Pregnancy | 3 |
| 10. Near-vision problems | 3 |



## 1. An introduction about comfort and CL surface properties

# What is comfort?


A state of physical ease and freedom from pain or constraint

# What discomfort is?

Something that disturbs one's comfort; an annoyance

To disturb the comfort or happiness of; make uneasy

Multiple symptoms:

- Soreness
- Redness
- Burning
- Dryness
- Grittiness
- Scratchiness
- Pain
- Itchiness
- Watering
- Aching
- Excessive Blinking
- Blurring
- Tiredness

## 1. An introduction about comfort and CL surface properties

- Study at CCLRU clinics
- 883 participants (171 SCL) rated the frequency of their symptoms on a 4-point Likert scale (never, sometimes, often, constantly)
- Symptoms: Tiredness, Redness, Itchiness, Watering, Burning, Pain, Dryness, Grittiness, Excessive Blinking, Aching

1040-5488/99/7610-0705/0 VOL. 76, NO. 10, PP. 705–711
OPTOMETRY AND VISION SCIENCE


ORIGINAL ARTICLE

### The Frequency of Ocular Symptoms during Spectacle and Daily Soft and Rigid Contact Lens Wear

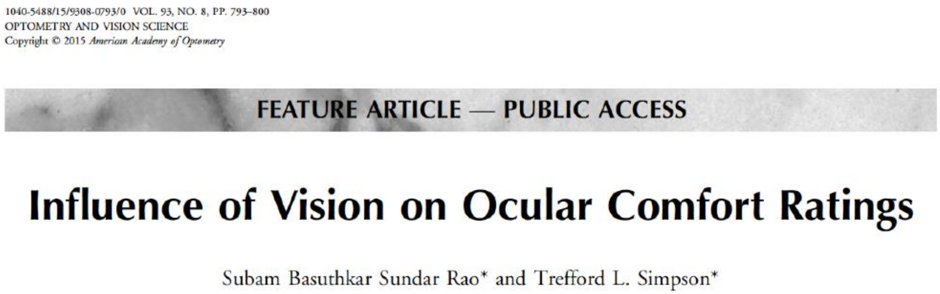
CLAIRE VAJDIC, BOptom, BRIEN A. HOLDEN, BAppSc, PhD, LOSc, FAAO, DCLP, DSc, OAM, DEBORAH F. SWEENEY, BOptom, PhD, FAAO, AND RUTH M. CORNISH, BScOptom

*The Cornea and Contact Lens Research Unit, School of Optometry and The Cooperative Research Centre for Eye Research and Technology, The University of New South Wales, Sydney, Australia*

## None of the symptoms were highly correlated

| | Redness | Grittiness | Itchiness | Aching | Tiredness | Watering | Burning | Pain | Excessive Blinking |
|---|---|---|---|---|---|---|---|---|---|
| SCL Wearers | | | | | | | | | |
| Dryness | — | | 0.21 | 0.23 | 0.33 | 0.26 | 0.20 | 0.30 | |
| Redness | — | 0.23 | 0.11 | 0.21 | 0.36 | 0.37 | 0.26 | 0.38 | 0.19 |
| Grittiness | — | — | 0.27 | 0.26 | 0.27 | 0.31 | | 0.25 | |
| Itchiness | — | — | — | 0.19 | 0.29 | 0.35 | 0.38 | 0.24 | 0.17 |
| Aching | — | — | — | — | 0.27 | 0.21 | 0.24 | 0.32 | |
| Tiredness | — | — | — | — | — | 0.30 | 0.25 | 0.36 | 0.21 |
| Watering | — | — | — | — | — | — | 0.45 | 0.35 | 0.24 |
| Burning | — | — | — | — | — | — | — | 0.32 | 0.27 |
| Pain | — | — | — | — | — | — | — | — | |

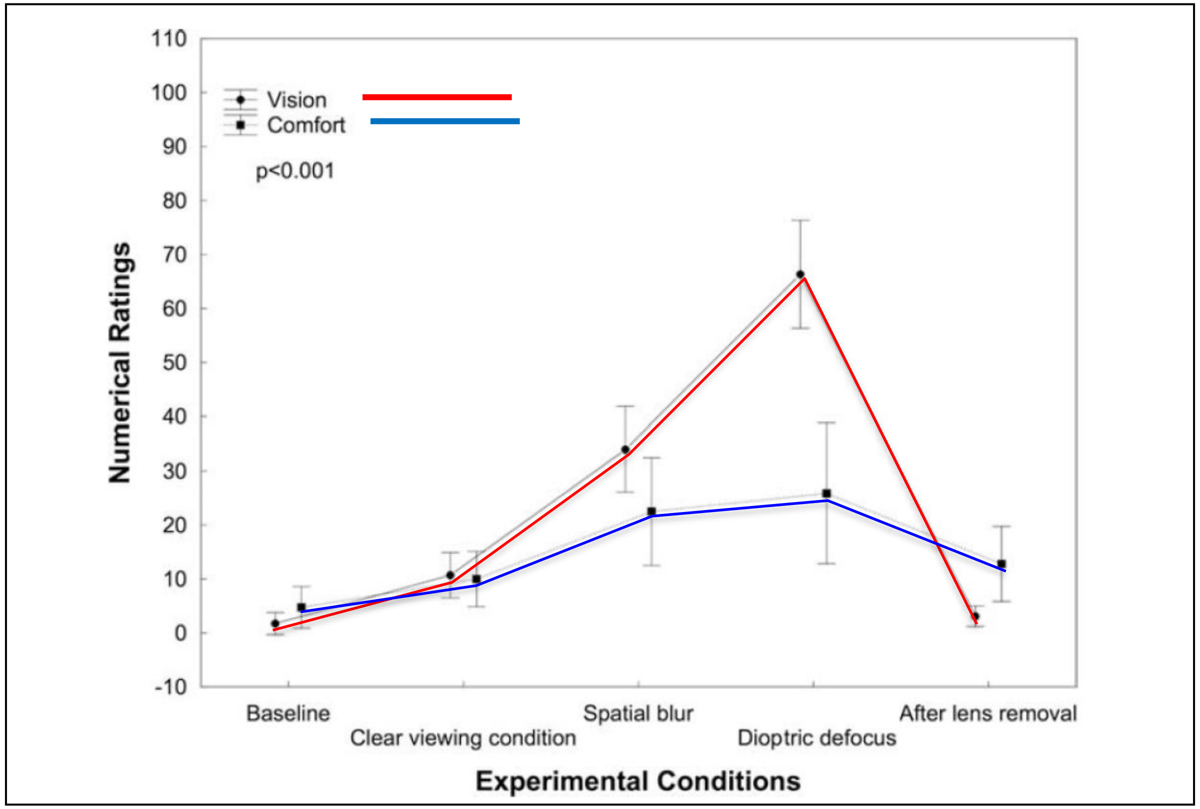

# Can vision issues be classified as discomfort?


1040-5488/15/9308-0793/0 VOL. 93, NO. 8, PP. 793–800
OPTOMETRY AND VISION SCIENCE


FEATURE ARTICLE — PUBLIC ACCESS

## Influence of Vision on Ocular Comfort Ratings

Subam Basuthkar Sundar Rao* and Trefford L. Simpson*




- 20 emmetropic subjects rated vision, ocular comfort, and other sensations under clear viewing condition, spatial blur, and dioptric defocus, each lasting for 5 min.
- For the comfort scale, 0 indicated ‘‘no discomfort’’ and 100 indicated ‘‘worst discomfort imaginable.’’
- It does seem to be an association between clarity of vision and ocular comfort


# Can vision issues be classified as discomfort?

ARTICLE IN PRESS

Contact Lens and Anterior Eye xxx (xxxx) xxx

Contents lists available at ScienceDirect

Contact Lens and Anterior Eye

journal homepage: www.elsevier.com/locate/clae

The association of comfort and vision in soft toric contact lens wear

Carole Maldonado-Codina [a,*], Maria Navascues Cornago [a], Michael L. Read [a], Andrew J. Plowright [a], Jose Vega [b], Gary N. Orsborn [b], Philip B. Morgan [a]

[a] Eurolens Research, Division of Pharmacy and Optometry, Faculty of Biology, Medicine and Health, The University of Manchester, Oxford Rd, Manchester, M13 9PL, UK
[b] CooperVision Incorporated, 6101 Bollinger Canyon Rd, Suite 500, San Ramon, CA, 94583, USA

- single-site, prospective, randomised, subject-masked, cross-over study where participants received three sequential interventions (three lens types) in separate treatment phases.
- ocular surface comfort was recorded with a scale 0-10 (0=painful, 10=lenses cannot be felt).
- Symptoms of ocular discomfort may be more intense if there is also perceived visual compromise in daily disposable soft toric lenses.

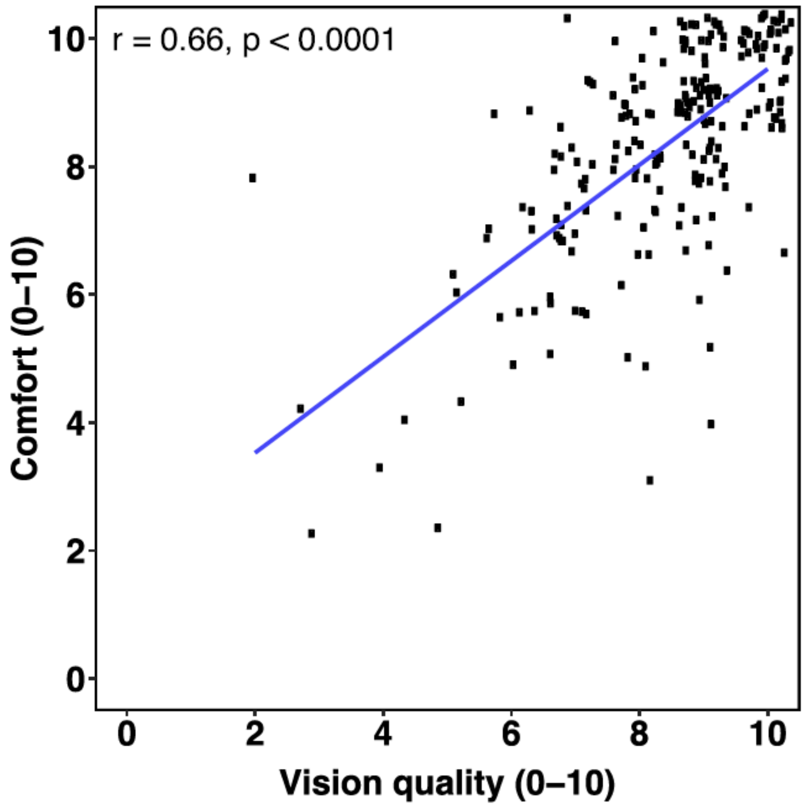



**Fig. 3.** Relationship between comfort and vision quality. Relationship between comfort and vision quality. To avoid overlapping data, random jitter was applied to each data point in the x and y directions (n = 220 observations).

# Definition of CL discomfort

Special Issue

**The TFOS International Workshop on Contact Lens Discomfort: Report of the Definition and Classification Subcommittee**

Kelly K. Nichols,[1] Rachel L. Redfern,[1] Jean T. Jacob,[2] J. Daniel Nelson,[3] Desmond Fonn,[4] S. Lance Forstot,[5] Jing-Feng Huang,[6] Brien A. Holden,[7-9] Jason J. Nichols,[1] and the members of the TFOS Internation

*CL discomfort is a condition characterised by episodic or persistent adverse ocular sensations related to lens wear, either with or without visual disturbance, resulting from reduced compatibility between the CL and the ocular environment, which can lead to decreased wearing time and discontinuation of CL wear*

# Prevalence of CL discomfort

Special Iss

**The TFC Discomf**

Kathy Dumbl
Takashi Kojin
J. Daniel Nels
Discomfort

TABLE 1. Prevalence of CLD From Population-Based Studies

| Study | Location | Number of Contact Lens Wearers | Age | Sex | Symptom Assessment | P | ...rences |
|---|---|---|---|---|---|---|---|
| CANDEES study | Canada | 3285 | 10–80 y | Not reported for contact lens weare... | Presence o... | | ...t al., |
| Koumi study | Japan | 105 | ≥40 y | Male ... | | | |
| Japanese VDT users study | Japan | 1... | | | | | ...mo et al., 2008[96] |
| Japanese high school stud... study | | | | | ...ms of ... ocular dryness and irritation | Male 36.8%, female 37.4% | Uchino et al., 2008[94] |
| Chinese senior h... school students study | | | ...ioned | Not mentioned | Severe symptoms of both ocular dryness and irritation | Overall: 32.8% | Zhang et al., 2012[95] |

-SCL wearers experienced symptoms significantly more frequently than non-wearers

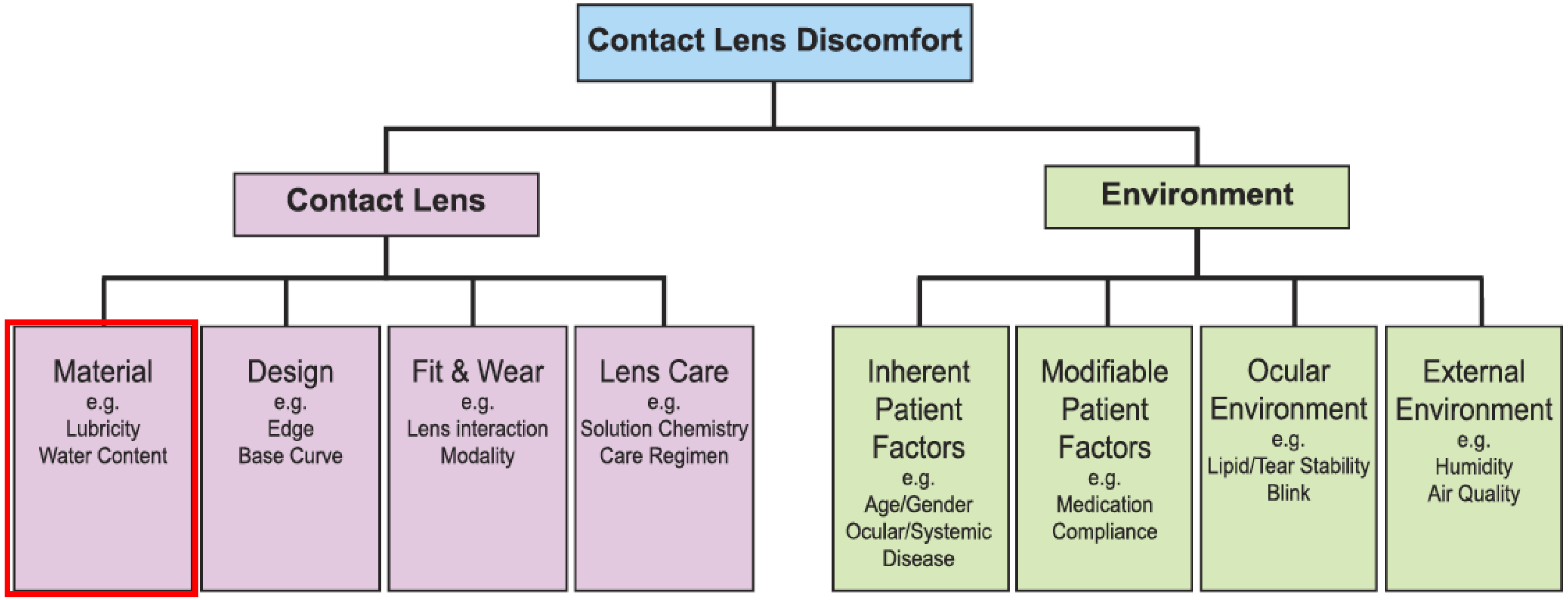
-On average, 50% of CL wearers experience CLD or dryness at least occasionally

Special Issue

**The TFOS International Workshop on Contact Lens Discomfort: Report of the Contact Lens Materials, Design, and Care Subcommittee**

Lyndon Jones,[1] Noel A. Brennan,[2] José González-Méijome,[3] John Lally,[4] Carole Maldonado-Codina,[5] Tannin A. Schmidt,[6] Lakshman Subbaraman,[1] Graeme Young,[7] Jason J. Nichols,[8] and the members of the TFOS International Workshop on Contact Lens Discomfort

## What causes CL discomfort?

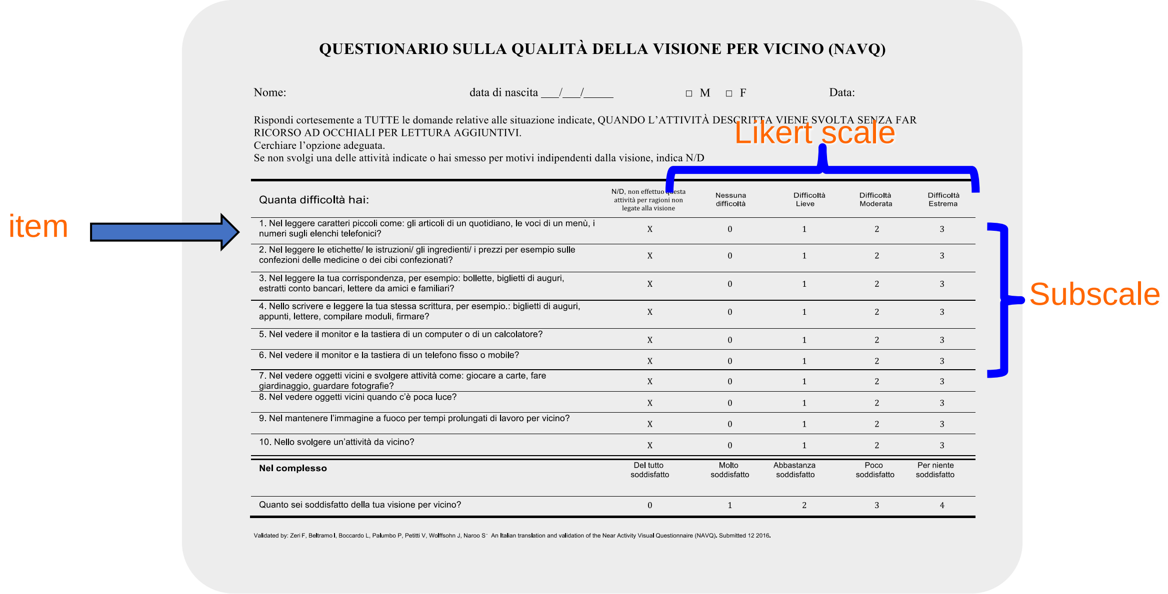


## Can we measure CL discomfort?

# Subjective measure of CLD

Questionnaires are instruments formed by items (questions) that require dichotomous answer (e.g. agree or disagree) or with a polytomous rating (Likert scale) to quantify the agreement with a certain statement.

The items might be grouped into domains or subscales.




**QUESTIONARIO SULLA QUALITÀ DELLA VISIONE PER VICINO (NAVQ)**

Nome: data di nascita ___/___/_____ ☐ M ☐ F Data:

Rispondi cortesemente a TUTTE le domande relative alle situazione indicate, QUANDO L'ATTIVITÀ DESCRITTA VIENE SVOLTA SENZA FAR RICORSO AD OCCHIALI PER LETTURA AGGIUNTIVI.
Cerchiare l'opzione adeguata.
Se non svolgi una delle attività indicate o hai smesso per motivi indipendenti dalla visione, indica N/D

| Quanta difficoltà hai: | N/D, non effettuo questa attività per ragioni non legate alla visione | Nessuna difficoltà | Difficoltà Lieve | Difficoltà Moderata | Difficoltà Estrema |
|---|---|---|---|---|---|
| 1. Nel leggere caratteri piccoli come: gli articoli di un quotidiano, le voci di un menù, i numeri sugli elenchi telefonici? | X | 0 | 1 | 2 | 3 |
| 2. Nel leggere le etichette/ le istruzioni/ gli ingredienti/ i prezzi per esempio sulle confezioni delle medicine o dei cibi confezionati? | X | 0 | 1 | 2 | 3 |
| 3. Nel leggere la tua corrispondenza, per esempio: bollette, biglietti di auguri, estratti conto bancari, lettere da amici e familiari? | X | 0 | 1 | 2 | 3 |
| 4. Nello scrivere e leggere la tua stessa scrittura, per esempio.: biglietti di auguri, appunti, lettere, compilare moduli, firmare? | X | 0 | 1 | 2 | 3 |
| 5. Nel vedere il monitor e la tastiera di un computer o di un calcolatore? | X | 0 | 1 | 2 | 3 |
| 6. Nel vedere il monitor e la tastiera di un telefono fisso o mobile? | X | 0 | 1 | 2 | 3 |
| 7. Nel vedere oggetti vicini e svolgere attività come: giocare a carte, fare giardinaggio, guardare fotografie? | X | 0 | 1 | 2 | 3 |
| 8. Nel vedere oggetti vicini quando c'è poca luce? | X | 0 | 1 | 2 | 3 |
| 9. Nel mantenere l'immagine a fuoco per tempi prolungati di lavoro per vicino? | X | 0 | 1 | 2 | 3 |
| 10. Nello svolgere un'attività da vicino? | X | 0 | 1 | 2 | 3 |
| **Nel complesso** | Del tutto soddisfatto | Molto soddisfatto | Abbastanza soddisfatto | Poco soddisfatto | Per niente soddisfatto |
| Quanto sei soddisfatto della tua visione per vicino? | 0 | 1 | 2 | 3 | 4 |

Validated by: Zeri F, Beltramo I, Boccardo L, Palumbo P, Petitti V, Wolffsohn J, Naroo S¨ An Italian translation and validation of the Near Activity Visual Questionnaire (NAVQ). Submitted 12 2016.

- **Validated Questionnaire**
  - Contact Lens Dry Eye Questionnaire (Nichols et al 2002, Chalmers et al 2012): dryness
  - The Ocular Comfort Index (Johnson et al, 2007) not specific for CL
  - Quality of Vision Questionnaire (McAlinden et al 2010) not specific for CL
  - NAVQ (Buckhurst, 2012): for presbyopia correction
  - Contact Lens Impact on Quality of Life Questionnaire (Pesudovs et al, 2006): provides only a single overall score on CL related QoL for keratoconic patients

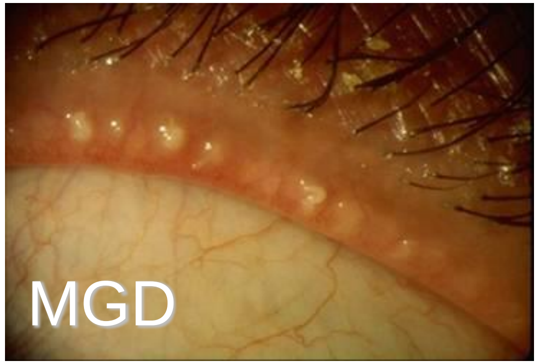
# Can we measure CL discomfort?

Special Issue

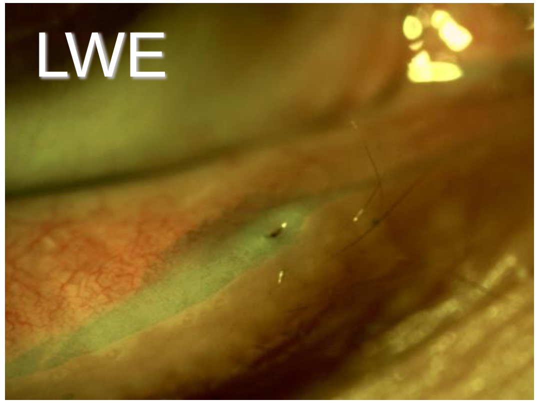
**The TFOS International Workshop on Contact Lens Discomfort: Report of the Contact Lens Interactions With the Ocular Surface and Adnexa Subcommittee**

Nathan Efron,[1] Lyndon Jones,[2] Anthony J. Bron,[3] Erich Knop,[4] Reiko Arita,[5] Stefano Barabino,[6] Alison M. McDermott,[7] Edoardo Villani,[8] Mark D. P. Willcox,[9] Maria Markoulli,[9] and the members of the TFOS International Workshop on Contact Lens Discomfort

## Objective correlates of CLD




- Bilateral
- Non-inflammatory
- Changes in the MG fluid from clear & free-flowing to cloudy & viscous
- Incidence: non-CL 20%; CL 30%

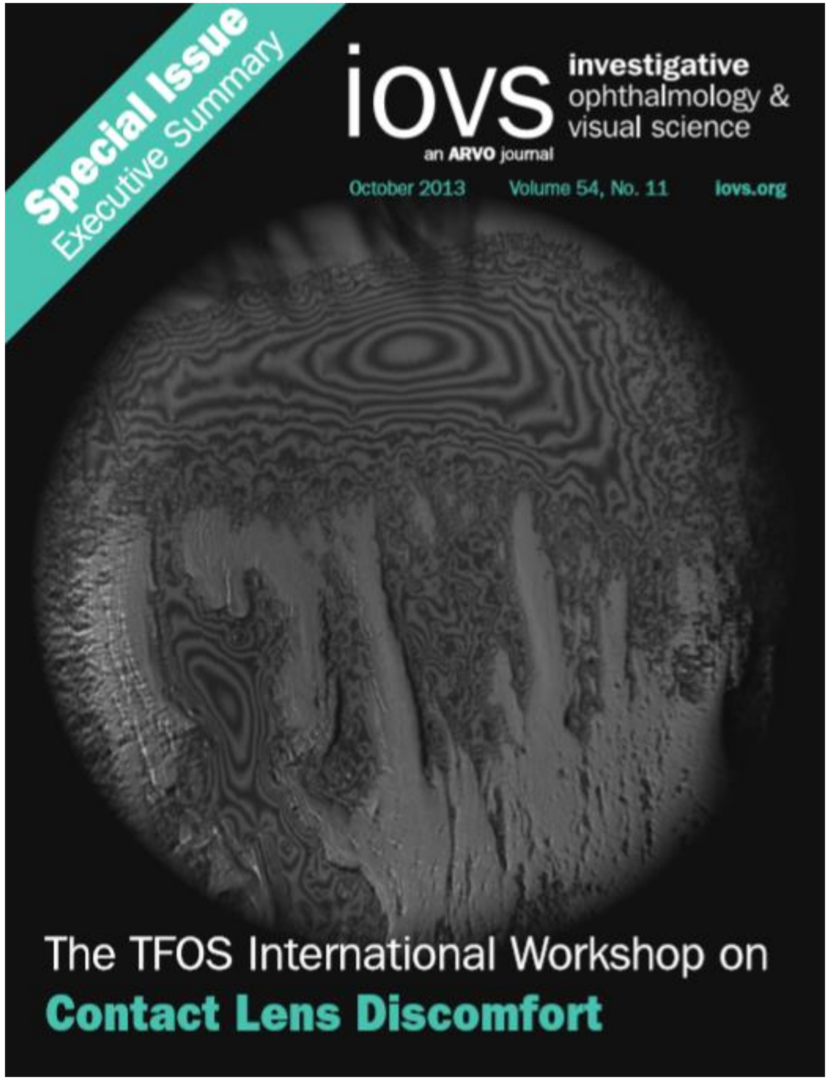



- Alteration of the epithelium of that portion of the marginal conjunctiva of the upper eyelid that wipes the ocular surface, diagnosed by staining
- 80% of the symptomatic subjects displayed LWE compared to 13% of the asymptomatic (Korb et al, 2002)

## Measuring CL comfort/discomfort is challenging, difficult to perform and weak in terms of reliability.

- There is a lack of a validated instrument for measuring discomfort
- Discomfort is a multidimensional concept rather than a uniform notion
- Comfort can be affected to some extent by the poor quality of vision
- Comfort can be measured in different way (moment of a day) using different modalities (paper, mobile)
- Clinical signs have been studied to understand the effect of the material on comfort.
- No studies have evaluated comfort through a systematic analysis of all the factors potentially affecting comfort (lens material, design parameters, etc)

# Evidence based relationship between CL surface properties and comfort




- Few significant links between CLD and CL material were present
- NO systematic association between in-vitro wettability and comfort

# Evidence based relationship between CL surface properties and comfort

REVIEW ARTICLE

## Impact of Contact Lens Material, Design, and Fitting on Discomfort

*Fiona Stapleton*, Ph.D., M.C.Optom., D.C.L.P., F.B.C.L.A. and *Jacqueline Tan*, Ph.D., B.Optom., P.G.Cert.Oc.Ther.

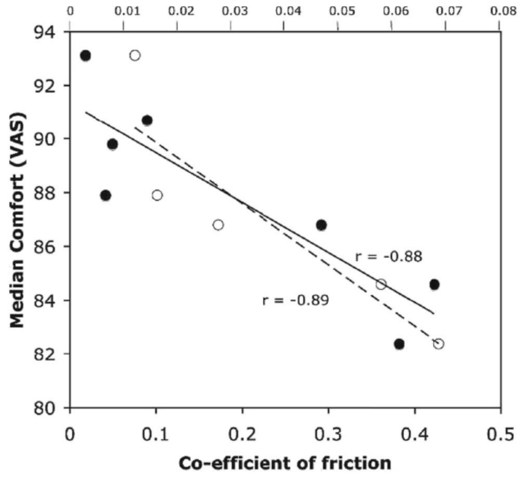
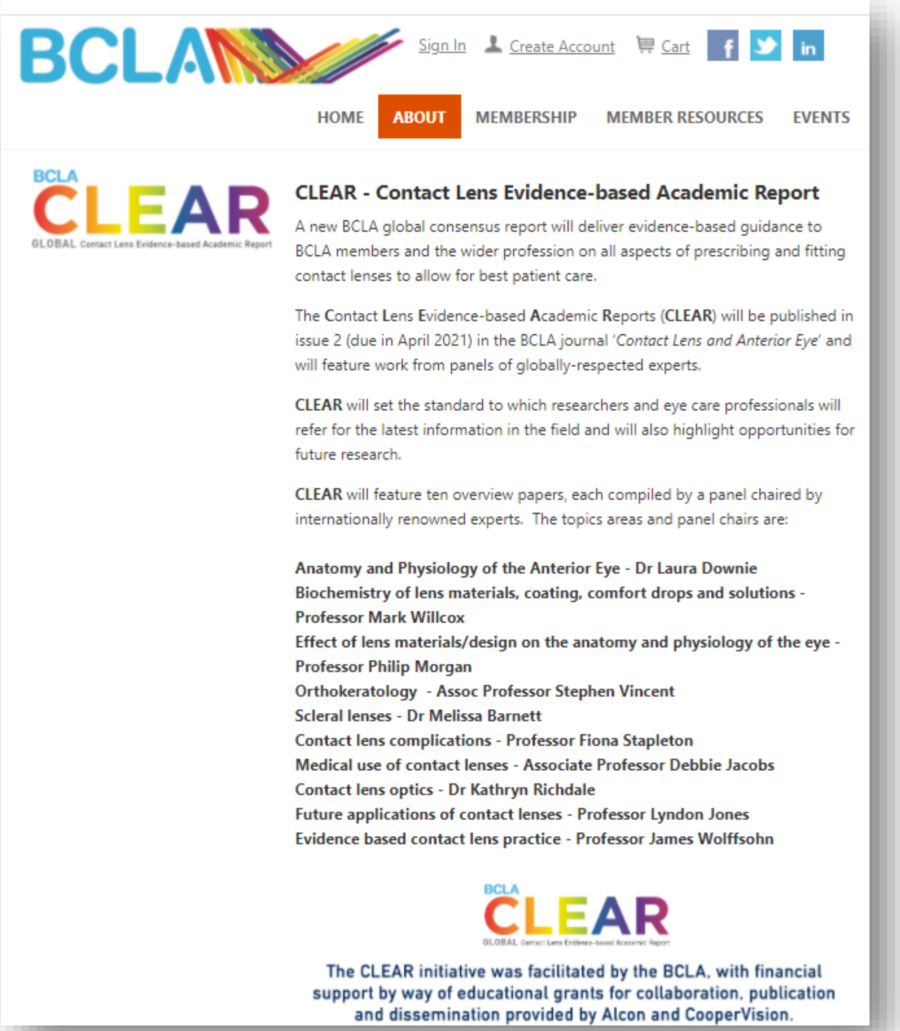



FIG. 2. Plot of median end-of-day comfort versus material coefficient of friction. Reproduced with permission from Jones L, Brennan NA, González-Méijome J, et al. The TFOS International Workshop on Contact Lens Discomfort: Report of the Contact Lens Materials, Design, and Care Subcommittee. TFOS International Workshop on CLD. *Investigative Ophthalmol Vis Sci* 2013;54:TFOS37–70. Copyright © 2013 The Association for Research in Vision and Ophthalmology, Inc.

- **No evidence to support a difference in comfort between silicone hydrogel and hydrogel CLs.**
- **Although surface properties such as friction or the use of wetting agents could have an important role in enhancing CL comfort, limited data to confirm this was reported**

# Evidence based relationship between CL surface properties and comfort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BCLA CLEAR GLOBAL Contact Lens Evidence-based Academic Report

**CLEAR - Contact Lens Evidence-based Academic Report**

A new BCLA global consensus report will deliver evidence-based guidance to BCLA members and the wider profession on all aspects of prescribing and fitting contact lenses to allow for best patient care.

The Contact Lens Evidence-based Academic Reports (**CLEAR**) will be published in issue 2 (due in April 2021) in the BCLA journal '*Contact Lens and Anterior Eye*' and will feature work from panels of globally-respected experts.

**CLEAR** will set the standard to which researchers and eye care professionals will refer for the latest information in the field and will also highlight opportunities for future research.

**CLEAR** will feature ten overview papers, each compiled by a panel chaired by internationally renowned experts. The topics areas and panel chairs are:

**Anatomy and Physiology of the Anterior Eye - Dr Laura Downie**
**Biochemistry of lens materials, coating, comfort drops and solutions - Professor Mark Willcox**
**Effect of lens materials/design on the anatomy and physiology of the eye - Professor Philip Morgan**
**Orthokeratology - Assoc Professor Stephen Vincent**
**Scleral lenses - Dr Melissa Barnett**
**Contact lens complications - Professor Fiona Stapleton**
**Medical use of contact lenses - Associate Professor Debbie Jacobs**
**Contact lens optics - Dr Kathryn Richdale**
**Future applications of contact lenses - Professor Lyndon Jones**
**Evidence based contact lens practice - Professor James Wolffsohn**

BCLA CLEAR

**The CLEAR initiative was facilitated by the BCLA, with financial support by way of educational grants for collaboration, publication and dissemination provided by Alcon and CooperVision.**

**No systematic association between surface material properties and comfort is evident.**

**No clear association between contact lens wettability and comfort,**

A methodological bias has to be pointed out as influencing most of the examined researches (Guillon, 2013). The relationship between comfort and a material property has been assessed without considering the effects of other changing variables (design characteristics of the CL, the replacement frequency, the regime of use, and the lens care system in case of reusable lenses)

# OUTLINE Lenti a Contatto: proprietà superficiali

1. An introduction about comfort and CL surface properties
2. In-vitro measurements of wettability and friction
3. In-vivo measurements of wettability and friction

> J Biomed Mater Res B Appl Biomater. 2013 Nov;101(8):1585-93. doi: 10.1002/jbm.b.32901. Epub 2013 Apr 4.

# Surface properties and wear performances of siloxane-hydrogel contact lenses

Michela Bettuelli [1], Silvia Trabattoni, Matteo Fagnola, Silvia Tavazzi, Laura Introzzi, Stefano Farris

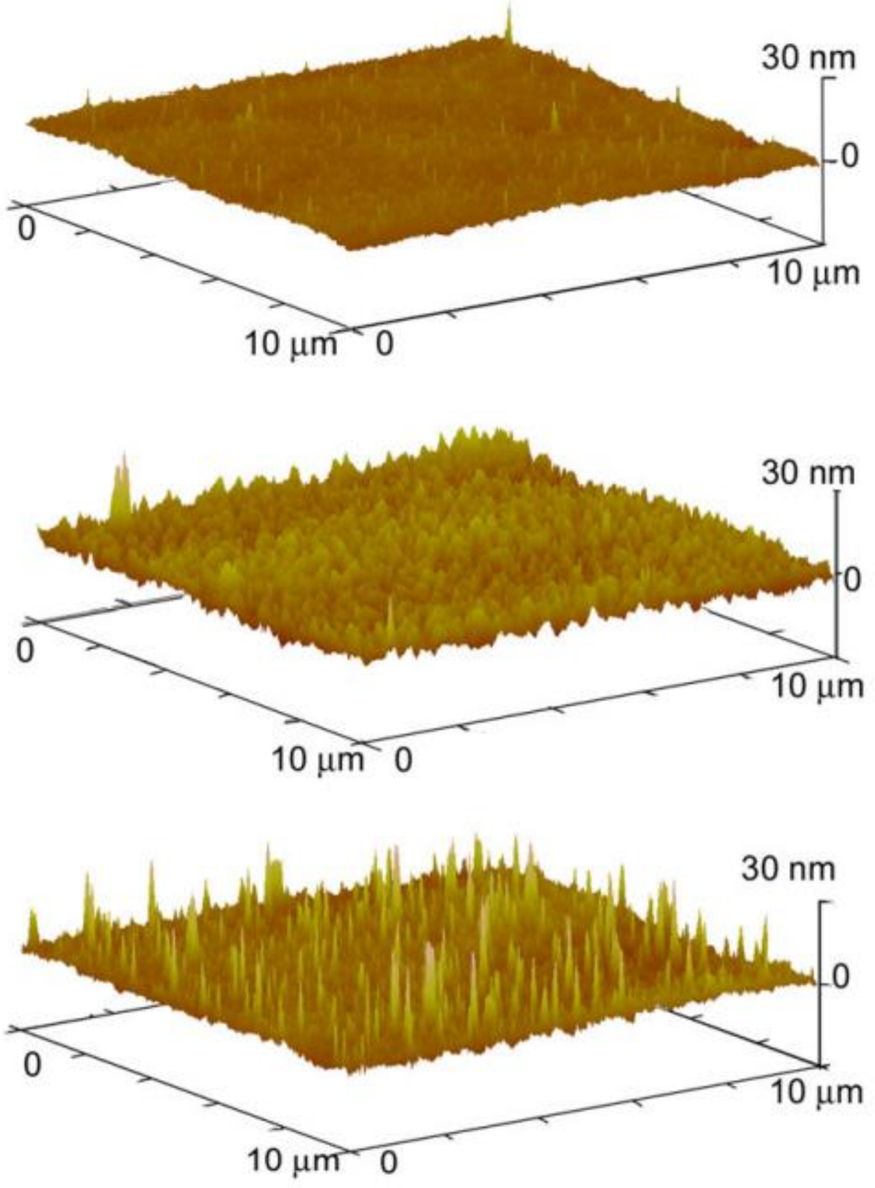



**FIGURE 5.** 3D AFM plots of lenses taken from the blister and rinsed in deionized water ($CL_{rins}$; first panel) and worn for 8 h, preserved for 12 h in saline solution, and rinsed in deionized water ($CL_{worn}$, second panel: smooth type and third panel: sharp type). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

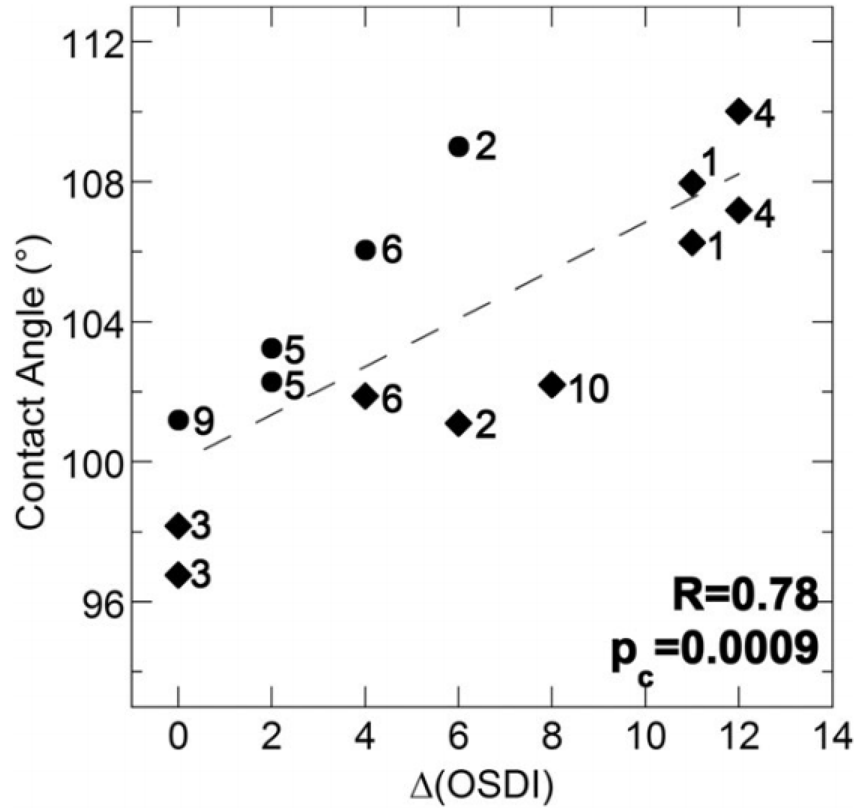
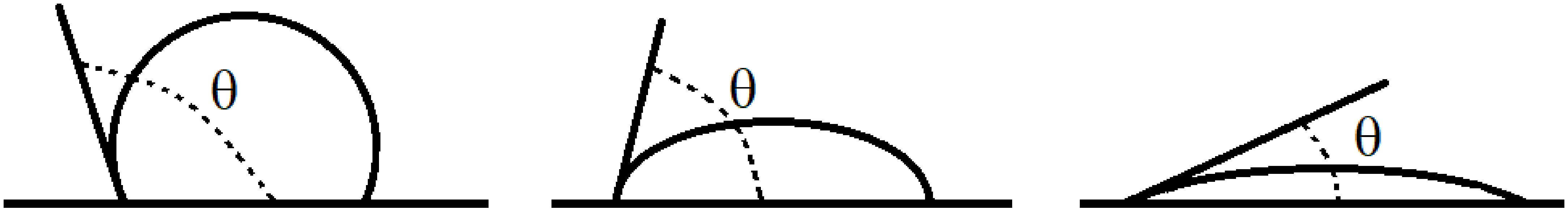



**FIGURE 8.** Measured contact angle of worn contact lenses as a function of the change of the OSDI. A continuous line indicates the result of the linear fitting of the data.

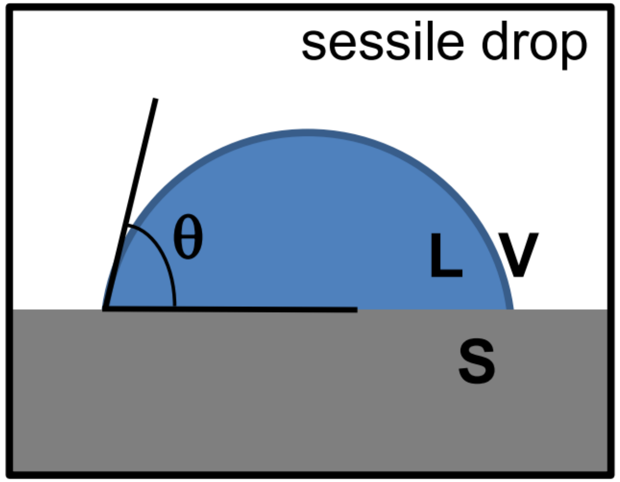
Wetting is the ability of a liquid deposited on a solid surface (or the surface of another immiscible liquid) to **spread out and maintain contact with that surface**.

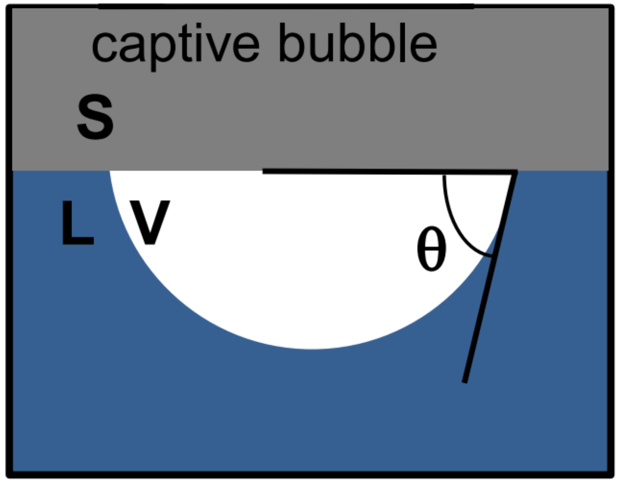


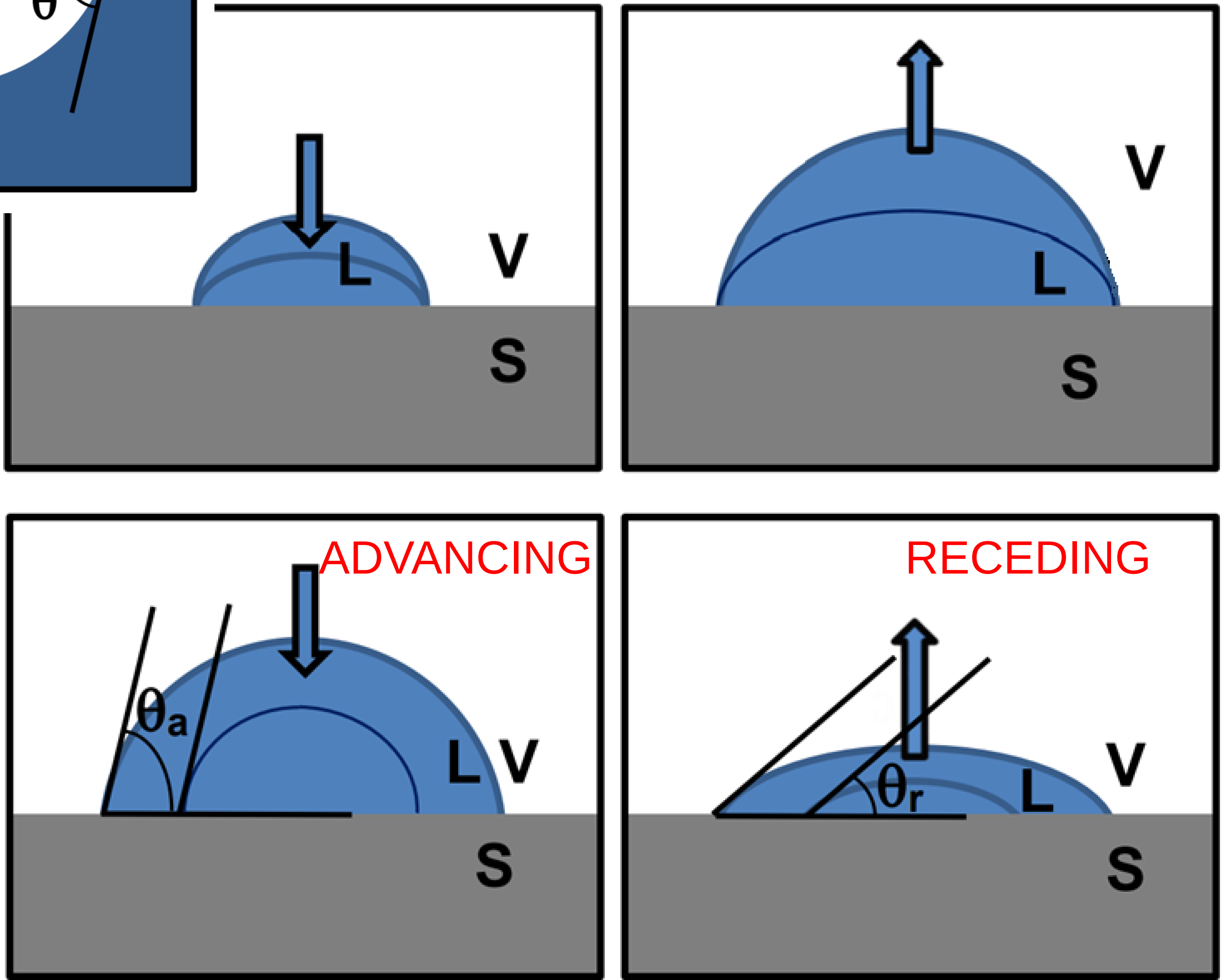

θ is the contact angle (CA)

higher CA corresponds to lower wettability and vice versa

DISCOMFORT (OSDI) ←




M. Willcox, N. Keir, V. Maseedupally, S. Masoudi, A. McDermott, R. Mobeen, C. Purslow, J. Santodomingo-Rubido, S. Tavazzi, F. Zeri, L. Jones

**Contact lenses: wettability, cleaning, disinfection and interactions with tears**

*Cont. Lens Anter. Eye (in press)*

*Eye & Contact Lens* • Volume 39, Number 6, November 2013

# Contact Lens In Vitro Wettability by Interferometry Measures of Drying Dynamics

*Raied Fagehi,* B.Sc., *Alan Tomlinson,* D.Sc., F.C.Optom., F.A.A.O., *Velitchko Manahilov,* Ph.D., *and Mera Haddad,* Ph.D.

thin film interferometer:

- wet CL surface illuminated with monochromatic light (546 nm)
- fringes produced by destructive interference of light reflected from pre-lens liquid and CL surface

- CL drying properties: time to first break-up (onset latency), duration of lens surface drying (drying duration), maximum speed of increase in the drying area (maximum speed), time to reach maximum drying speed (peak latency)

Contact Lens and Anterior Eye 40 (2017) 382–388

A novel *in-vitro* method for assessing contact lens surface dewetting: Non-invasive keratograph dry-up time (NIK-DUT)

Sebastian Marx[a,*], Wolfgang Sickenberger[a,b]

**keratograph dry-up time** (NIK-DUT)

adapted corneal topographer to analyse **in-vitro CL surface dewetting**

Contact Lens and Anterior Eye 42 (2019) 614–619

Videokeratoscopic assessment of silicone hydrogel contact lens wettability using a new in-vitro method

Erol Havuz*, Muveyla N. Gurkaynak

- in-vitro videokeratoscopy
- CL wettability on an in-vitro cornea model

Contact Lens and Anterior Eye 42 (2019) 178–184

Novel *in vitro* method to determine *pre-lens* tear break-up time of hydrogel and silicone hydrogel contact lenses

Hendrik Walther*, Lakshman. N. Subbaraman, Lyndon Jones

In vitro model to determine pre-lens non-invasive break-up time (NIBUT)

- A model blink cell of polytetrafluoroethylene (PTFE/Teflon™) was used to incubate the CLs and to mimic intermittent air exposure
- A motor raises and lowers the plate in and out of the test solution
- Regulated humidity and temperature

# Young's equation:

$$\cos(\theta) = \frac{(\gamma_{SV} - \gamma_{SL})}{\gamma_{LV}}$$


$(\gamma_{SV} - \gamma_{SL})$ → adhesion tension

$\gamma_{LV}$ → surface tension of the liquid exposed to air causing the drop to ball up:

WETTABILITY IS PROMOTED BY a relatively **low surface tension of the liquid** $(\gamma_{LV})$

| | $\gamma_{LV}$ @20°C (mJ/m²) |
|---|---|
| Water | 73 |
| Tears | 42-46 |

main components responsible for the surface tension of human tears: complex of **lipocalin with a polar lipid fraction**

Current Eye Research ›

Volume 19, 1999 - Issue 1

**Components responsible for the surface tension of human tears**

B. Nagyová & J.M. Tiffany

Pages 4-11 | Published online: 02 Jul 2009

> Curr Eye Res. 2004 Feb;28(2):93-108. doi: 10.1076/ceyr.28.2.93.26231.

# Wettability of silicone-hydrogel contact lenses in the presence of tear-film components

Lily Cheng [1], Susan J Muller, Clayton J Radke

Captive-bubble, advancing and receding CAs of:

- two SHy CLs (PureVision, Focus Night & Day)
- one Hy CL (Acuvue)

In isotonic solution, all three lenses displayed CA **hysteresis**. When **lysozyme and/or mucin** were added to the aqueous solution, **hysteresis was eliminated and higher wetting was achieved.**
→ importance of measuring lens **wettability in the presence of tear-film components**

Biological Interactions on Materials Surfaces pp 1-18 | Cite as

# Protein Adsorption to Biomaterials

David Richard Schmidt, Heather Waldeck, Weiyuan John Kao

biomaterials in contact with a biological fluid: **protein non-specific adsorption (biofilm formation)**

over time, **higher-affinity proteins can be replaced by lower-affinity proteins in a dynamic process (dynamic layer of proteins)**.

> Optom Vis Sci. 2007 Oct;84(10):946-53. doi: 10.1097/OPX.0b013e318157a6c1.

# The impact of lipid on contact angle wettability

Holly Lorentz [1], Ronan Rogers, Lyndon Jones

- 5 SHy + 4 Hy
- incubated in cholesterol, cholesteryl oleate, oleic acid, oleic acid methyl ester, and triolein OR soaked in phosphate buffered saline (PBS)
- advancing CAs (sessile drop)

→ Exposure to lipid may improve the wettability of certain SHy and Hy materials, particularly those SHy materials that are surface treated. This may help to explain **why certain SHy materials appear to improve in comfort for some patients during the first few hours or days of wear**.

Contact Lens and Anterior Eye 42 (2019) 178–184

# Novel *in vitro* method to determine *pre-lens* tear break-up time of hydrogel and silicone hydrogel contact lenses

Hendrik Walther*, Lakshman. N. Subbaraman, Lyndon Jones

Exposure of the CLs to an artificial solution containing **various lipids**, **various salts**, **urea**, **glucose**, **proteins**, and **mucin**.

- out of the blister pack, **Hy revealed longer NIBUTs** than the investigated Shy
- at the end of the **incubation** periods in an artificial tear solution, **the NIBUTs became very similar.**

Eur. Phys. J. Special Topics **197**, 295–303 (2011)

DOI: 10.1140/epjst/e2011-01471-6

THE EUROPEAN PHYSICAL JOURNAL SPECIAL TOPICS

Regular Article

# Wettability conundrum: Discrepancies of soft contact lens performance *in vitro* and *in vivo*

T.F. Svitova[a] and M.C. Lin

Clinical Research Center, School of Optometry, University of California, Berkeley, CA 94720-2020, USA

*Etafilcon A worn contralaterally*

- ❑ taken directly from the blister
- ❑ pre-soaked in surfactant-free solution 7 days

- Wearers <u>unable</u> to distinguish the two CLs
- Clinicians <u>unable</u> to distinguish the two CLs NIBUT (30 mins after CL insertion)

*Etafilcon A worn contralaterally*

- ❑ taken directly from the blister
- ❑ pre-soaked in surfactant-free solution 7 days

- Wearers unable to distinguish the two CLs
- Clinicians unable to distinguish the two CLs NIBUT (30 mins after CL insertion)
- Wettability of the two CLs ex-vivo similar to the new CL taken directly from the blister

# TRIBOLOGY

TRIBOLOGY studies the **interaction between surfaces in relative motion**.

- contact pressure (ratio of the normal load to the true contact area $F_N/A$): **1-10 kPa**
- blinking average speed: **12 cm $s^{-1}$**
- max blink speed: **~100 cm $s^{-1}$**

*Am J Ophthalmol 1980;89: 507*
*Langmuir 2003;19:3453.*
*Tribol Int 2013;63:45*
*The Ocular Surface 2015;13:236*

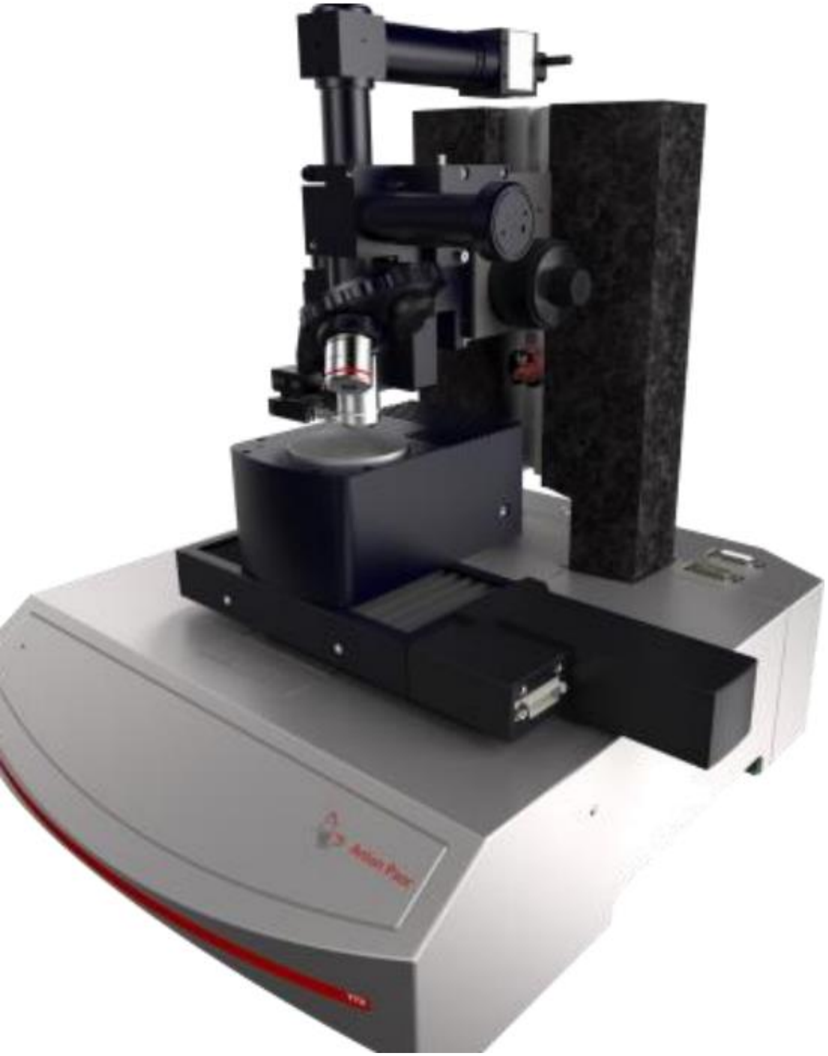
# FRICTION

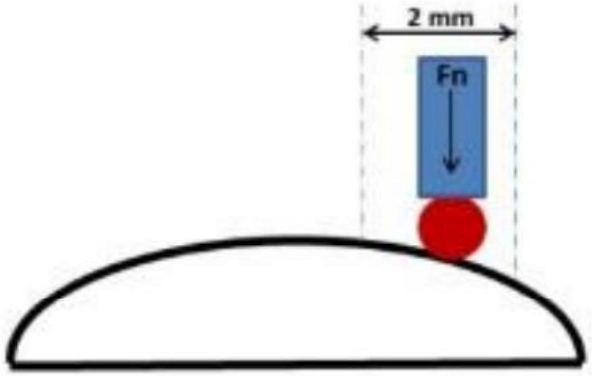
Friction is the **force resisting the relative motion of two components sliding against each other**.

The coefficient of friction ($\mu$) is the ratio

$$\mu = \frac{\text{frictional force (force resisting the relative motion)}}{\text{normal force (force compressing the two surfaces together)}}$$

$$F_{friction} = \mu \, F_N$$




- ruby/sapphire ball
- CL immersed in PBS or TLF

**Contact pressure P** calculated using Hertz model for spherical contact:

$$P = \frac{F_N}{\pi a^2}$$

$$a = \sqrt[3]{\frac{3F_N R}{4E}}$$

$F_{friction} = \mu F_N$

R = radius of the hemispherical counterbody
E = Young’s modulus of the CL

Tribol Lett (2014) 54:59–66

# Gemini Interfaces in Aqueous Lubrication with Hydrogels

Alison C. Dunn · W. Gregory Sawyer ·
Thomas E. Angelini

Measuring the friction response on just one-half of the cornea– eyelid interface using a stiff, impermeable probe may not reproduce physiological lubrication.

Tribol Lett (2016) 63:9
DOI 10.1007/s11249-016-0696-5

# Tribological Classification of Contact Lenses: From Coefficient of Friction to Sliding Work

**O. Sterner[1] · R. Aeschlimann[1] · S. Zürcher[1,2] · C. Scales[3] · D. Riederer[3] · N. D. Spencer[2] · S. G. P. Tosatti[1]**

contact area between glass disk and CL measured in situ

On the cornea, the contact area was observed via the expulsion of a fluorescent marker from the contact region.

Tribol Lett (2016) 63:9
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~~$F_{friction} = \mu \, F_N$~~

A classification in terms of $\mu$ is not always applicable to soft materials due to **nonlinearity between lateral and normal forces**.

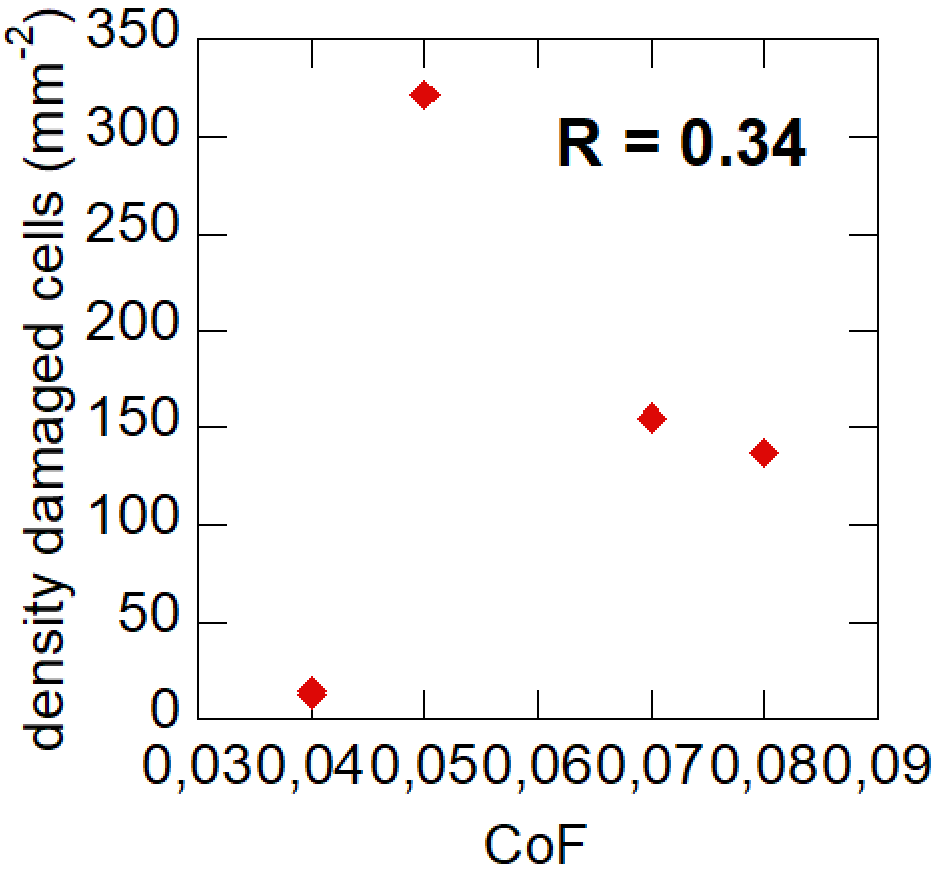
Average work is defined as the **average value of a nonlinear function fitted to the friction versus normal force data, multiplied by a relevant sliding distance**.

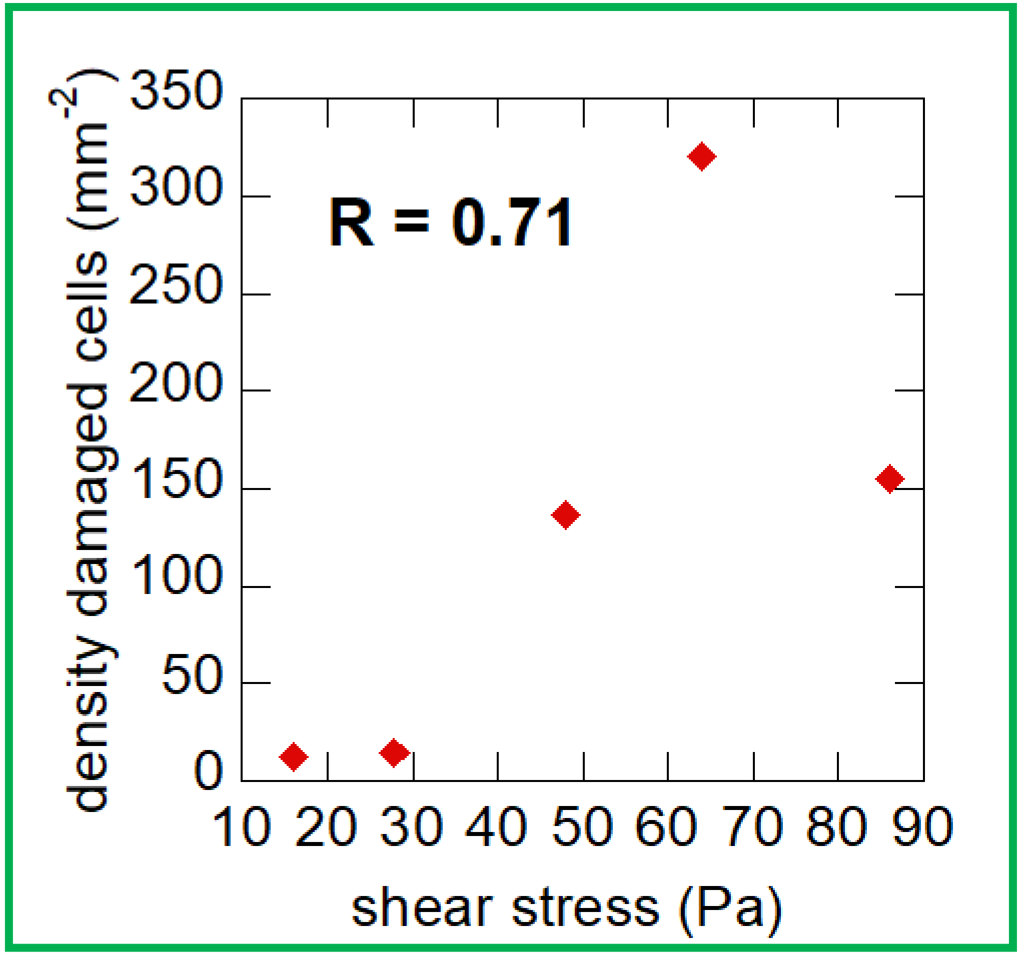
Tribology Letters (2020) 68:106

**Surface Gel Layers Reduce Shear Stress and Damage of Corneal Epithelial Cells**

Samuel M. Hart[1] · Eric O. McGhee[2] · Juan Manuel Urueña[1] · Padraic P. Levings[3] · Stephen S. Eikenberry[4] · Matthew A. Schaller[5] · Angela A. Pitenis[6] · W. Gregory Sawyer[1,2]

«It is also important to note that there is no correlation between friction coefcient and cell damage […]. Shear stress is the critical parameter from which to examine damage responses in the epithelial cells». **Shear stress: ratio between parallel force and cross-sectional area**.



# Spontaneous Blinking from a Tribological Viewpoint

HEIKO PULT, MSC, PHD,[1,2,3] SAMUELE G.P. TOSATTI, PHD,[4] NICHOLAS D. SPENCER, MA, PHD,[5] JEAN-MICHEL ASFOUR, DIPL-PHYS,[6] MICHAEL EBENHOCH, DR-ING,[7] AND PAUL J. MURPHY, BSC, MBA, PHD[8]

THE OCULAR SURFACE / JULY 2015, VOL. 13 NO. 3 / www.theocularsurface.com

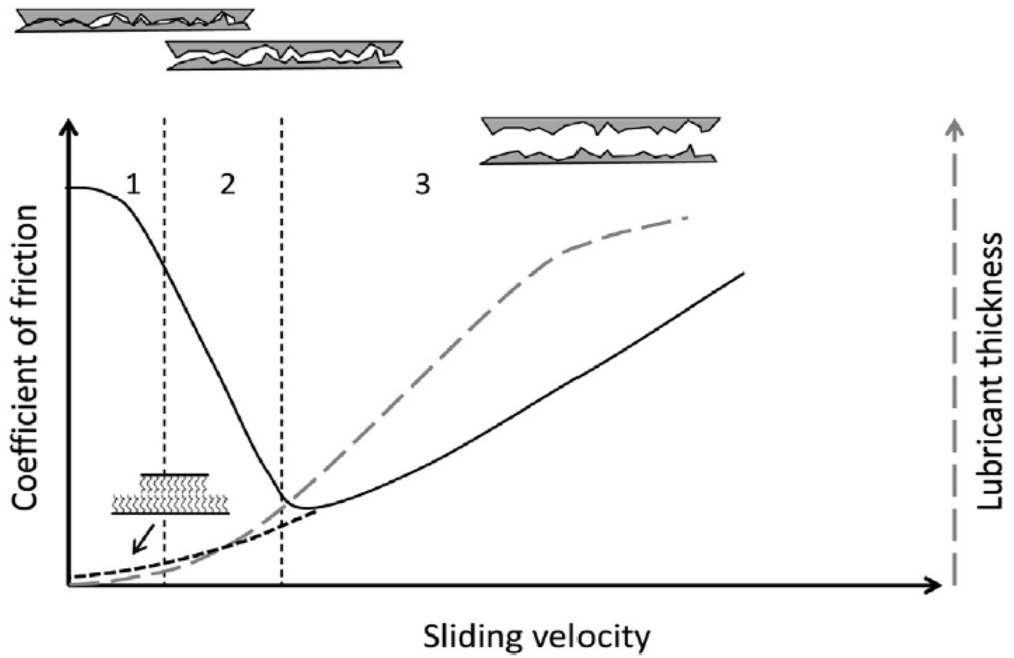
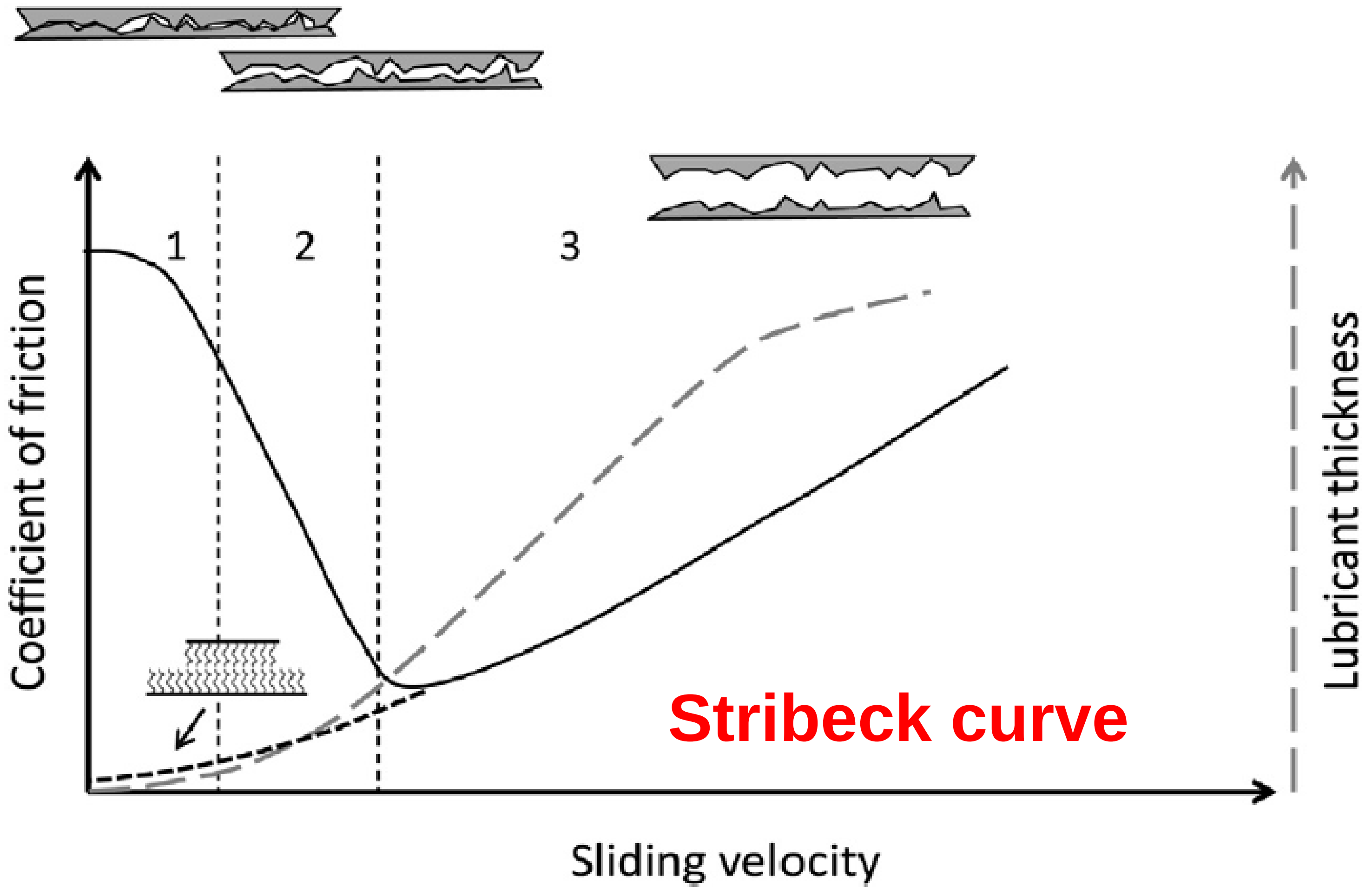



**Figure 3.** Schematic of a Stribeck curve showing lubricant thickness variation. Linear scale: 1= boundary lubrication, 2= mixed lubrication, 3= hydrodynamic, or full fluid film lubrication. The grey, dashed line shows the increase in lubricant thickness between the sliding partners; the black, dashed line represents brush-to-brush friction.

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1. BOUNDARY REGIME: there is a close contact of the solid surfaces. The material surface quality mainly influences friction.
2. MIXED REGIME: occasional contact between the solid surfaces
3. **HYDRODYNAMIC REGIME: full lubricant film is present between the two surfaces moving relative to each other. Both surfaces are fully separated and friction depends on the viscosity of the fluid.**

Tribol Lett (2016) 63:9
DOI 10.1007/s11249-016-0696-5

# Tribological Classification of Contact Lenses: From Coefficient of Friction to Sliding Work

O. Sterner[1] · R. Aeschlimann[1] · S. Zürcher[1,2] · C. Scales[3] · D. Riederer[3] · N. D. Spencer[2] · S. G. P. Tosatti[1]

primarily hydrodynamic lubrication regime
→ during the majority of a blink cycle, the sliding resistance is governed by the **viscous shear of the lubricant**.

TEAR FILM VISCOSITY

- non-Newtonian: highest viscosity at low shear rates (promoting stability), it decreases during eyelid movement
- generally thought that mucins are the main components contributing to the viscosity, with tear proteins and lipids also being involved

# **CONTACT LENS** and TEAR FILM VISCOSITY

In healthy eyes, the friction between the sliding partners (the cornea and lid wiper or CLs and lid wiper) is considered independent of the surface of the partners when moving at high velocity, since full fluid film lubrication is operating. However…..

- Changes in the tear film composition
- Changes in mucin fragmentation
- Changes in the tear-exchange rate
- Changes in the stability and activity of lipids and proteins in the lubricant

Tribol Lett (2016) 63:9
DOI 10.1007/s11249-016-0696-5

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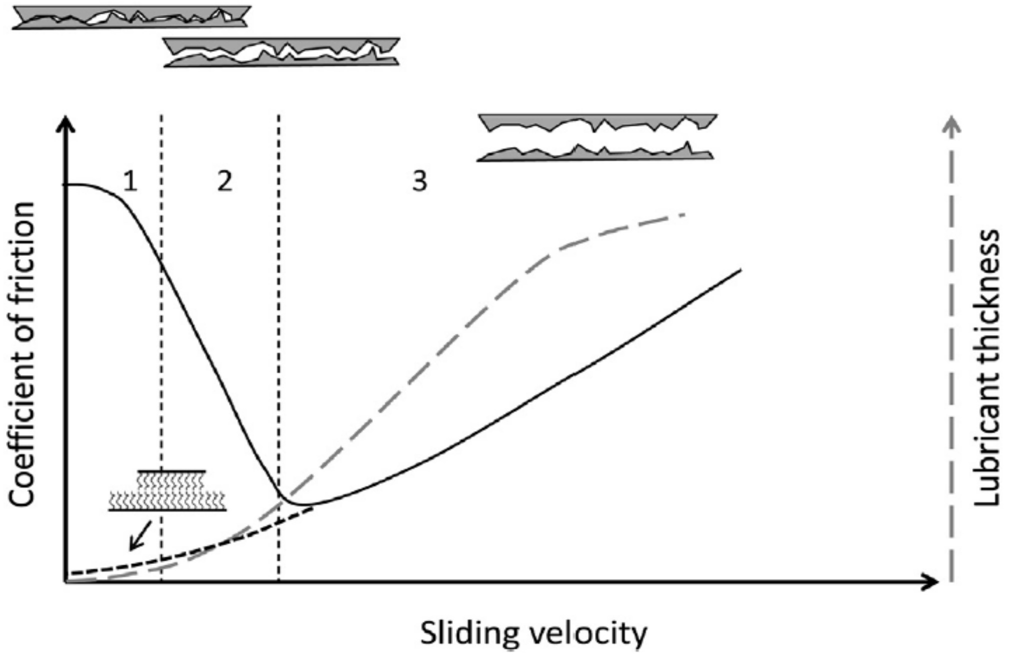
The glycocalyx ensure low interfacial shear stresses:

- where the speed approaches zero
- between CL back surface and cornea

The classic form of the Stribeck curve **cannot be applied**.

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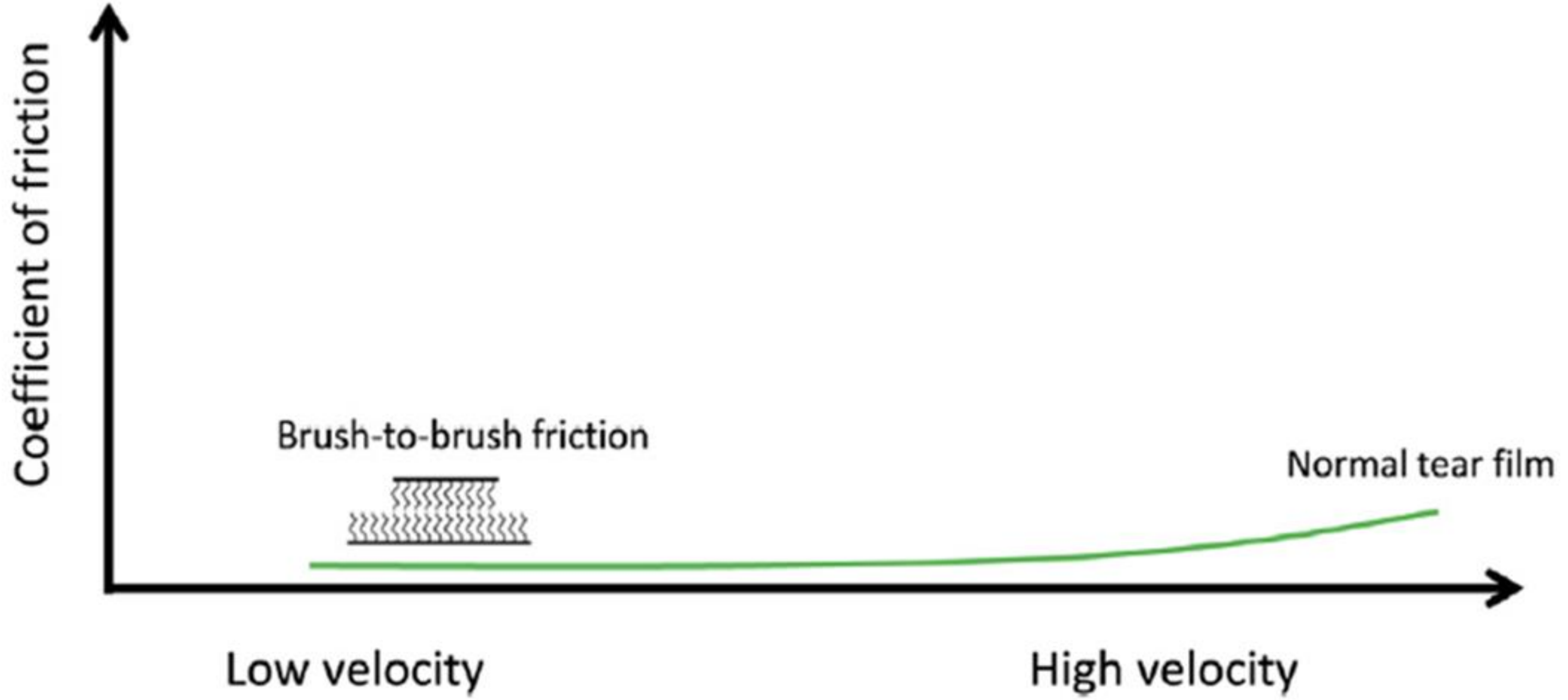
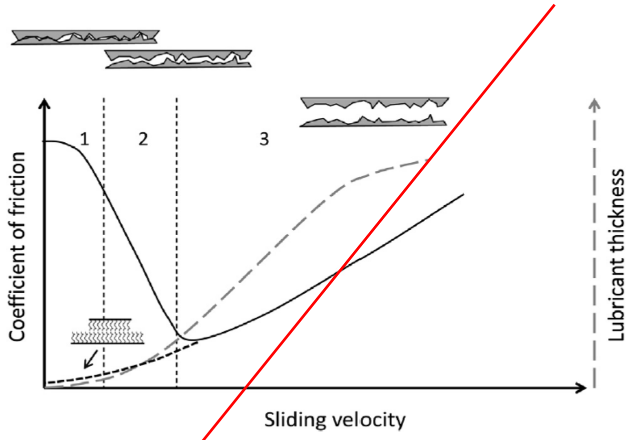



**Figure 5.** Schematic sketch showing friction in healthy (green curve) and dry eyes (red curve).

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Heiko Pult, MSc, PhD,[1,2,3] Samuele G.P. Tosatti, PhD,[4] Nicholas D. Spencer, MA, PhD,[5] Jean-Michel Asfour, Dipl-Phys,[6] Michael Ebenhoch, Dr-Ing,[7] and Paul J. Murphy, BSc, MBA, PhD[8]

THE OCULAR SURFACE / JULY 2015, VOL. 13 NO. 3 / www.theocularsurface.com

Mucins are glycoproteins with high molecular weights (0.5 - 40 Mda) and highly negatively charged.

Mucins enable **brush-to-brush friction** due to their **high hydration** and by generating **repulsive steric and electrostatic forces.**

Tribology Letters (2020) 68:106

# Surface Gel Layers Reduce Shear Stress and Damage of Corneal Epithelial Cells

Samuel M. Hart[1] · Eric O. McGhee[2] · Juan Manuel Urueña[1] · Padraic P. Levings[3] · Stephen S. Eikenberry[4] · Matthew A. Schaller[5] · Angela A. Pitenis[6] · W. Gregory Sawyer[1,2]

The mucins present in the tear film (MUC1, MUC2, MUC4, MUC5AC, and MUC16) arrange into a **graded gel layer**. The membrane-bound mucins (e.g. MUC1) form the anchor layer for this gel network. <u>The higher molecular weight secretory mucins (e.g. MUC5AC) develop into the lower density gel network</u>. These mucins create a gel-spanning network through transient crosslinks (hydrogen and disulfide bonds) and even shorter-living physical entanglements.

# Proteoglycan 4 (PRG4, also known as lubricin)

mucin-like glycoprotein acting also on articular cartilages to minimize friction

- Schmidt *et al. (*2013): evidence of PRG4 on ocular surface
- Subbaraman et al. (2012) and Samsom et al. (2015): PRG4 to enhance the wettability and lubricity of hydrogel and silicone hydrogel CLs
- Korogiannaki et al. (2018): PRG4 grafted onto the surface of hydrogel and silicone hydrogel CLs.
- Cheung et al. (2020): sorption f PRG4 to commercial CLs
- Morrison *et al. (*2012), Bayer (2018), Samsom *et al. (*2018): HA/PRG4 complex to reduce friction

Tribology International 89 (2015) 27–33

*In vitro* friction testing of contact lenses and human ocular tissues: Effect of proteoglycan 4 (PRG4)

M. Samsom [a], A. Chan [b], Y. Iwabuchi [c], L. Subbaraman [d], L. Jones [d], T.A. Schmidt [a,b,c,*]

# PARAMETERS THAT MAY INFLUENCE THE QUALITY OF THE BRUSH

**Spontaneous Blinking from a Tribological Viewpoint**

HEIKO PULT, MSC, PHD,[1,2,3] SAMUELE G.P. TOSATTI, PHD,[4] NICHOLAS D. SPENCER, MA, PHD,[5] JEAN-MICHEL ASFOUR, DIPL-PHYS,[6] MICHAEL EBENHOCH, DR-ING,[7] AND PAUL J. MURPHY, BSC, MBA, PHD[8]

THE OCULAR SURFACE / JULY 2015, VOL. 13 NO. 3 / www.theocularsurface.com

The brush regime depends mainly on:

- surface density and molecular weight of the adsorbed biomolecules
- changes in the pH, osmolality,
  and temperature

If the mucin layer and glycocalyx brushes are collapsed, damaged, less densely packed, less hydrated, thinner or absent, this will result in a higher coefficient of friction at low sliding velocities.

# **CONTACT LENS** and BRUSH-TO-BRUSH FRICTION

## Spontaneous Blinking from a Tribological Viewpoint

Heiko Pult, MSc, PhD,[1,2,3] Samuele G.P. Tosatti, PhD,[4] Nicholas D. Spencer, MA, PhD,[5] Jean-Michel Asfour, Dipl-Phys,[6] Michael Ebenhoch, Dr-Ing,[7] and Paul J. Murphy, BSc, MBA, PhD[8]

THE OCULAR SURFACE / JULY 2015, VOL. 13 NO. 3 / www.theocularsurface.com

"A CL carrying a densely packed polymeric brush capable of resisting higher contact pressures is needed.
Currently, this can be achieved by using water-soluble surface-brushes commonly defined in the field as wetting agents. **The use of such hydrophilic materials would explain why several studies report wettability of soft CLs to be related to CL discomfort."**

**The TFOS International Workshop on Contact Lens Discomfort: Report of the Contact Lens Materials, Design, and Care Subcommittee**

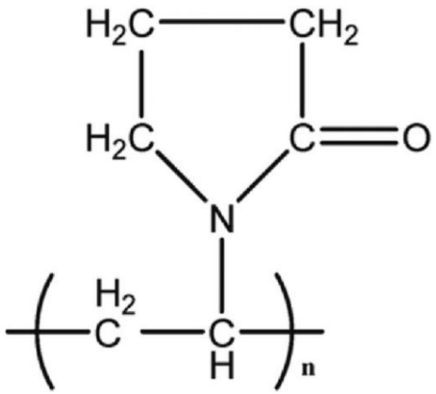
Lyndon Jones,[1] Noel A. Brennan,[2] José González-Méijome,[3] John Lally,[4] Carole Maldonado-Codina,[5] Tannin A. Schmidt,[6] Lakshman Subbaraman,[1] Graeme Young,[7] Jason J. Nichols,[8] and the members of the TFOS International Workshop on Contact Lens Discomfort

Investigative Ophthalmology & Visual Science October 2013, Vol.54, TFOS37-TFOS70.

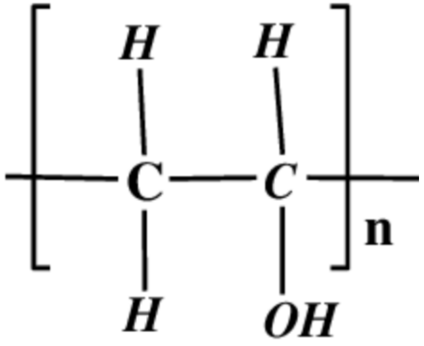
<u>Low-coefficient-of-friction lenses</u>:

- high water content surfaces
- incorporated wetting agents such as poly(vinylpyrrolidone) (PVP) or poly(vinyl alcohol) (PVA)

$(C_6H_9NO)_n$



$(C_2H_4O)_n$



# **CONTACT LENS** and BRUSH-TO-BRUSH FRICTION

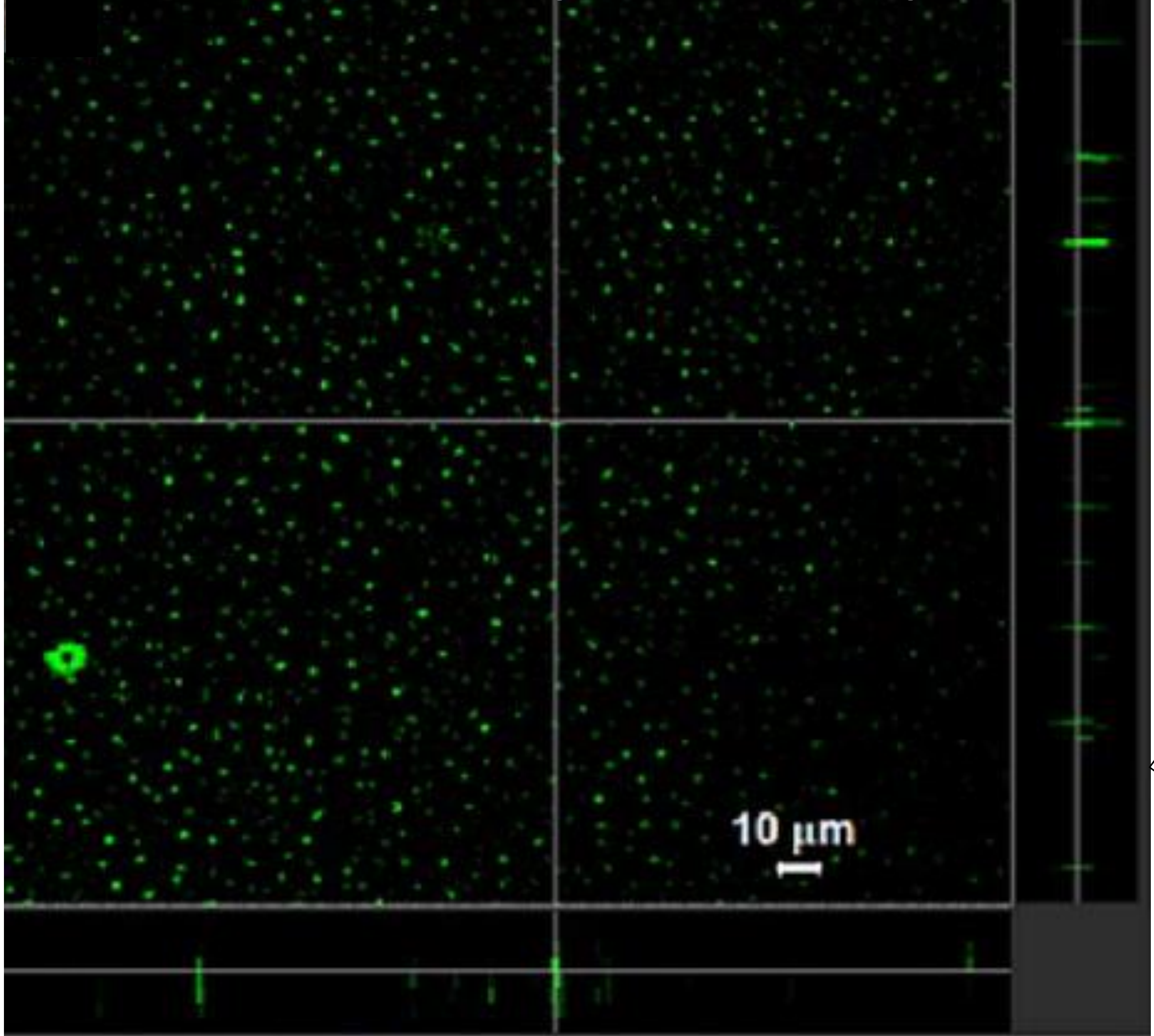
Tribol Lett (2013) 49:371–378

**Lubricity of Surface Hydrogel Layers**

**Alison C. Dunn · Juan Manuel Urueña · Yuchen Huo · Scott S. Perry · Thomas E. Angelini · W. Gregory Sawyer**

**SHy EWC ~33% + Hy layer (~5 µm) EWC > 80%**

# confocal PL – HA penetration depth




J Biomed Mater Res B Appl Biomater. 2015 Jul;103(5):1092-8. doi: 10.1002/jbm.b.33278. Epub 2014 Sep 23.

**Wear effects on microscopic morphology and hyaluronan uptake in siloxane-hydrogel contact lenses**

Silvia Tavazzi [1], Martina Tonveronachi [1], Matteo Fagnola [1], Federica Cozza [1], Lorenzo Ferraro [1], Alessandro Borghesi [1], Miriam Ascagni [2], Stefano Farris [3]

# **CONTACT LENS** and BRUSH-TO-BRUSH FRICTION

Tribol Lett (2013) 49:371–378

**Lubricity of Surface Hydrogel Layers**

**Alison C. Dunn · Juan Manuel Urueña · Yuchen Huo · Scott S. Perry · Thomas E. Angelini · W. Gregory Sawyer**

**SHy EWC ~33% + Hy layer (~5 µm) EWC > 80%**

- Microtribological experiments at low contact pressures (6–30 kPa) and at slow sliding speeds (<0.02 cm/s): $\mu < 0.02$
- At higher contact pressures, the gel collapsed: $\mu > 0.5$.

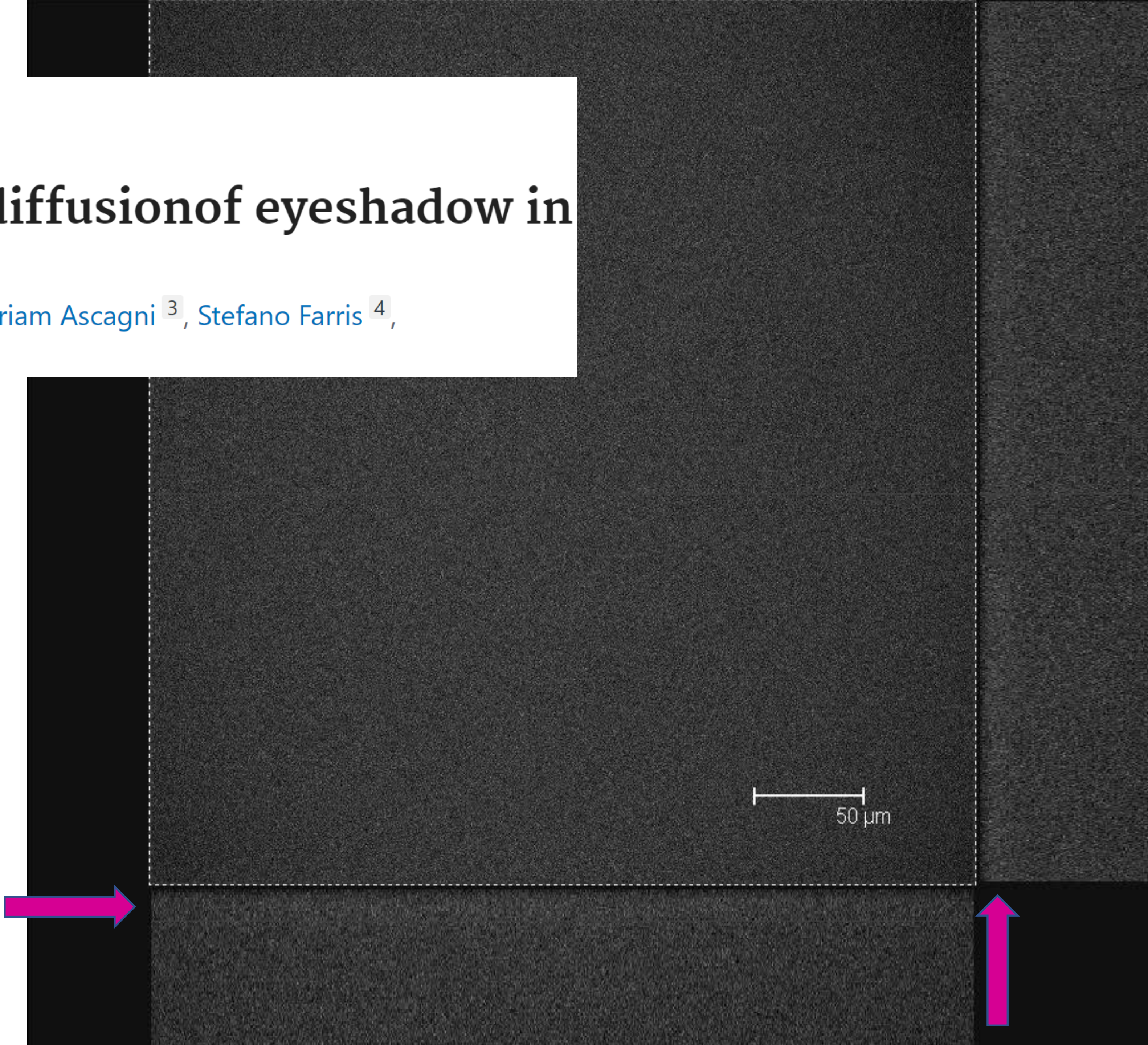
The ability of the soft **surface hydrogel layers** to provide lubricity depends on their **ability to support the applied pressure without dehydrating**. The **transition pressure is 10–20 kPa**. These transitions were found to be **reversible**.

> Cont Lens Anterior Eye. 2017 Oct;40(5):335-339.
doi: 10.1016/j.clae.2017.06.003. Epub 2017 Jul 8.

# Polymer–interaction driven diffusionof eyeshadow in soft contact lenses

Silvia Tavazzi [1], Alessandra Rossi [2], Sara Picarazzi [2], Miriam Ascagni [3], Stefano Farris [4], Alessandro Borghesi [5]

Delefilcon A (**worn 8 h**)



Tribology Letters (2020) 68:106

# Surface Gel Layers Reduce Shear Stress and Damage of Corneal Epithelial Cells

Samuel M. Hart[1] · Eric O. McGhee[2] · Juan Manuel Urueña[1] · Padraic P. Levings[3] · Stephen S. Eikenberry[4] · Matthew A. Schaller[5] · Angela A. Pitenis[6] · W. Gregory Sawyer[1,2]

sensitivity of corneal epithelial cells to contact sliding against CLs with:
homogeneous designs          surface gel layers

- **epithelial cells** allowed to mature for 48 h to allow the **mucin layer** to develop and mature on the apical surfaces
- cells maintained at 37 °C, relative humidity >95%, 5% $CO_2$
- **contact area directly measured** (zero-order fringe contrast under the microscope)
- depending on the particular experiment, the **membrane probe thickness, t, was varied to control for contact pressure**

To evaluate the CLs under equivalent contact pressures (P), individual membrane probes were made for each CL to set the contact pressures to 400 Pa at 200 µN of load.

Tribology Letters (2020) 68:106

**Surface Gel Layers Reduce Shear Stress and Damage of Corneal Epithelial Cells**

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| | $F_n$ (µN) | $\mu$ | $<P>$ (Pa) | $\tau$ (Pa) | #/mm$^2$ |
|---|---|---|---|---|---|
| etafilcon A | 200 ± 20 | 0.07 | 400 ± 40 | 28 ± 4 | 126 ± 29 |
| stenfilcon A | 200 ± 20 | 0.07 | 400 ± 40 | 28 ± 4 | 58 ± 4 |
| somofilcon A | 200 ± 20 | 0.05 | 400 ± 40 | 20 ± 3 | 38 ± 10 |
| delefilcon A | 200 ± 20 | 0.04 | 400 ± 40 | 16 ± 2 | 12 ± 7 |
| verofilcon A | 200 ± 20 | 0.04 | 400 ± 40 | 16 ± 2 | 11 ± 4 |

low levels of **shear stress ($\tau$)**

for CLs with surface gel layers

Tribology Letters (2020) 68:106

**Surface Gel Layers Reduce Shear Stress and Damage of Corneal Epithelial Cells**

Samuel M. Hart[1] · Eric O. McGhee[2] · Juan Manuel Urueña[1] · Padraic P. Levings[3] · Stephen S. Eikenberry[4] · Matthew A. Schaller[5] · Angela A. Pitenis[6] · W. Gregory Sawyer[1,2]

($\tau$ is ratio between parallel force and cross-sectional area)

| | $F_n$ (μN) | $\mu$ | $<P>$ (Pa) | $\tau$ (Pa) | #/mm$^2$ |
|---|---|---|---|---|---|
| etafilcon A | 200 ± 20 | 0.07 | 400 ± 40 | 28 ± 4 | 126 ± 29 |
| stenfilcon A | 200 ± 20 | 0.07 | 400 ± 40 | 28 ± 4 | 58 ± 4 |
| somofilcon A | 200 ± 20 | 0.05 | 400 ± 40 | 20 ± 3 | 38 ± 10 |
| delefilcon A | 200 ± 20 | 0.04 | 400 ± 40 | 16 ± 2 | 12 ± 7 |
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Tribology Letters (2020) 68:106

**Surface Gel Layers Reduce Shear Stress and Damage of Corneal Epithelial Cells**

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**density of damaged cells:**

difference between the CLs

with and without surface gel layers

| | $F_n$ (μN) | $\mu$ | <P> (Pa) | τ (Pa) | #/mm$^2$ |
|---|---|---|---|---|---|
| etafilcon A | 200 ± 20 | 0.07 | 400 ± 40 | 28 ± 4 | 126 ± 29 |
| stenfilcon A | 200 ± 20 | 0.07 | 400 ± 40 | 28 ± 4 | 58 ± 4 |
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contactlens & ANTERIOR EYE
The Journal of the British Contact Lens Association
BCLA

82 | VOLUME 36, SUPPLEMENT 2, E43, DECEMBER 01, 2013

# Confocal microscopy of the lid margin area of contact lens wearers

Philip Morgan, PhD MCOptom FAAO FBCLA • Ioannis Petropoulos, BOptom (Hons) MSc • Michael Read, PhD MCOptom • Rayaz Malik, MBChB FRCP PhD • Carole Maldonado-Codina, PhD MCOptom FAAO FBCLA

**Inflammatory signs** of the lid wiper in CL wearers were higher late in the afternoon compared to morning observations.

This was more pronounced in high-coefficient-of-friction CLs, compared to low coefficient-of-friction CLs.

# IN-VITRO FRICTION vs IN-VIVO COMFORT: SOME EVIDENCE

- Brennan (2009), Contact lens-based correlates of soft lens wearing **comfort**. Optom Vis Sci. 86: **e**90957
- Coles et al. (2012), Coefficient of friction and soft contact lens **comfort**. Optom. Vis. Sci. 89, **e**125603.
- Kern et al. (2013), Assessment of the relationship between contact lens coefficient of friction and subject lens **comfort**, Investigative Ophthalmology & Visual Science 54:ARVO **E**-Abstract 494
- Kern et al. (2013), Relationship between contact lens coefficient of friction and subjective lens **comfort**. Cont. Lens Anterior Eye 36, **e**26.

However, prudence was suggested in light of the fact that the measurement of comfort was performed on different lenses in which other parameters (eg edge design), not only friction, were changed.

Comparative Study > Optom Vis Sci. 2008 Oct;85(10):E930-8.

# Mucins and ocular signs in symptomatic and asymptomatic contact lens wear

Monica Berry [1], Heiko Pult, Christine Purslow, Paul J Murphy

- comfort evaluated using the Contact Lens Dry Eye Questionnaire
- mucins were assessed in dot-blots and Western blots after electrophoresis on 1% agarose or 4 to 12% NuPAGE Gels

- lid wiper epitheliopathy (LWE) and lid parallel conjunctival folds (LIPCOF) increased in symptomatics
- MUC5AC reactivity was significantly decreased in symptomatics
- MUC4 was correlated to LIPCOF and LWE
- MUC16 and MUC5AC correlated with corneal staining

**Mechanical forces: friction might follow from insufficient mucins, or an altered composition of the resident mucins at the ocular surface.**

Cornea. 2012 Jul;31(7):770-6. doi: 10.1097/ICO.0b013e3182254009.

# Contact lens materials, mucin fragmentation and relation to symptoms

Monica Berry [1], Chris Purslow, Paul J Murphy, Heiko Pult

mucin fragmentation on materials + correlation with wearing comfort

vifilcon A - senofilcon A - vifilcon A

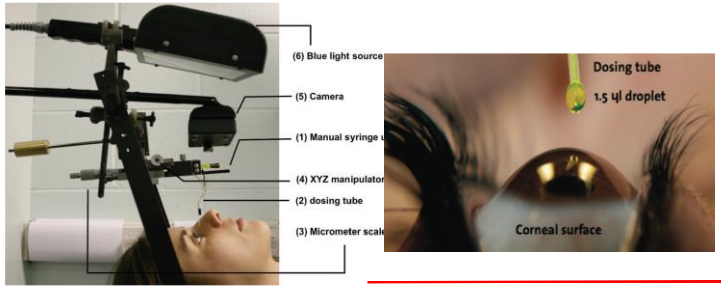
In asymptomatic CL wearers, only **changes in mucin fragmentation in response to a new material** were consistent and fast, irrespective of CL order.
Lack of change seems, therefore, to be connected with discomfort during CL wear.

# OUTLINE Lenti a Contatto: proprietà superficiali

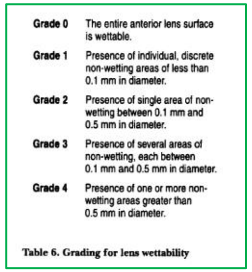
1. An introduction about comfort and CL surface properties
2. In-vitro measurements of wettability and friction
3. In-vivo measurements of wettability and friction

# Wettability assessment in-vivo: methods

When a contact lens is placed onto the ocular surface, factors in the ocular environment such as the temperature, osmolarity and composition of the tears can impact the chemistry of the material, changing its surface properties and in turn wettability (Keir & Jones, 2013).




*Hadad et al 2011*

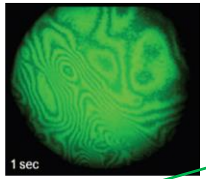


| | |
|---|---|
| Grade 0 | The entire anterior lens surface is wettable. |
| Grade 1 | Presence of individual, discrete non-wetting areas of less than 0.1 mm in diameter. |
| Grade 2 | Presence of single area of non-wetting between 0.1 mm and 0.5 mm in diameter. |
| Grade 3 | Presence of several areas of non-wetting, each between 0.1 mm and 0.5 mm in diameter. |
| Grade 4 | Presence of one or more non-wetting areas greater than 0.5 mm in diameter. |

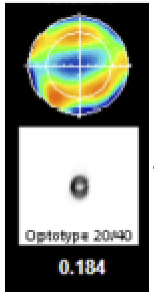
Table 6. Grading for lens wettability

*Morgan & Efron, 2002*


*Keir & Jones, 2013*




*Fagehi et al, 2017*




*Koh et al, 2019*

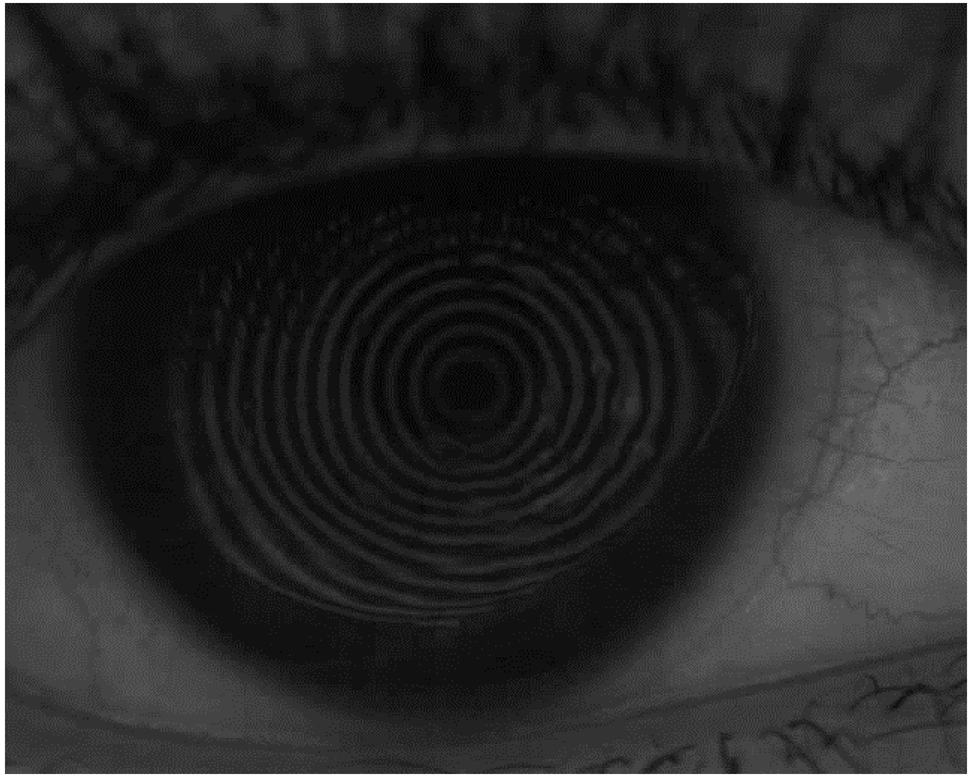
*Muller et al, 2020*

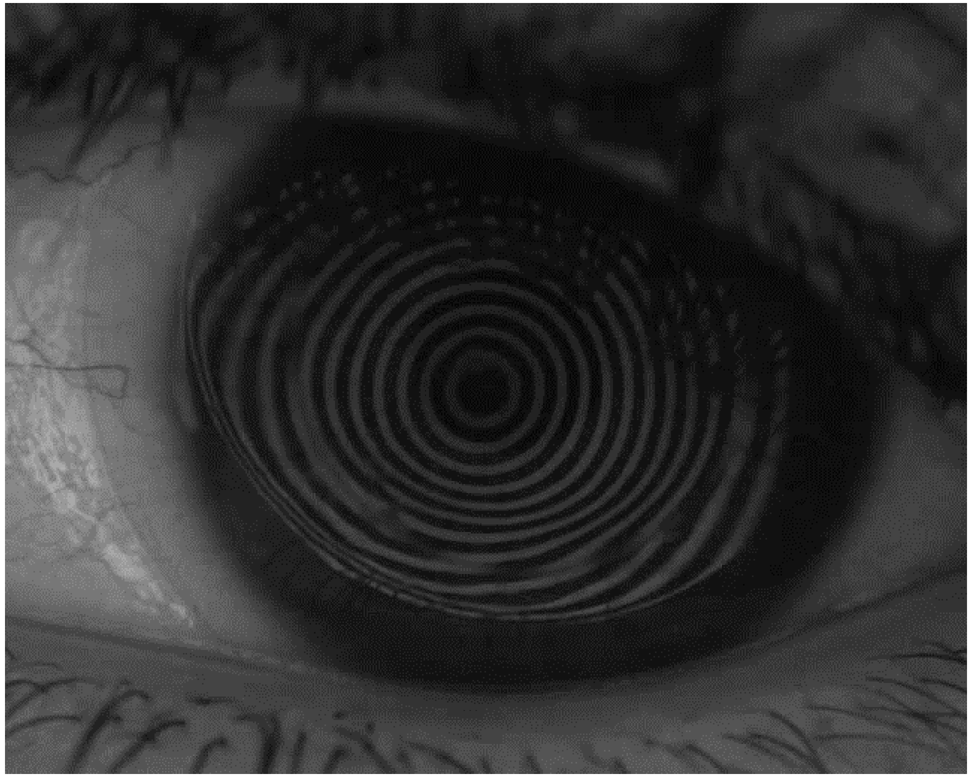
Direct Techniques

Indirect Techniques (on PLTF)

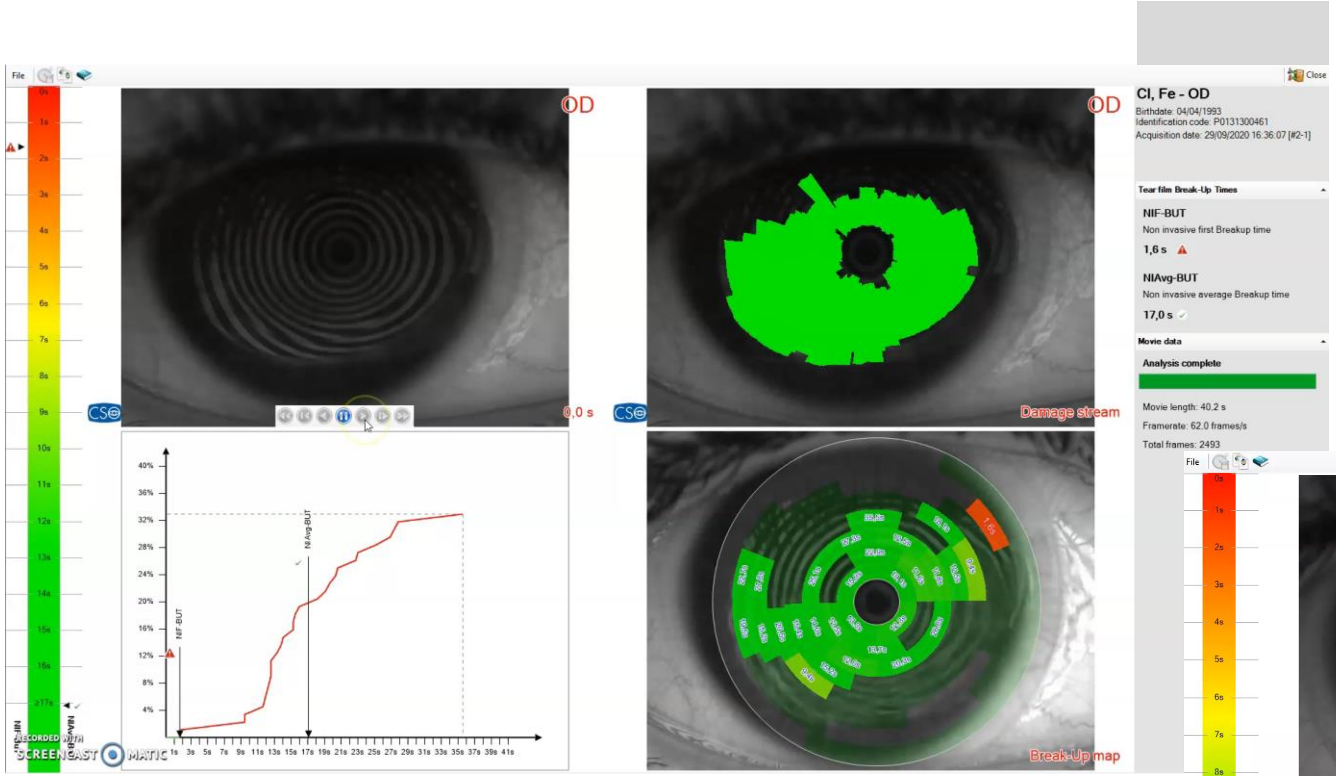
| Clinical-based methods (in vivo) | Paper |
|---|---|
| Sessile drop-based technique | on RGP (Benjamin, Piccolo and Toubiana, 1984)<br>on SCL (Haddad *et al.*, 2011) |
| Rate of liquid spreading | (Haddad *et al.*, 2011) |
| Tear coverage | (Morgan and Efron, 2002; Maldonado-Codina *et al.*, 2004; Brennan, Coles and Ang, 2006; Eiden, Davis and Bergenske, 2013; Morgan *et al.*, 2013) |
| Specular reflection quality | (Woods, Keir and Fonn, 2011; Keir and Jones, 2013) |
| Interferometry | (Szczesna-Iskander, 2014; Fagehi *et al.*, 2017) |
| Optical quality of lens surface (HoAs) | (Koh, Watanabe and Nishida, 2019) |
| Extended blink time elapsed between cessation of blinking and blur-out of a threshold letter on the acuity chart | (Schafer *et al.*, 2018) |
| NIBUT | (Guillon *et al.*, 2015; J. S. Wolffsohn *et al.*, 2015; Varikooty *et al.*, 2015; Lau *et al.*, 2016; Szczesna-Iskander, Alonso-Caneiro and Iskander, 2016; Vidal-Rohr *et al.*, 2018; Llorens-Quintana *et al.*, 2018; Guillon, Patel, *et al.*, 2019; Guillon, Theodoratos, *et al.*, 2019; Kolbe *et al.*, 2020; Müller *et al.*, 2020) |

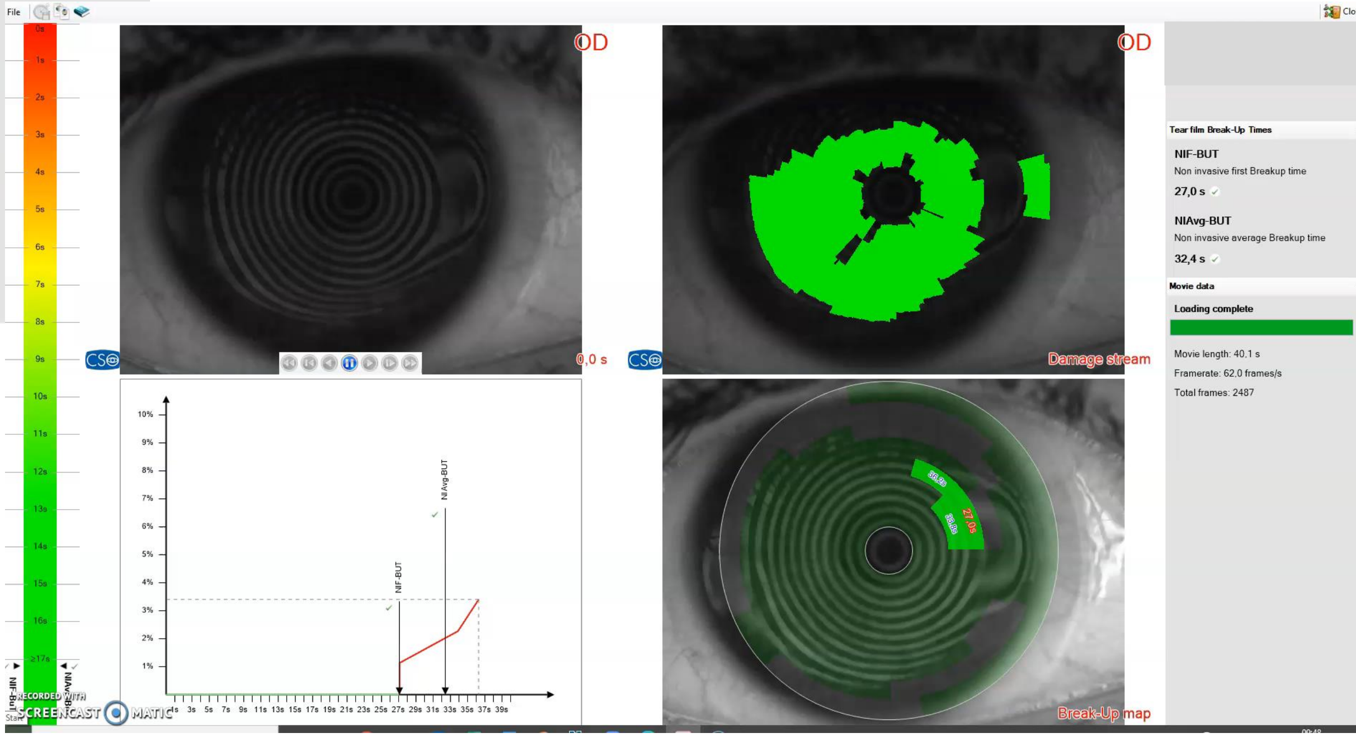
# Wettability assessment in-vivo: NIBUT or non-invasive surface drying time





# Wettability assessment in-vivo: NIBUT or non-invasive surface drying time




advantages

-accessibility for clinicians,

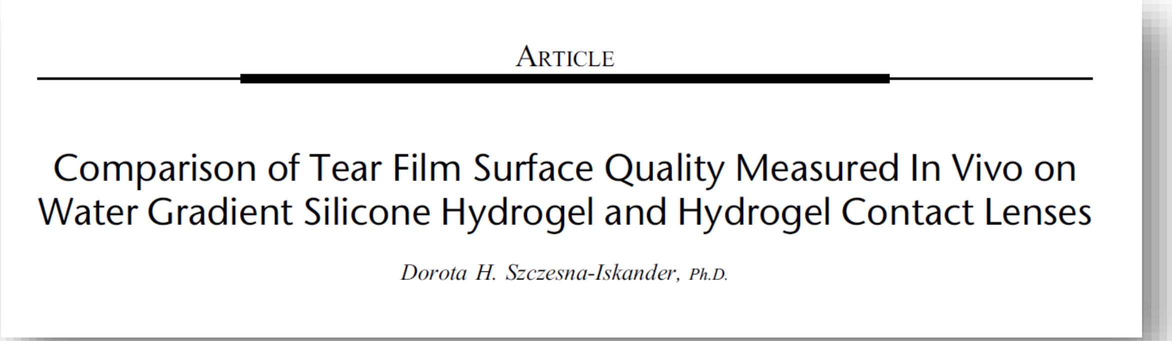
-coverage of a large portion of the contact lens surface

-minimum influence of eye movements

# Wettability assessment in-vivo and comfort: CLEAR results

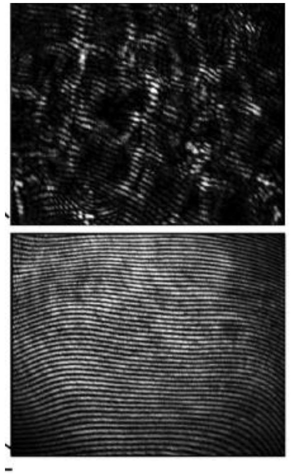
| Author, year | Study Design | Subjects | CL type | Kind of assessment on the lens material | Comfort Assessment | Effect on Comfort |
|---|---|---|---|---|---|---|
| (Vidal-Rohr *et al.*, 2018) | Randomized, double-masked, cross-over study | 20 CL wearers | formofilcon B with and without ultra-thin coating technology | In vivo PLTF NIBUT by Keratograph 5M | CLDEQ-8 and Comfort rated on Visual Analog Scale (at insertion, mid-day and end of the day) | **Subjective lens comfort was better for coated compared to uncoated lenses. The surface coating postponed the lens dewetting too.** |
| (Guillon *et al.*, 2016) | Study population, non-interventional, retrospective | 202 SCL wearers | SH and H CL | In vivo PLTF kinetics during the entire interblink period by high definition digital Tearscope videos | OSDI | **Symptomatic wearers had a shorter break-up time, lesser surface coverage by the tear film during the interblink period and greater surface exposure at the time of the blink.** |
| (Bettuelli *et al.*, 2013) | Correlational study | 11 CL wearers | Filcon V | In vitro Atomic force microscopy (to study surface morphology) and CA (sessile drop) | OSDI | **Comfort is correlated with the surface properties of the lens** |
| (Yuksel and Yaman, 2019) | Prospective, single blind, contralateral eye, | 30 non CL wearers | lotrafilcon B and samfilcon A with 2 different wetting agents | none | CLDEQ-8 | **No difference between the 2 groups** |
| (Varikooty *et al.*, 2013) | Prospective, randomized, bilateral, crossover trial. | 104 CL wearers (51 asymptomatic, 53 symptomatic) | delefilcon A, filcon II 3, narafilcon A | None | Comfort rated on Visual Analog Scale (after lens insertion and then every 4 hours and end of the day) | **Comfort during the first 12 hours was highest with delefilcon a (similar to narafilcon A) and lowest with filcon II C. End-of-day comfort was lowest with filcon II 3, and Cumulative comfort was highest for delefilcon A** |
| (Evans, Tattersall and Purslow, 2018) | Prospective, single-blind, randomised crossover trial | 35 successful CL wearers | etafilcon A with PVP and a novel polymer (SIB) with alginic acid | In vivo PLTF stability (no information about the assessment provided) | Comfortable wearing time | **no significant differences PLTF stability and comfort wearing time between the 2 lenses** |
| (Morgan *et al.*, 2013) | Prospective, single blind, randomized trial | 74 non-CL wearers | Narafilcon with PVP versus control group with no CL | In vivo wettability assessed evaluating the tear coverage looking at any PLTF deficiency on the CL surface, by a slit lamp observation and a grading scale | Comfort rated by 0–100 unit visual analogue scales at each follow up visit and during weeks 1 and 5 of the study using a SMS methodology five times per day, every day on a 1–5 Likert scale | **Comfort scores assessed by SMS were equivalent for the Narfilcon A group and control group** |
| (Eiden, Davis and Bergenske, 2013) | Prospective study | 117 habitual wearers | Lotrafilcon A | In vivo wettability and PLTF evaluated by a slit lamp observation and a grading scale (at the dispense, 1 week and 1 month) | Comfort rated by 0 (poor)-10 (excellent) scale at the dispense 1 week and 1 month. At 1 month 2 comfort parameters were assessed by a 4-step Likert scale | **Comfort did not deteriorate in one month of wear** |
| (Szczesna-Iskander, 2014) | Prospective, bilateral, masked, crossover study | 11 subjects (8 non CL wearers) | nelfilcon A, delefilcon A | PLTF surface quality assessed by lateral shearing interferometry | Comfort rated by 1 (best)-10 (worst) scale | **The delefilcon A impact less tear film surface quality than nelfilcon A. Lower values of discomfort was achieved with delefilcon A** |
| (J. S. Wolffsohn *et al.*, 2015) | Prospective, randomized, masked, 1-week crossover clinical trial | 39 CL wearers | narafilcon A, filcon II-3, delefilcon A | In vivo PLTF NIBUT CA-1000 topographer (Topcon, Newbury, UK), | Comfort rated on a scale from 1 to 10 (1, poor; 10, excellent). | **PLTF NIBUT differed between lens types but comfort was similar between the lenses** |
| (Sapkota, Franco and Lira, 2018) | Longitudinal, contralateral eye, clinical trial | 47 non CL wearers | a monthly CL in one eye (lotrafilcon B, comfilcon A, balafilcon A) a DD CL in the other (nelfilcon A, stenofilcon A, nesofilcon A) | None | Comfort rated at lens insertion and at the end-of-day on a 0 -100 scale | **Reduction in end-of-day comfort was not associated with the lens wearing modality but affected by the lens material** |
| (Schafer *et al.*, 2018) | Randomized, bilateral, masked, crossover study | 10 CL wearers (9 current and 1 former) | senofilcon A and samfilcon A with wetting agent polyvinylpyrrolidone (PVP) | Extended blink time (EBT) was used to assess visual stability, Wettability was assessed bu Slit lamp and grading scale | End-of-day comfort rated on a scale from 1 to 10 (1, poor; 10, excellent) | **More stable vision and wettability with samfilcon A. No difference in comfort** |
| (Diec, Tilia and Thomas, 2017) | Retrospective analysis | 201 myopic patients | DD SH (delefilcon A, somofilcon A, narafilcon A) and DD Hy (omafilcon A, nelfilcon A) | None | Comfort rated at insertion, during the day, and end of day on a 1 (poor)-10 (excellent), average comfortable CL wearing time was also required | **Neither material types showed superiority in comfort (comfortable wearing time, comfort at insertion, during day, and end of day)** |
| (Michaud and Forcier, 2016) | Multisite, prospective, randomized, cross-over, SCL clinical trial | 80 symptomatic CL wearers | nelfilcon A, delefilcon A | None | CLDEQ-8 and Comfort rated on a Likert-type scale from 1 (very comfortable) to 5 (very uncomfortable). | **Comfort of symptomatic CL wearers switched to DD CL is material related.** |

# Wettability assessment in-vivo and comfort: example of consistent result


ARTICLE

Comparison of Tear Film Surface Quality Measured In Vivo on Water Gradient Silicone Hydrogel and Hydrogel Contact Lenses

*Dorota H. Szczesna-Iskander, Ph.D.*



two interferograms illustrate fringe pattern on contact lens (upper) and on bare eye (lower).

- Prospective, bilateral, masked, crossover study
- 11 subjects (8 non CL wearers)
- nelfilcon A (Focus Dailies), delefilcon A (total 1)
- PLTF surface quality assessed by lateral shearing interferometry
- Comfort rated by 1 (best)-10 (worst) scale
- The delefilcon A impact less tear film surface quality than nelfilcon A. Lower values of discomfort was achieved with delefilcon A

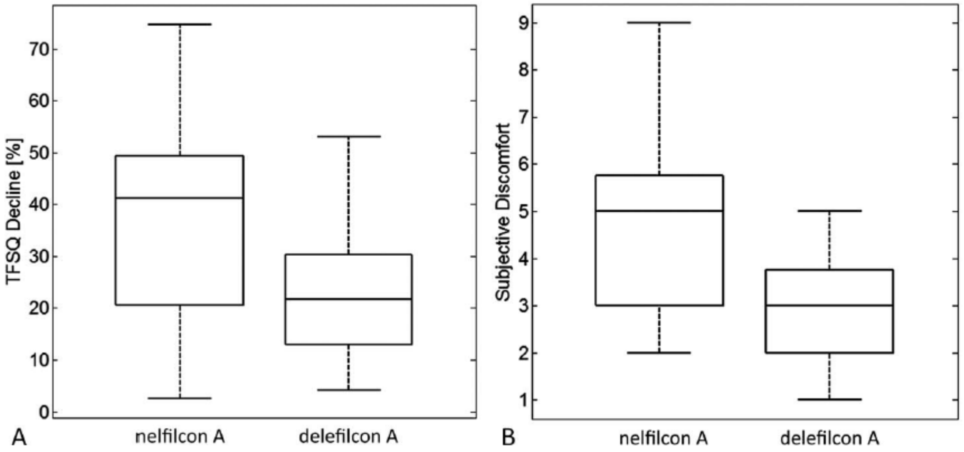
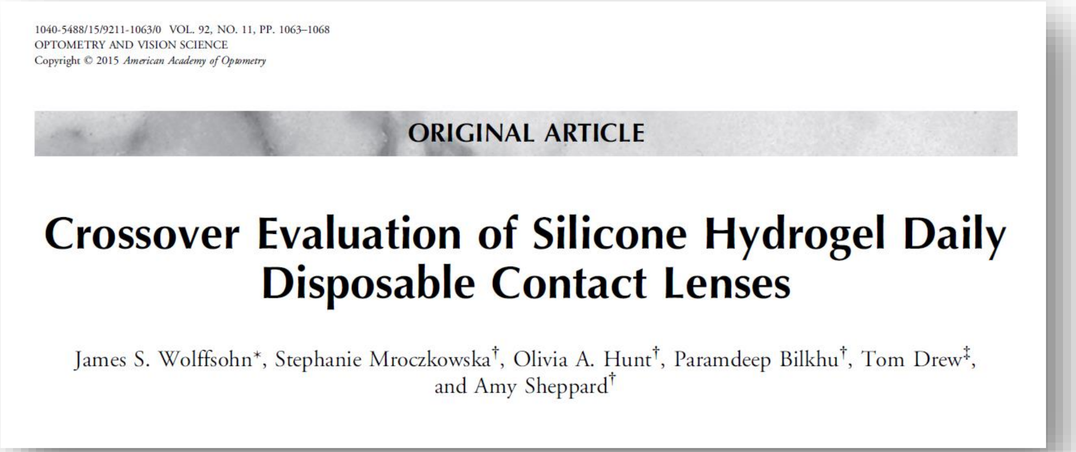



FIG. 2. Box and whiskers plot of (A) the decline in the average prelens tear film surface quality (TFSQ; in percentage) with respect to that of the precorneal tear film and (B) subjective discomfort on lenses.

# Wettability assessment in-vivo and comfort: example of non consistent result



1040-5488/15/9211-1063/0 VOL. 92, NO. 11, PP. 1063–1068
OPTOMETRY AND VISION SCIENCE
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ORIGINAL ARTICLE

**Crossover Evaluation of Silicone Hydrogel Daily Disposable Contact Lenses**

James S. Wolffsohn*, Stephanie Mroczkowska†, Olivia A. Hunt†, Paramdeep Bilkhu†, Tom Drew‡, and Amy Sheppard†

- Prospective, randomized, masked, 1-week crossover clinical trial
- 39 CL wearers
- narafilcon A (trueye) filcon II-3 (Clariti), delefilcon A (Total 1)
- In vivo PLTF NIBUT CA-1000 topographer (Topcon, Newbury, UK),
- Comfort rated on a scale from 1 to 10 (1, poor; 10, excellent).
- PLTF NIBUT differed between lens types but comfort was similar between the lenses

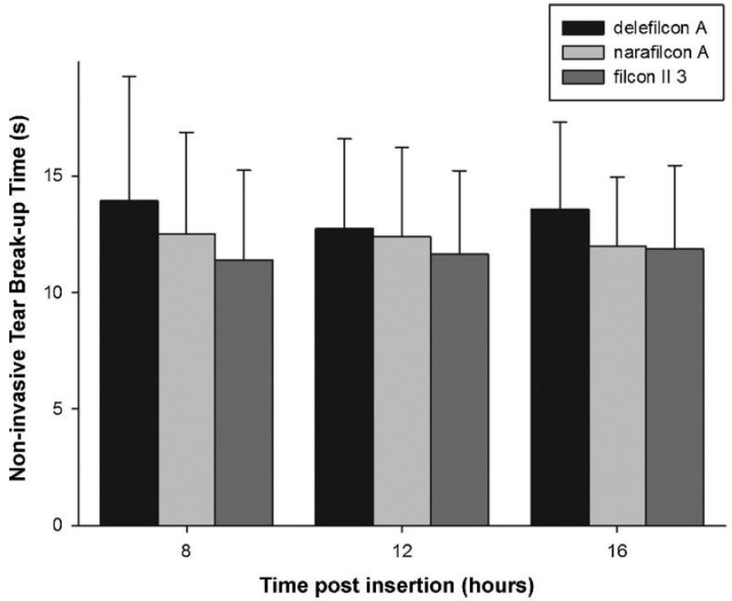


**FIGURE 1.**
Noninvasive tear breakup time for the delefilcon A, narafilcon A, and filcon II 3 lenses. n = 39. Error bars = 1 SD.

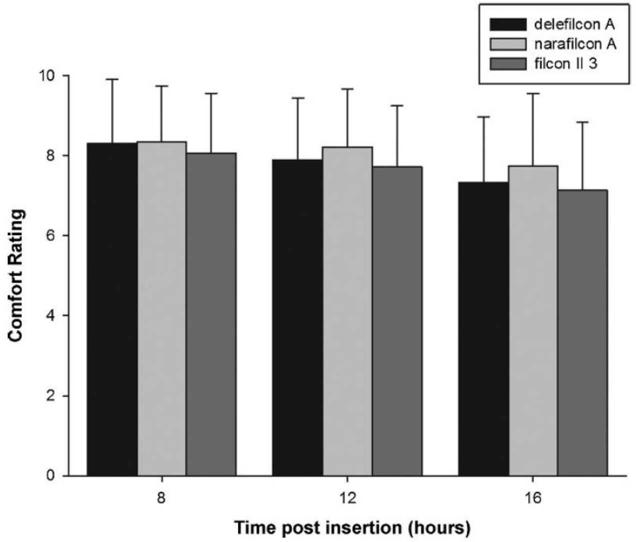


**FIGURE 3.**
Subjective comfort ratings for the delefilcon A, narafilcon A, and filcon II 3 lenses. n = 39. Error bars = 1 SD.

# Friction assessment in-vivo: methods

When a contact lens is placed onto the ocular surface, factors in the ocular environment such as the temperature, osmolarity and composition of the tears can impact the chemistry of the material, changing its surface properties (Keir & Jones, 2013).

## Indirect Techniques


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Review

Overview of factors that affect comfort with modern soft contact lenses

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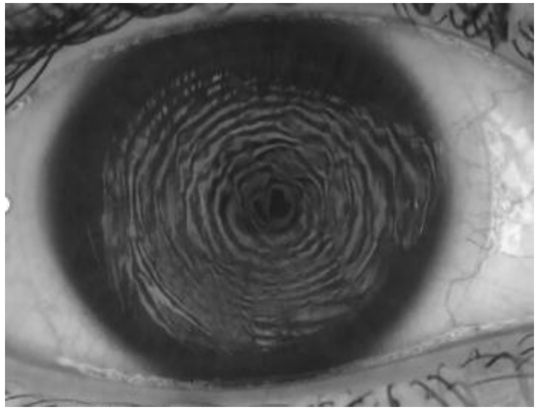
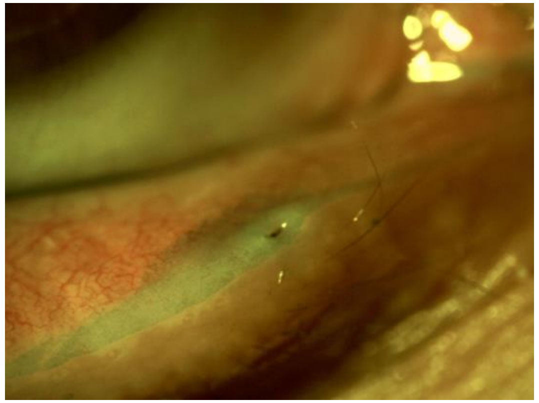


NIBUT on PLTF represents an indirect assessment of the lubricity and on-eye friction, which is impossible to measure directly in the eye (Chalmers, 2014).


REVIEW ARTICLE

Impact of Contact Lens Material, Design, and Fitting on Discomfort

*Fiona Stapleton, Ph.D., M.C.Optom., D.C.L.P., F.B.C.L.A. and Jacqueline Tan, Ph.D., B.Optom., P.G.Cert.Oc.Ther.*



The lid wiper epitheliopathy has been linked to friction and lubricity (Stapleton and Tan, 2017)

# Conclusions

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# Grazie per l'attenzione

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