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OPTICS AND OPTOMETRY
RESEARCH CENTER
UNIVERSITY OF MILANO BICOCCA



**Surface wetting and friction of Kalifilcon A,
a novel silicone-hydrogel contact lens**

Silvia TAVAZZI

OUTLINE

INTRODUCTION

- Is CL wear intrinsically inflammatory?
- Is CL-induced dry eye (CLIDE) more inflammatory than uncomplicated CL wear?

CLIDE ↔ In-vitro measurements on CL with WC < EWC

- Dehydration
- Wettability
- Friction

Five materials

- Omafilcon A
- Etafilcon A
- Senofilcon A
- Delefilcon A
- Kalifilcon A

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Efron, N. Contact lens wear is intrinsically inflammatory. *Clin. Exp. Optom.* 100, 3–19 (2017).

INFLAMMATION DEFINED AS:

1. pathological process provoked by actual or threat of imminent **physical, chemical, or biological injury**

Efron, N. Contact lens wear is intrinsically inflammatory. *Clin. Exp. Optom.* 100, 3–19 (2017)

INFLAMMATION DEFINED AS

1. normal pathological process provoked by actual or threat of imminent **physical, chemical, or biological injury... the CL itself**

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INFLAMMATION DEFINED AS:

1. normal pathological process provoked by actual or threat of imminent **physical, chemical, or biological injury... the CL itself**
2. characterised by **five classic signs**
 - rubor (redness)
 - calor (heat)
 - tumor (swelling)
 - dolor (pain)
 - functio laesa (loss of function)

INFLAMMATION DEFINED AS

1. normal pathological process provoked by actual or threat of imminent **physical, chemical, or biological injury.... the contact lens itself**
2. characterised by **five classic signs**
 - rubor (redness).... **limbal and conjunctival redness due to CL-induced hypoxia**
 - calor (heat)... **changes of temperature are equivocal: are they modulated by simple heat diffusion through the CL?**
 - tumor (swelling)... **corneal swelling (edema)**
 - dolor (pain)... **discomfort**
 - functio laesa (loss of function)

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 - tumor (swelling)... **corneal swelling (edema)**
 - dolor (pain)... **discomfort**
 - functio laesa (loss of function)
3. mediated by a series of **biochemical and cellular reactions** in affected blood vessels and adjacent tissues

biochemical reactions

Baleriola-Lucas C, Fukuda M, Willcox MD et al. Fibronectin concentration in tears of contact lens wearers. *Exp Eye Res* 1997; **64**: 37– 43

- soft CLs
- fibronectin, albumin and total protein in tears

level of **fibronectin** in the tears of **CL wearers** (120 ng ml⁻¹) significantly higher than in the tears of non-wearers (21 ng ml⁻¹; P < 0.01)

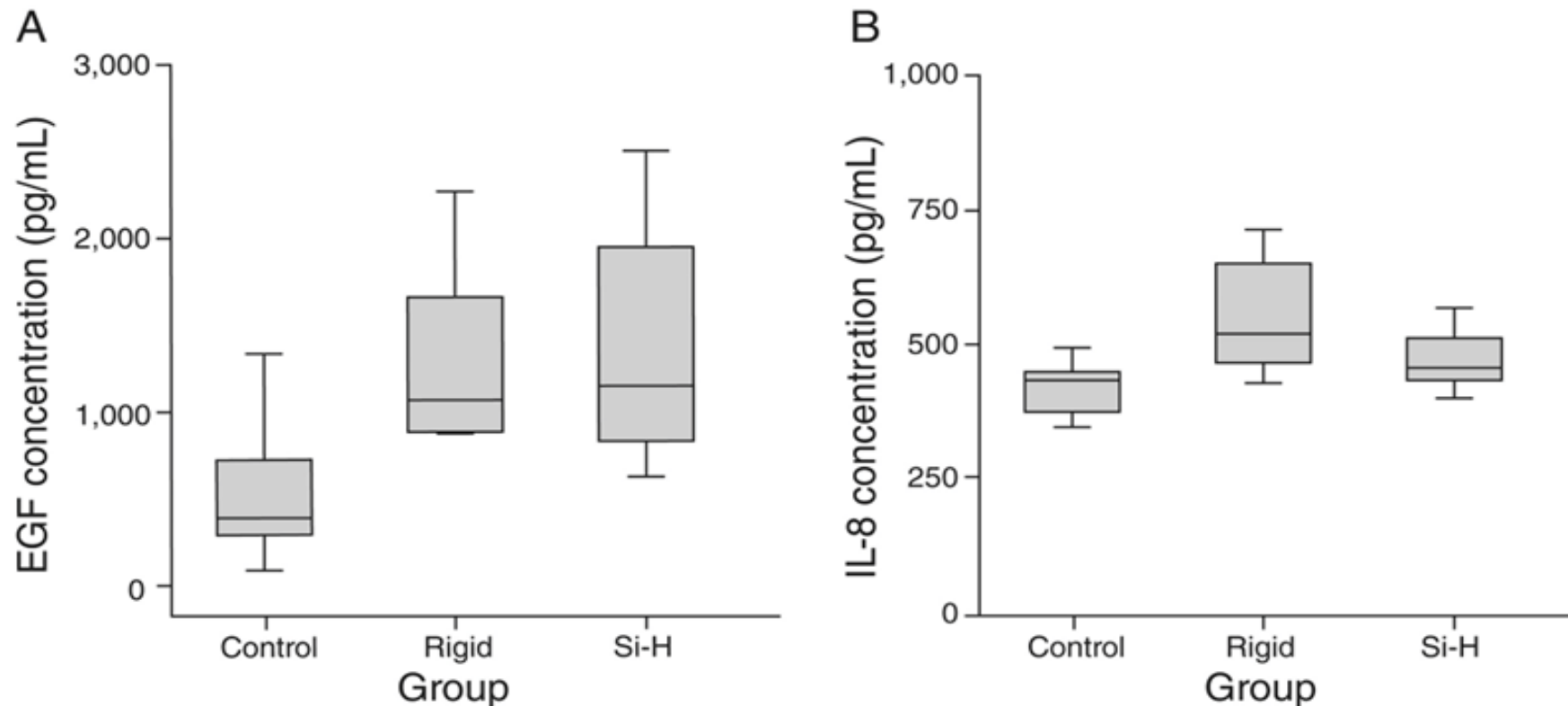
no differences in the amount of albumin or total protein

biochemical reactions

Kallinikos P, Morgan P, Efron N. Assessment of stromal keratocytes and tear film inflammatory mediators during extended wear of contact lenses. *Cornea* 2006; **25**: 1.

Up-regulation of inflammatory mediators during CL wear:

- **epidermal growth factor** concentration higher in tears of **SH CL wearers** ($p = 0.017$) and **rigid CL wearers** ($p = 0.015$) compared with control subjects
- **Interleukin-8** concentration higher in tears of **rigid CL wearers** compared with control subjects ($p = 0.012$)



biochemical reactions

Lema I, Duran JA, Ruiz C et al. Inflammatory response to contact lenses in patients with keratoconus compared with myopic subjects. *Cornea* 2008; **27**: 758– 763

- ✓ myopic CL wearers
- ✓ myopic non-wearers
- cytokines (interleukin-6 IL-6, interleukin-10 IL-10, tumor necrosis factor TNF-alpha)
- cell adhesion molecules (intercellular adhesion molecule 1 ICAM-1, and vascular cell adhesion molecule 1 VCAM-1)
- matrix metalloproteinase MMP-9

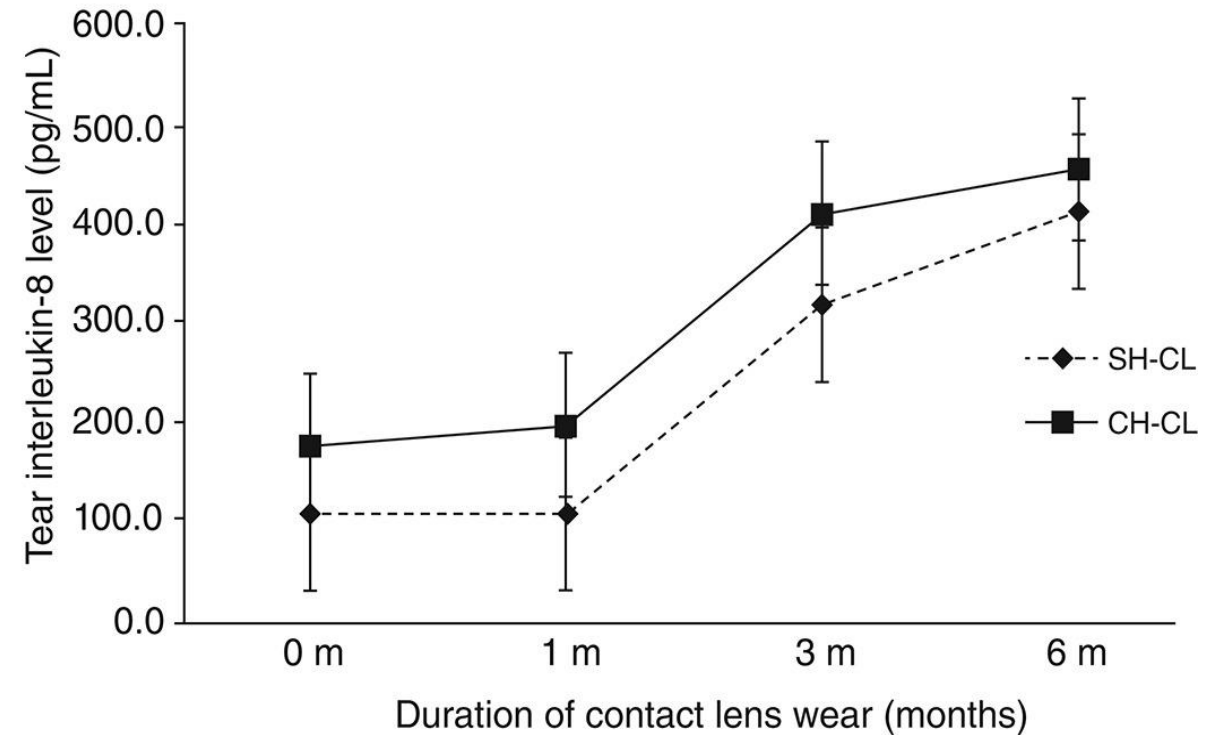
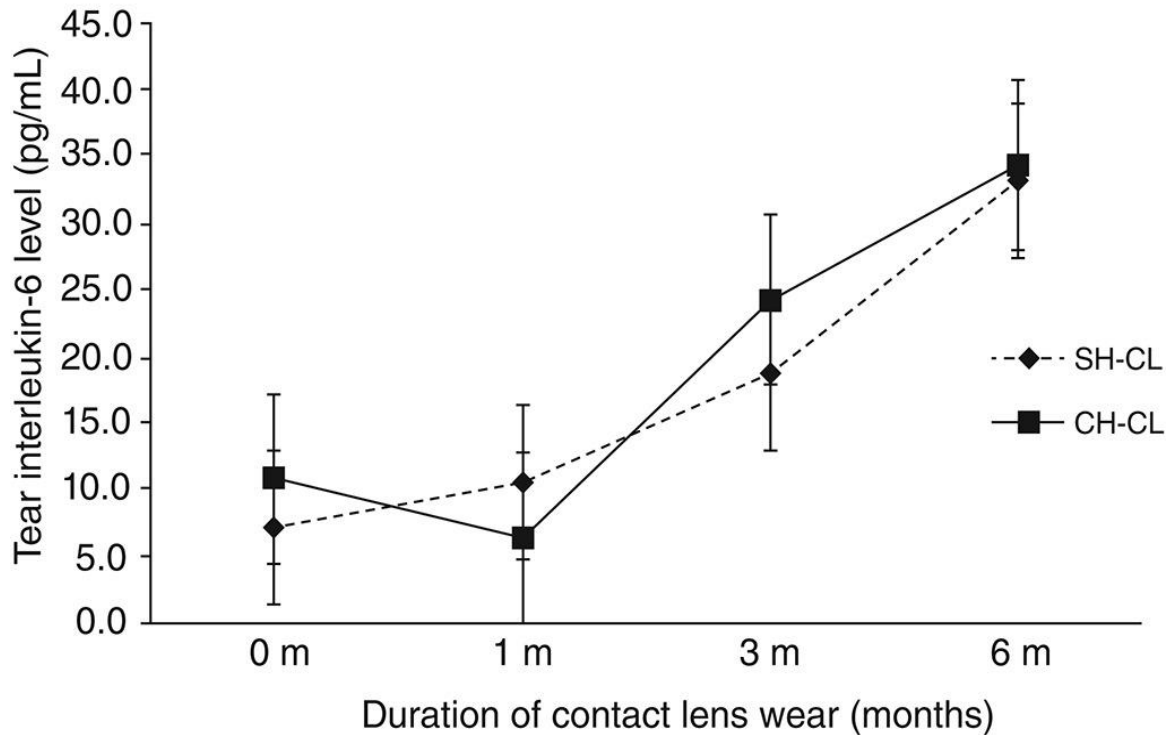
Increased levels of **tumor necrosis factor TNF-alpha** and **matrix metalloproteinase MMP-9** were associated with the wearing of **RGP CLs**.

biochemical reactions

Poyraz C, Irkeç M, Mocan MC. Elevated tear interleukin-6 and interleukin-8 levels associated with silicone hydrogel and conventional hydrogel contact lens wear. *Eye Contact Lens* 2012; **38**: 146– 149.

interleukin IL-6 and IL-8 in tears of neophyte CL users who had been commenced on either SH-CL or CH-CL

The SH-CL and CH-CL wear is associated with elevation of **IL-6 and IL-8** levels in the tears of healthy, nonatopic neophyte CL users.



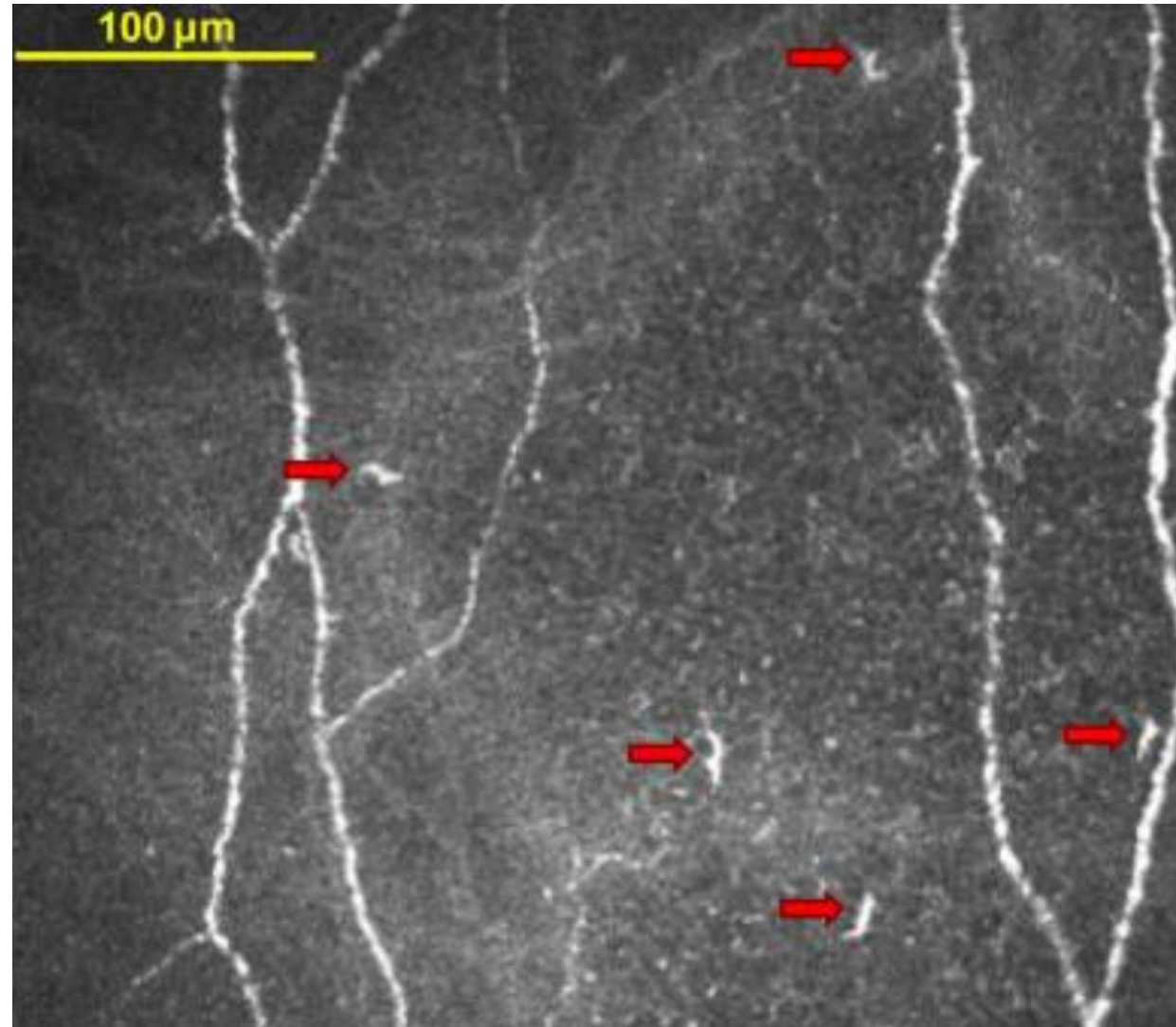
cellular reactions

In vivo confocal microscopy image of dendritic immune cells in the central cornea

[Dendritic immune cell densities in the central cornea associated with soft contact lens types and lens care solution types: a pilot study. Clin Ophthalmol 2012; 6: 511]

Central corneal dendritic immune cell densities:

- **Higher in CL wearers** (64 ± 71 cells/mm²) than **non-wearers** (29 ± 23 cells/mm²)
- **Higher with SH CLs** (69 ± 77 cells/mm²) than with **CH CLs** (47 ± 44 cells/mm²)



Efron, N. Contact lens wear is intrinsically inflammatory. *Clin. Exp. Optom.* 100, 3–19 (2017)
inflammatory cells are presumed to be **Langerhans cells** (dendritic cells)

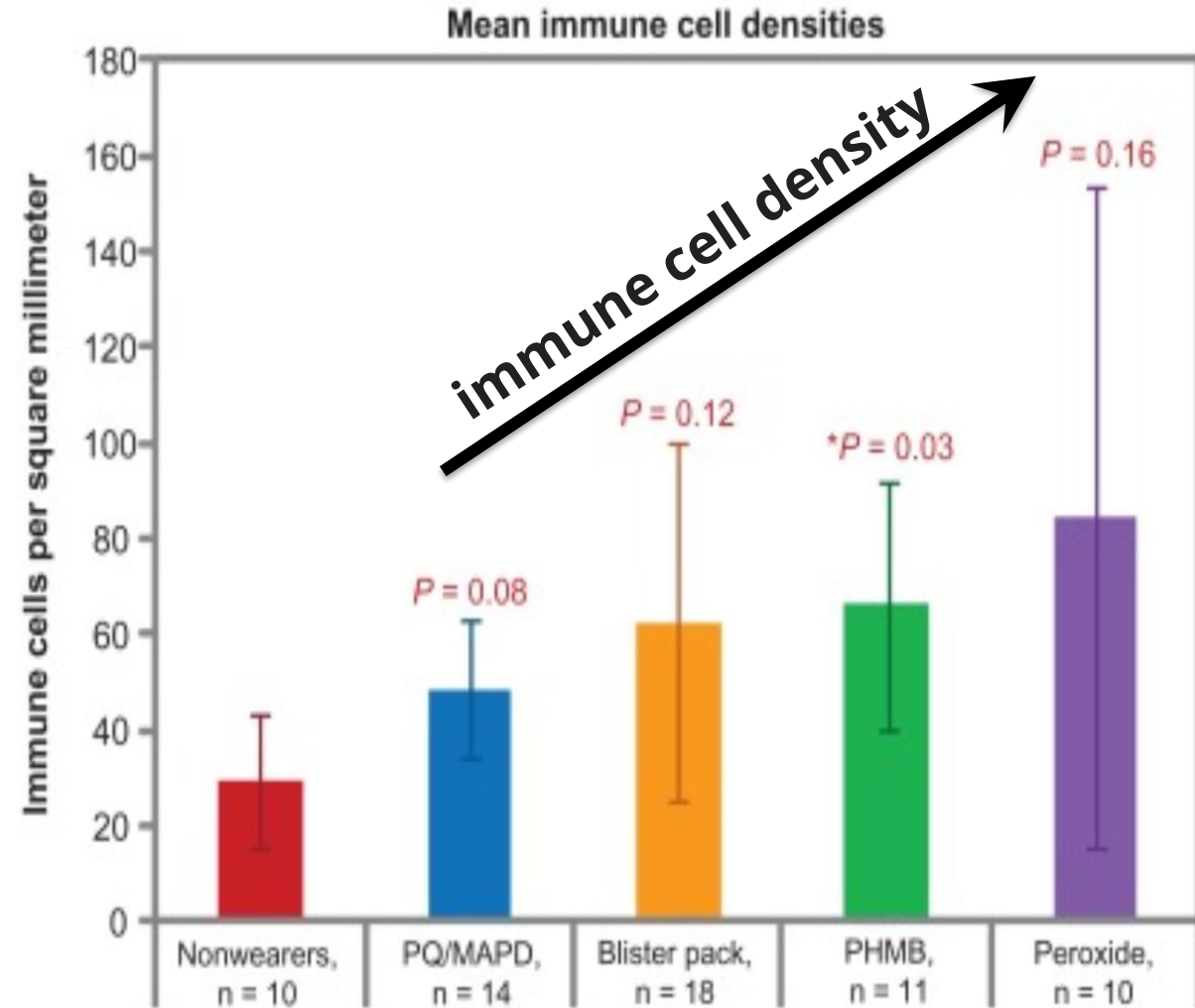
cellular reactions

Dendritic immune cell densities in the central cornea associated with soft contact lens types and lens care solution types: a pilot study. Clin Ophthalmol 2012; 6: 511-519

in vivo confocal microscopy

Different density of central corneal dendritic immune cells depending on the CL blister solution

- PQ/MAPD: polyquaternium-1 and myristamidopropyl dimethylamine
- blister pack solution (daily disposables)
- PHMB (polyhexamethylene biguanide)
- peroxide solution

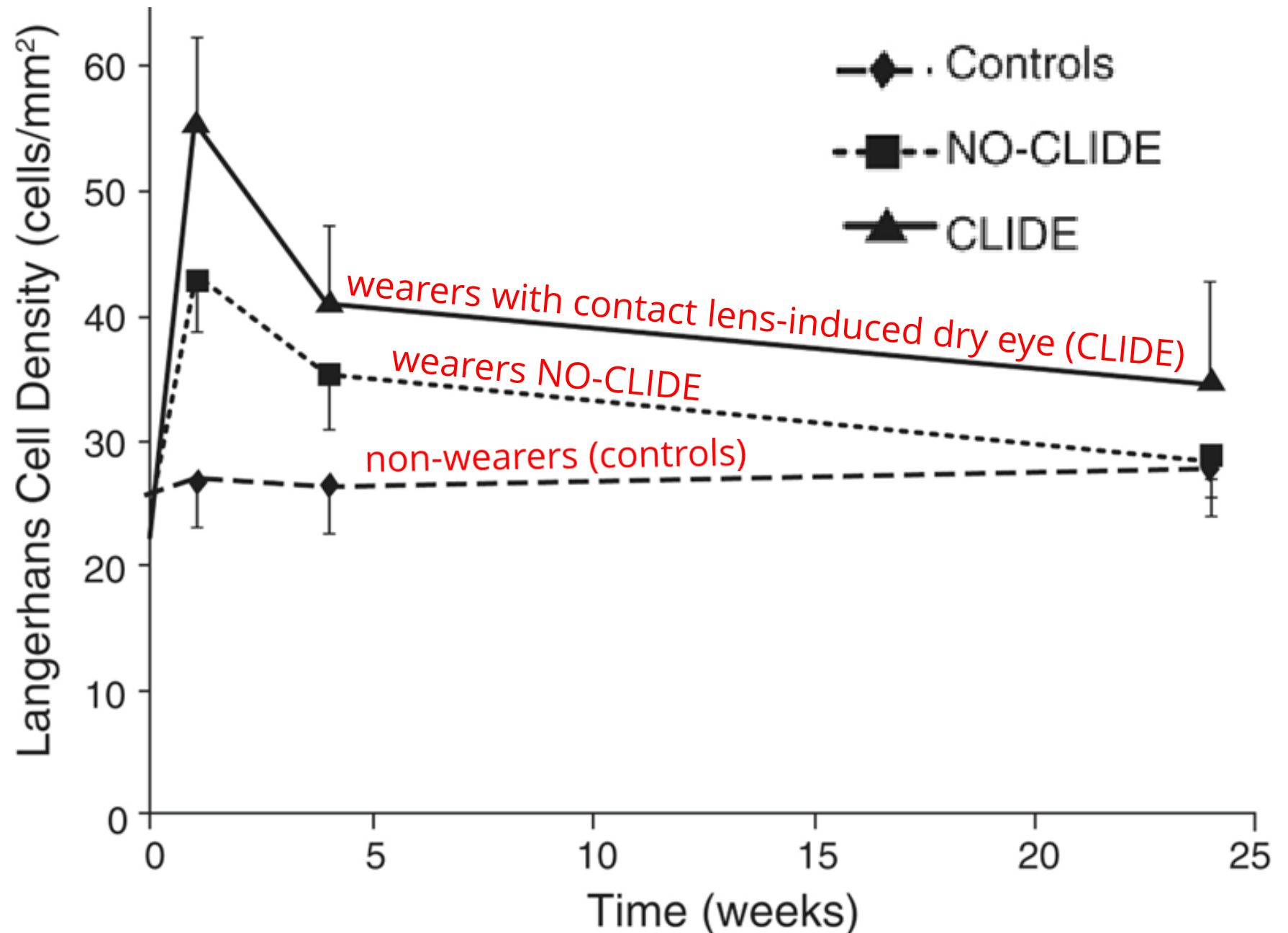


cellular reactions

Alzahrani Y, Colorado LH, Pritchard N et al. Longitudinal changes in Langerhans cell density of the cornea and conjunctiva in contact lens induced dry eye. Clin Exp Optom 2017; 100:33-40

confocal microscope

cornea of patients who had not previously worn CLs



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In this work, five different CLs were compared in vitro in a condition of reduced hydration (mimicking a 6 hour wear).

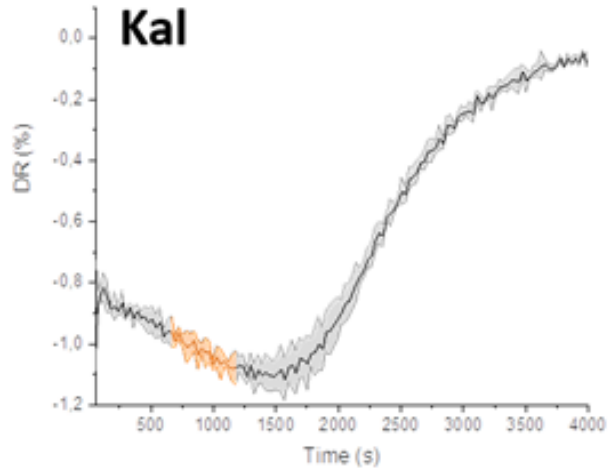
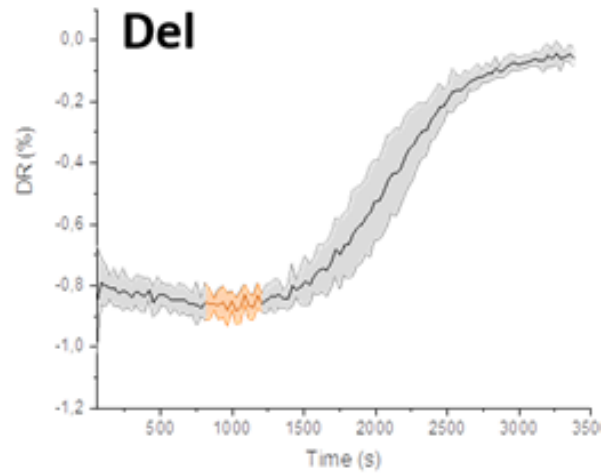
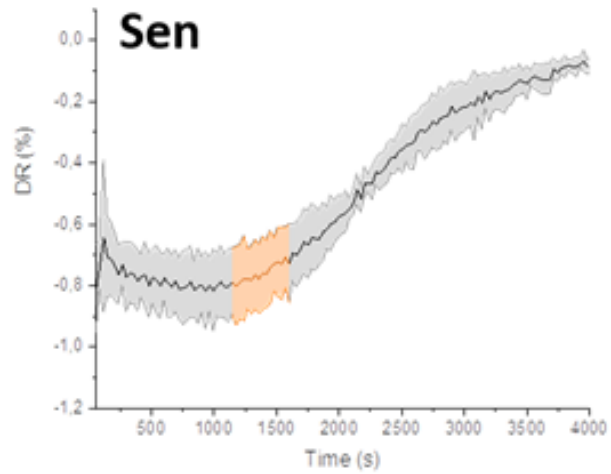
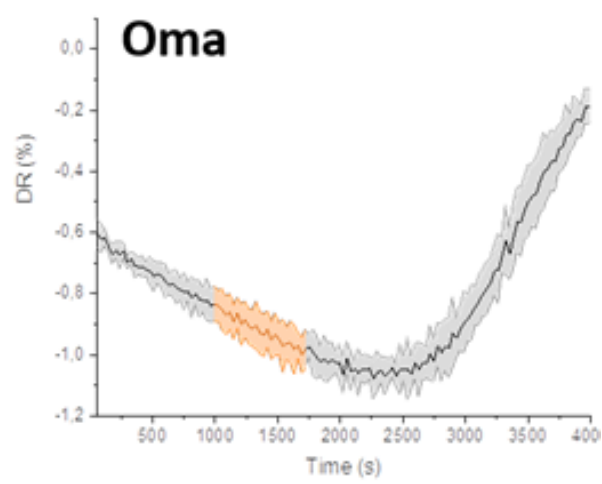
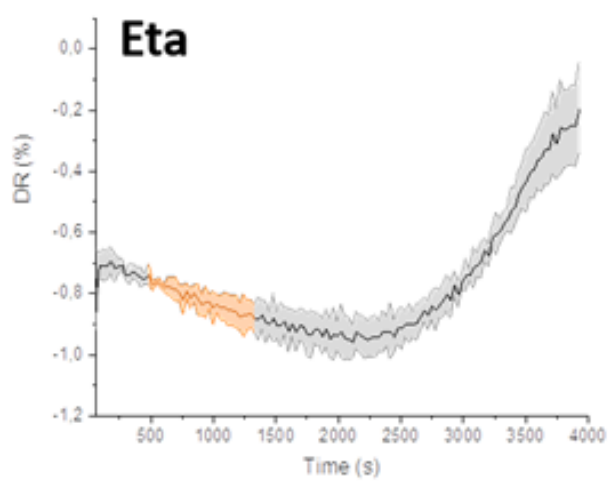
Material (FDA group)	<u>Omafilcon A</u> CH (II)	<u>Etafilcon A</u> CH (IV)	<u>Senofilcon A</u> SH (V)	<u>Delefilcon A</u> SH (V)	<u>Kalifilcon A</u> SH (V)
Brand	Proclear1 Day	1Day <u>Acuvue Moist</u>	<u>Acuvue Oasys</u>	Dailies Total1	Infuse/Ultra One Day
Manufacturer	<u>CooperVision</u>	<u>Johnson&Johnson</u>	<u>Johnson&Johnson</u>	Alcon	<u>Bausch+Lomb</u>
EWC (%)	60	58	38	33 (outer layer >80)	55
WC (%) Mean ± SD	59.2 ± 1.2	53.5 ± 0.8	35.0 ± 1.1	32.1 ± 1.5	49.1 ± 1.9
Blister solution	Buffered saline (plus surface-active agents)	Borate buffered saline with povidone	Buffered saline with methyl ether cellulose	Phosphatidylcholine in buffered saline with polymeric wetting agents	Phosphate buffered saline with potassium chloride, poloxamine, poloxamer 181, glycerin, and erythritol

Dehydration

Wettability

Friction

Dehydration



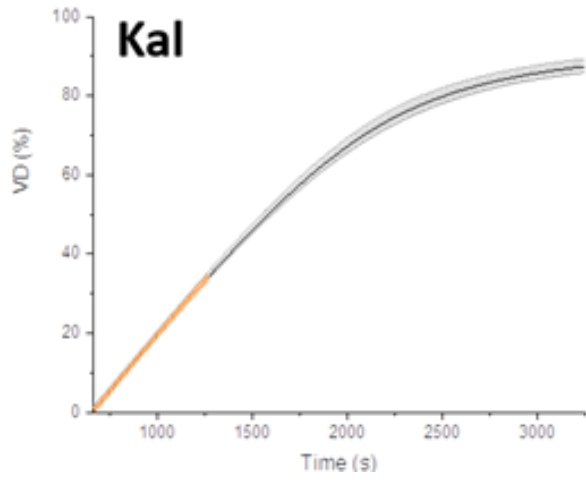
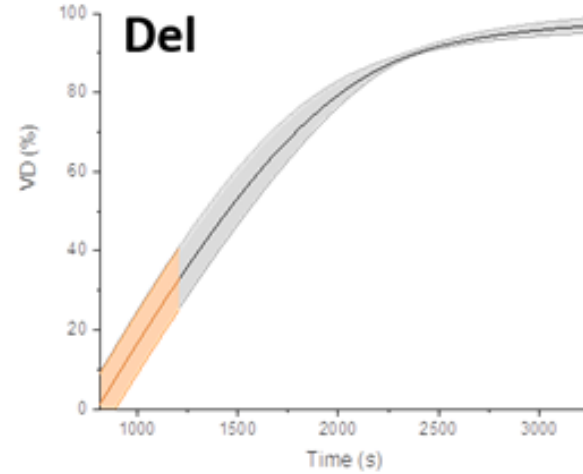
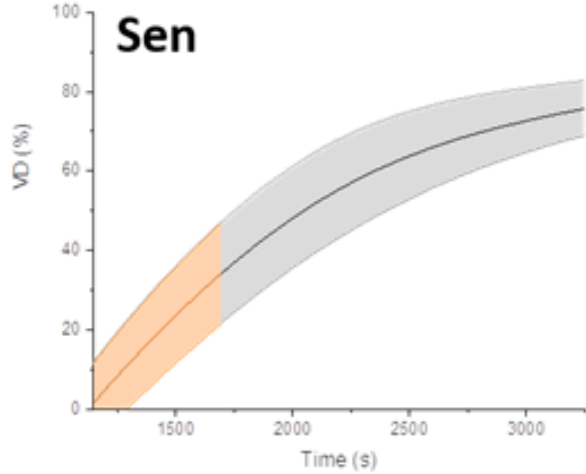
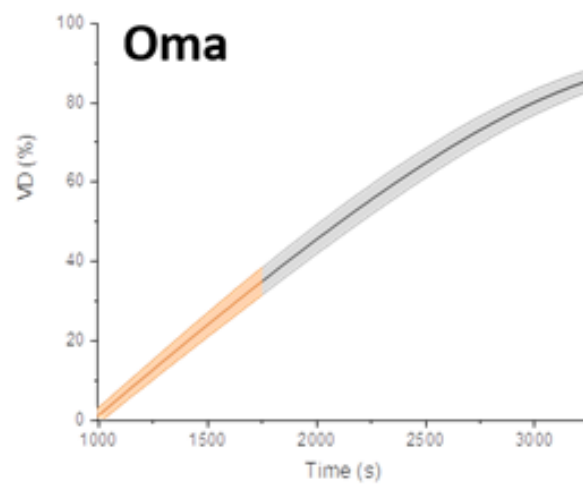
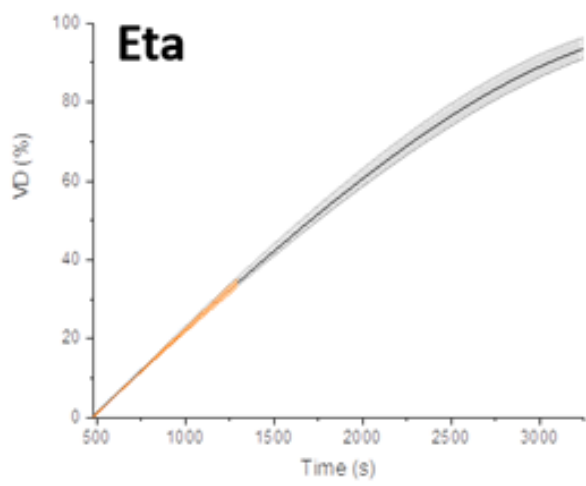
in-vitro dehydration
(gravimetric method)

controlled environmental conditions
(T=34°C, RH=60%)

dehydration rate DR =
$$\left[\frac{M_{t(n)} - M_{t(n-1)}}{M_{t(n)}} \right]$$

orange: from the EWC to 35% of water loss

(unpublished data)



in-vitro dehydration
(gravimetric method)

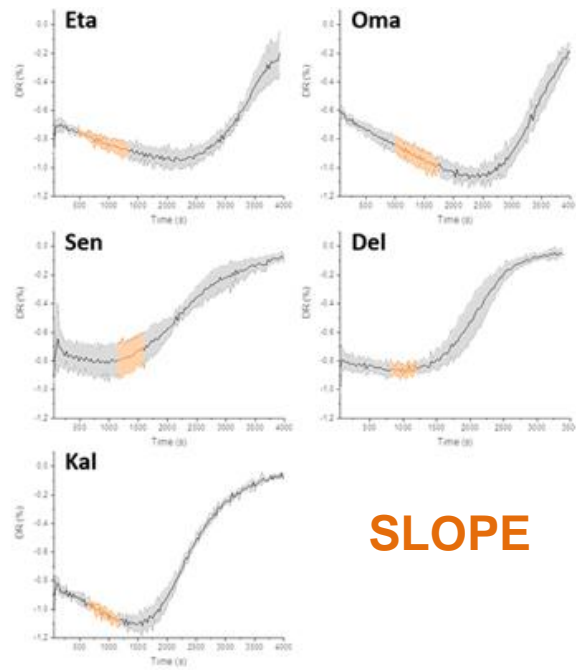
controlled environmental conditions
($T=34^{\circ}\text{C}$, $\text{RH}=60\%$)

valid dehydration $\text{VD} = \frac{m_t}{m_{\infty}} = kt^d$

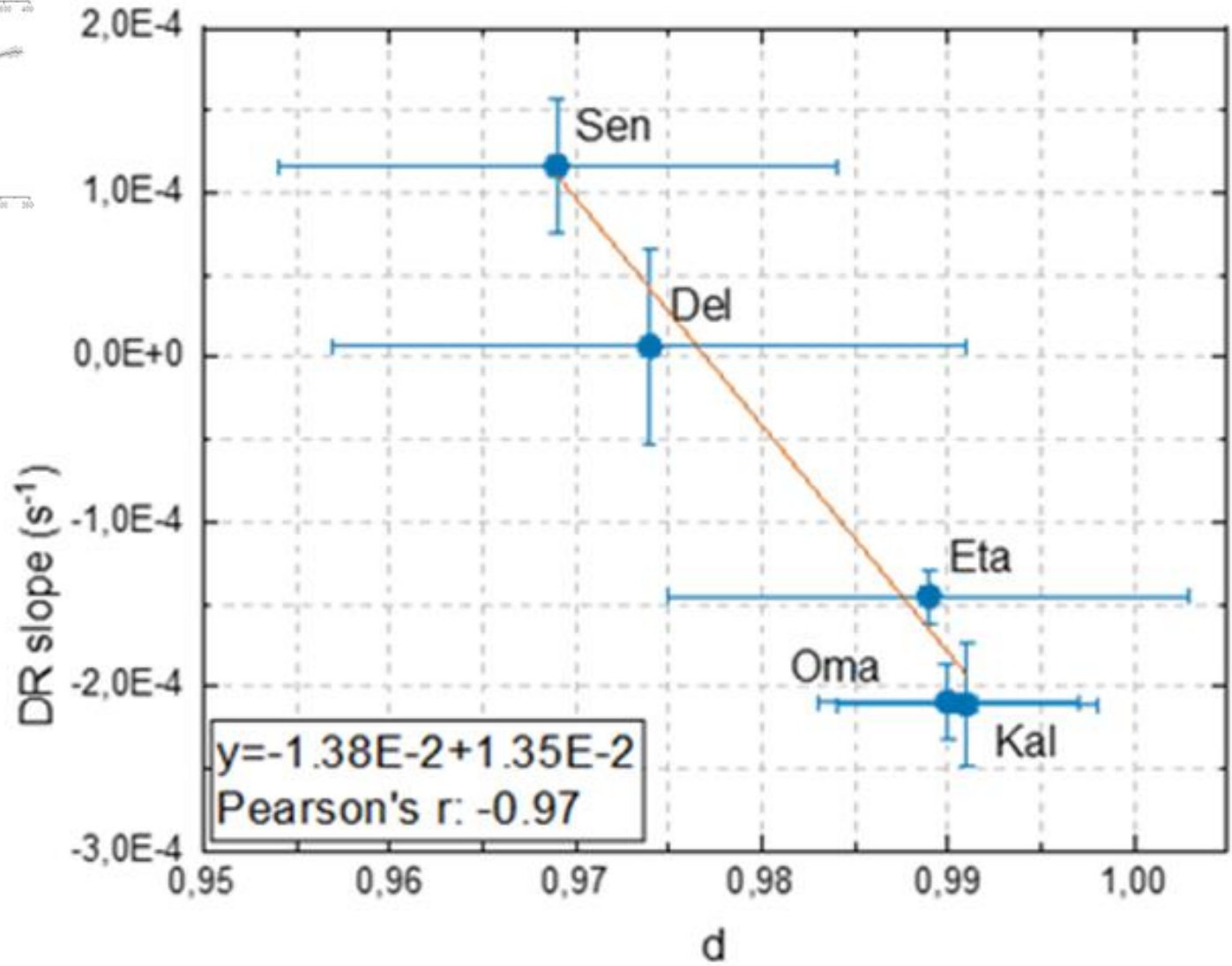
orange: from the EWC to 35% of
water loss

(unpublished data)

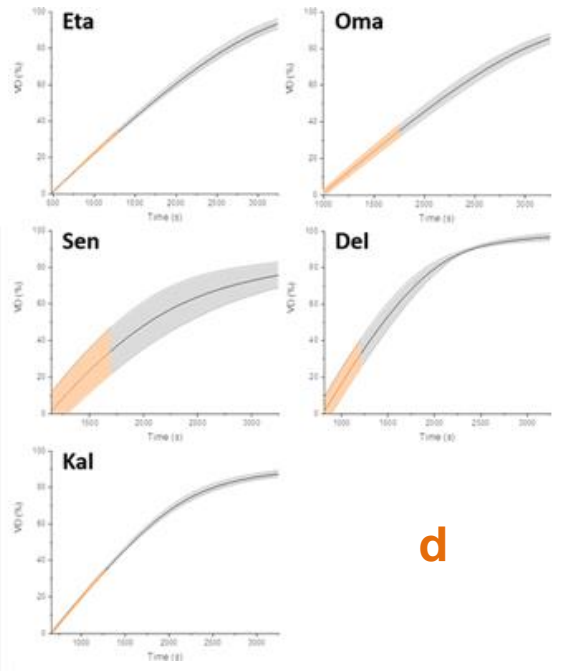
DR



SLOPE



VD



d

Oma (CH) vs

	Oma (H)	Eta (H)	Sen (SH)	Del (SH)	Kal (SH)
DR slope	-	0.70	0.01	0.02	0.52
d	-	0.48	0.0	0.05	0.42

Eta (CH) vs

	Oma (H)	Eta (H)	Sen (SH)	Del (SH)	Kal (SH)
DR slope	0.70	-	0.01	0.02	0.07
d	0.48	-	0.03	0.08	0.48

Sen (SH) vs

	Oma (H)	Eta (H)	Sen (SH)	Del (SH)	Kal (SH)
DR slope	0.01	0.01	-	0.39	0.01
d	0.00	0.03	-	0.20	0.01

Del (SH) vs

	Oma (H)	Eta (H)	Sen (SH)	Del (SH)	Kal (SH)
DR slope	0.02	0.02	0.39	-	0.01
d	0.05	0.08	0.20	-	0.04

Kal (SH) vs

	Oma (H)	Eta (H)	Sen (SH)	Del (SH)	Kal (SH)
DR slope	0.52	0.07	0.01	0.01	-
d	0.42	0.48	0.01	0.04	-

Comparison between different materials:
P-values (Mann-Whitney U test)

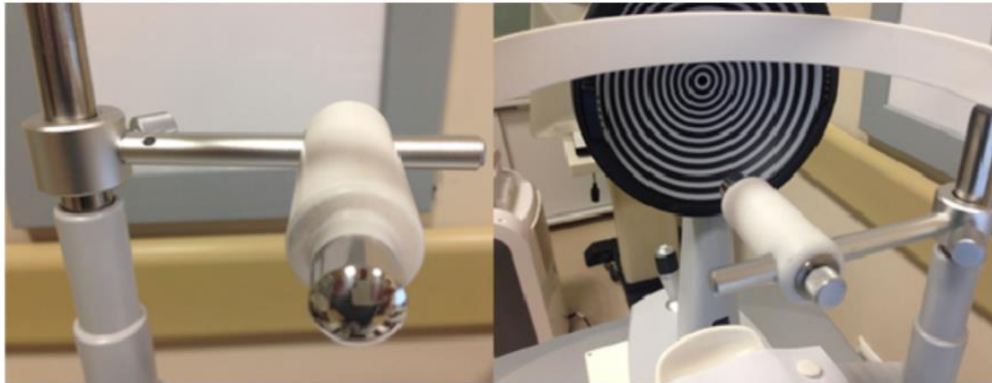
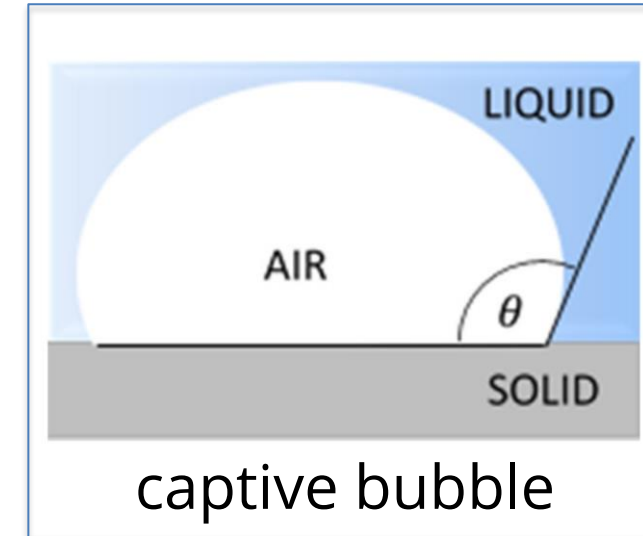
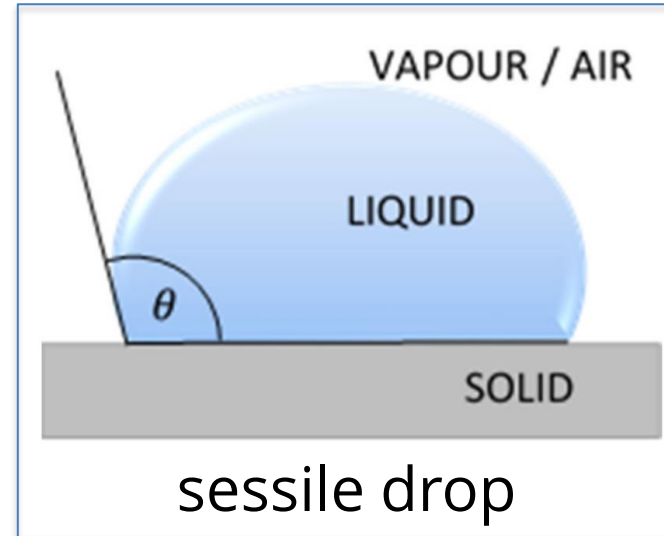
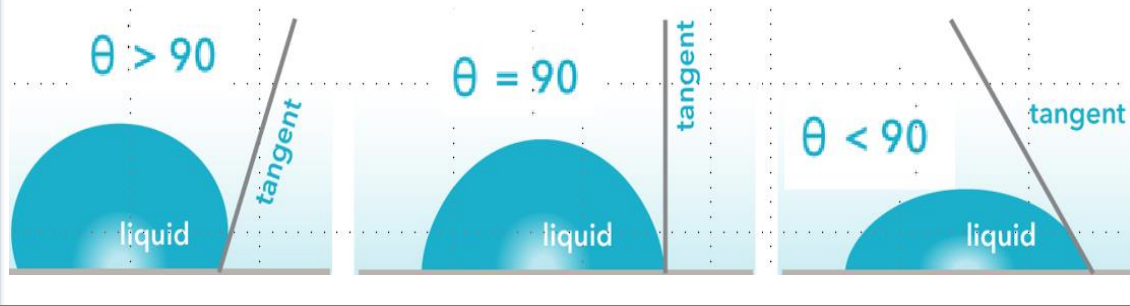
threshold of statistical significance 0.05

Wettability

In-vitro wettability measurements

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

Higher CAs correspond to lower wettability, and vice versa.



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

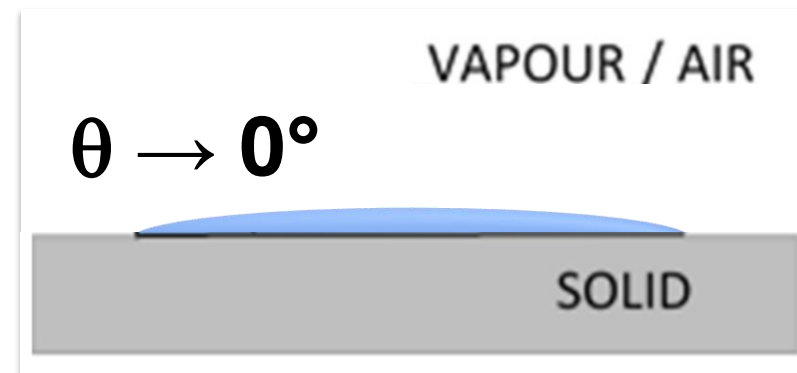
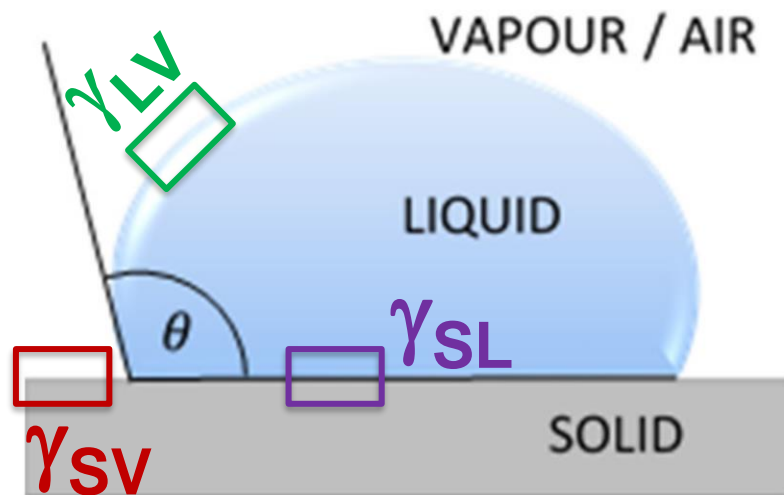
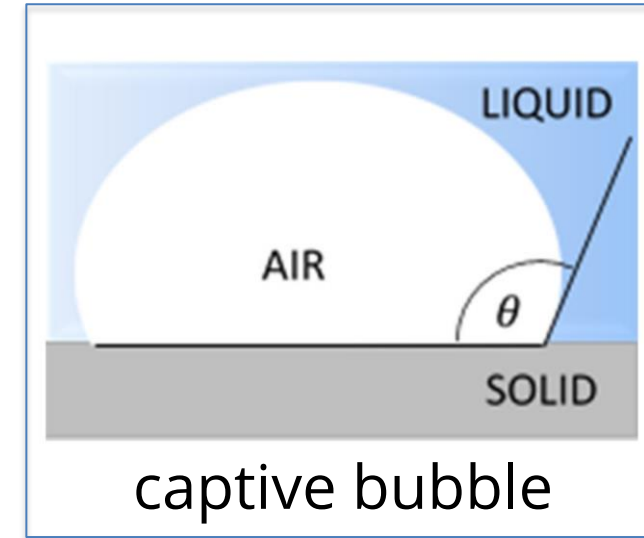
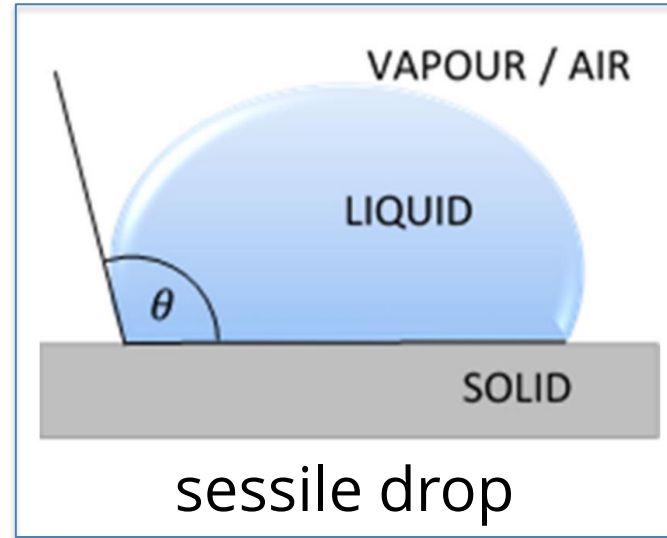
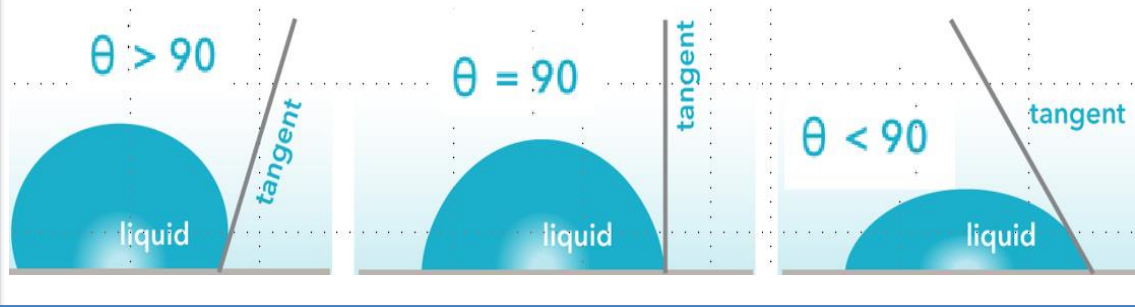
Fig. 1. Artificial cornea model (A) Teflon-chrome material, (B) Setting up on keratoscope.

In-vitro wettability measurements using techniques similar to in-vivo methods

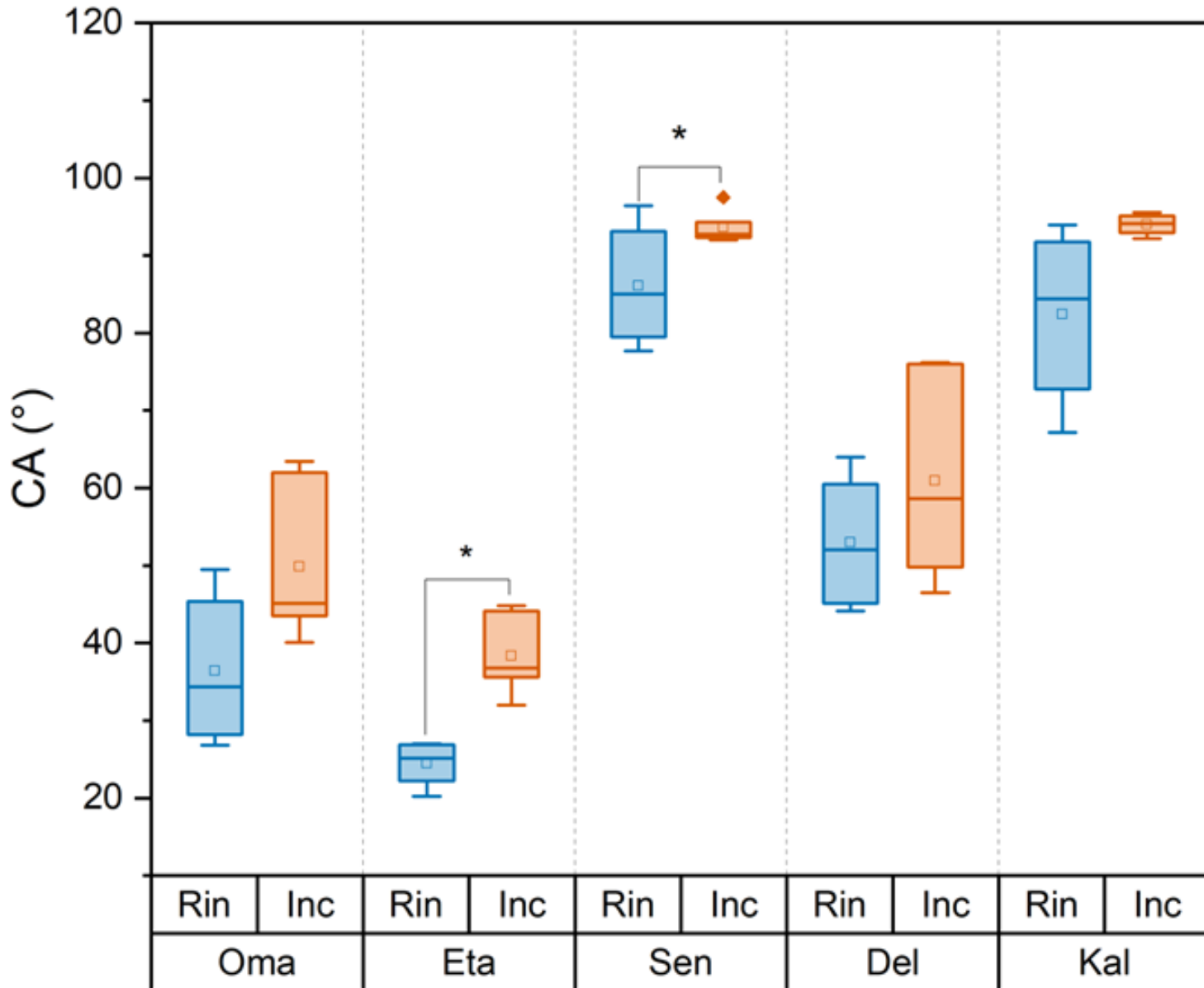
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25%~75%
 Range within 1.5IQR
 Median Line
 Mean
 Outliers



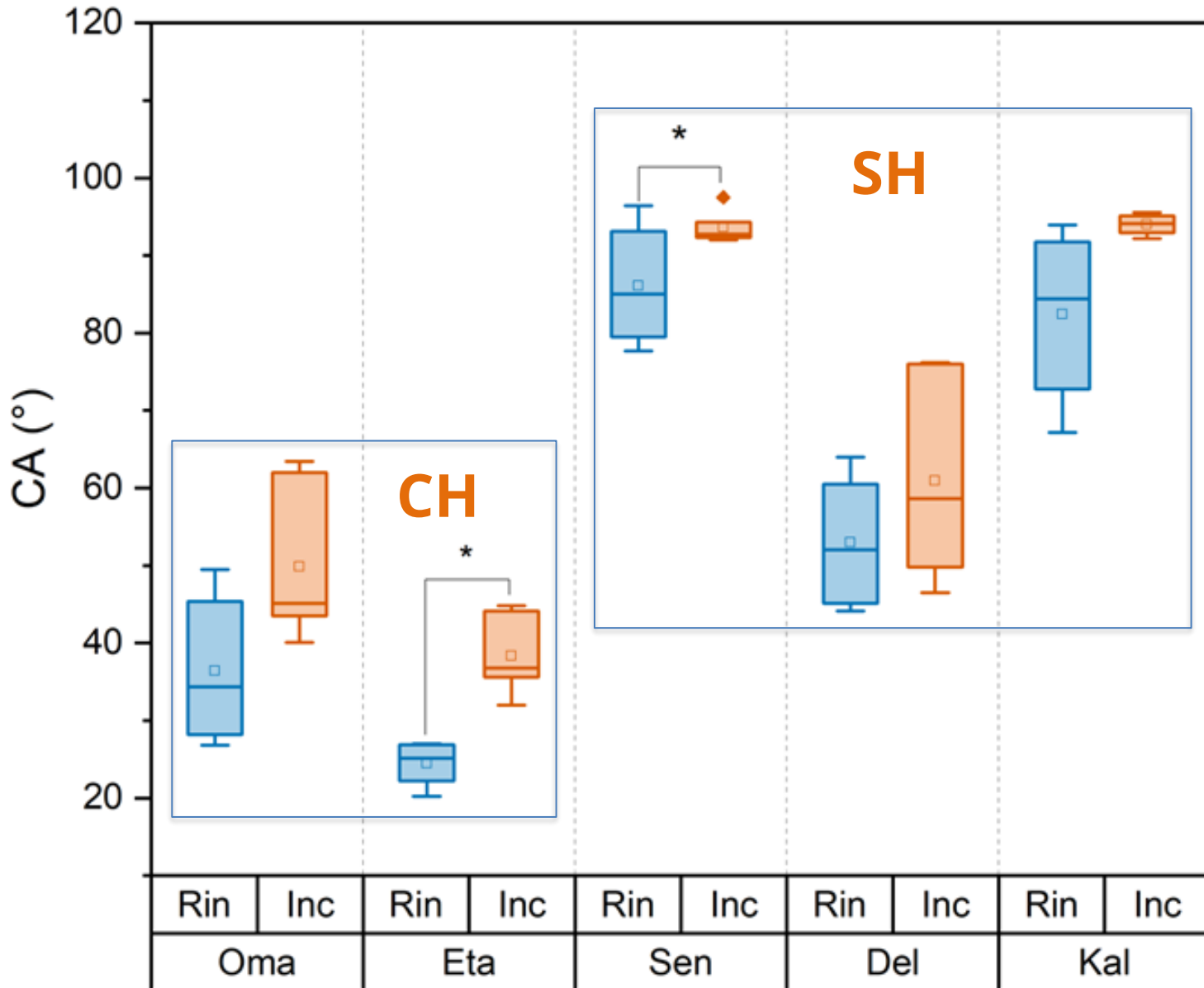
brief rinse ("Rin", blue boxes) in saline solution

24-hour incubation ("Inc", orange boxes) in saline solution

Measurements carried out in the condition of **hydration corresponding to WC.**

(unpublished data)

25%~75%
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 Median Line
 Mean
 Outliers



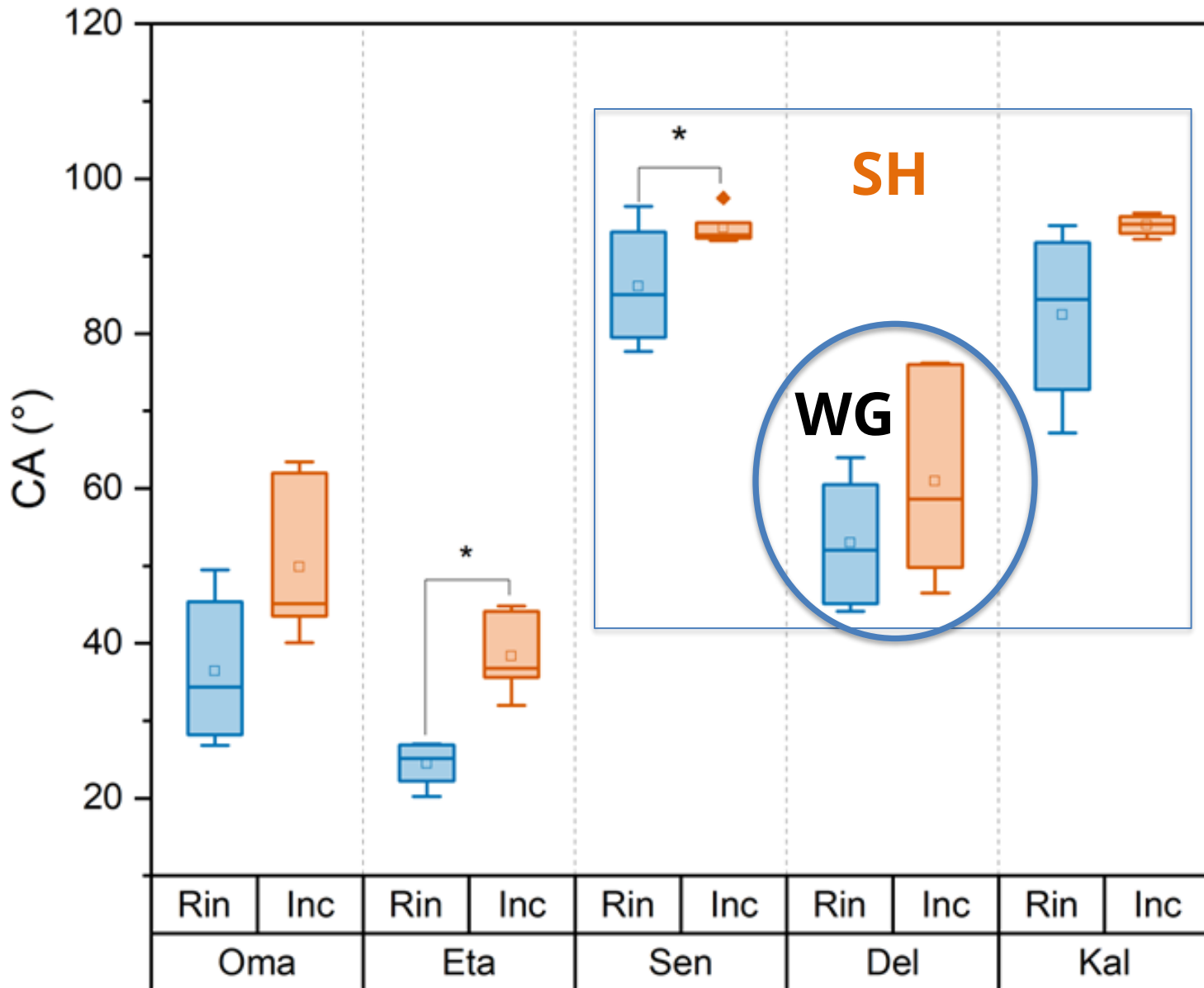
brief rinse ("Rin", blue boxes) in saline solution

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Measurements carried out in the condition of **hydration corresponding to WC**

The wettability of Kalifilcon A is mainly influenced by its SH composition.

25%~75%
 Range within 1.5IQR
 — Median Line
 ◻ Mean
 ◆ Outliers



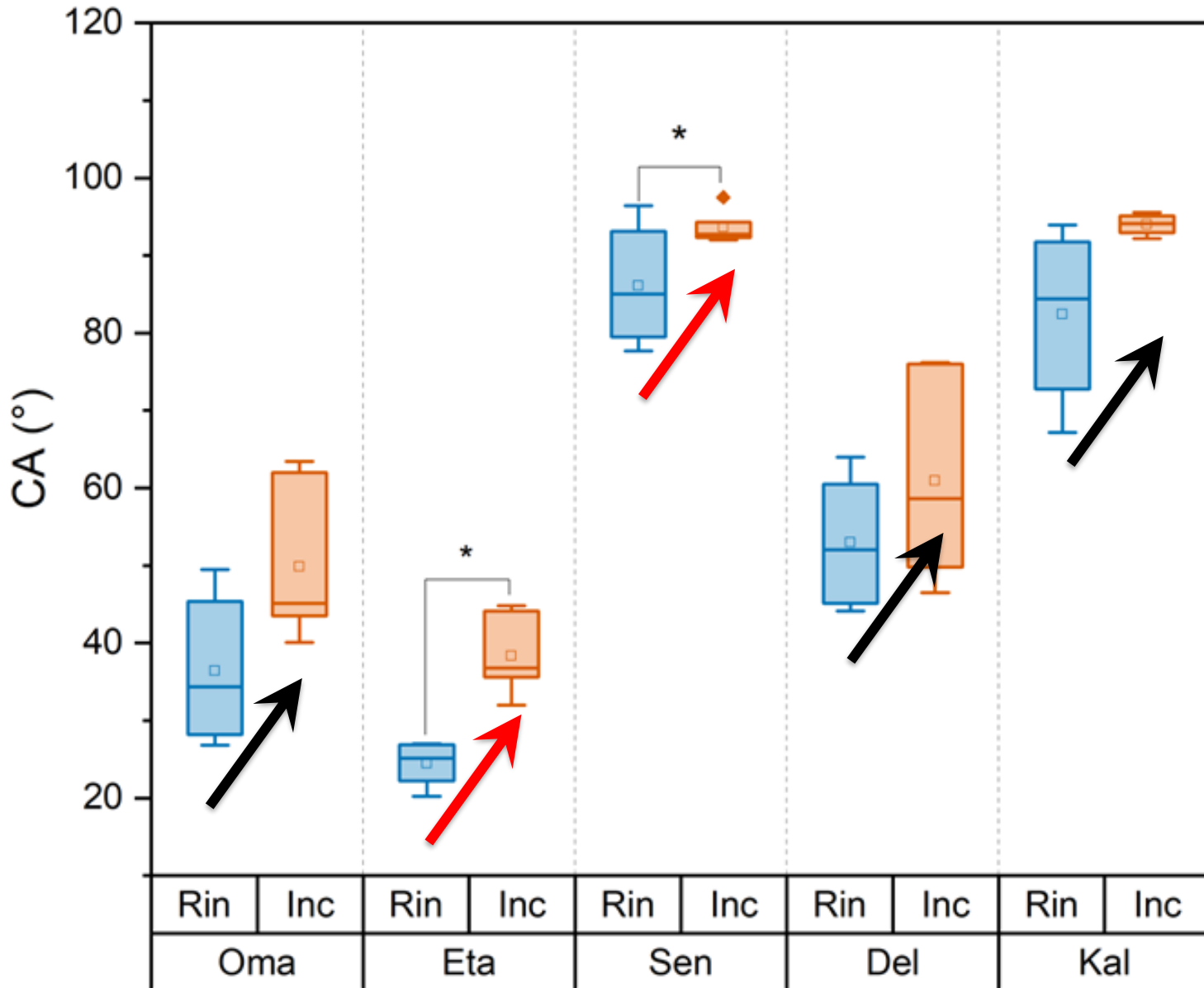
brief rinse (“Rin”, blue boxes) in saline solution

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Measurements carried out in the condition of **hydration corresponding to WC**

Although its high-hydration (>80%) outer layer, Delefilcon A SH CLs showed an intermediate surface wettability between SHs and Hs.

25%~75%
 Range within 1.5IQR
 Median Line
 Mean
 Outliers

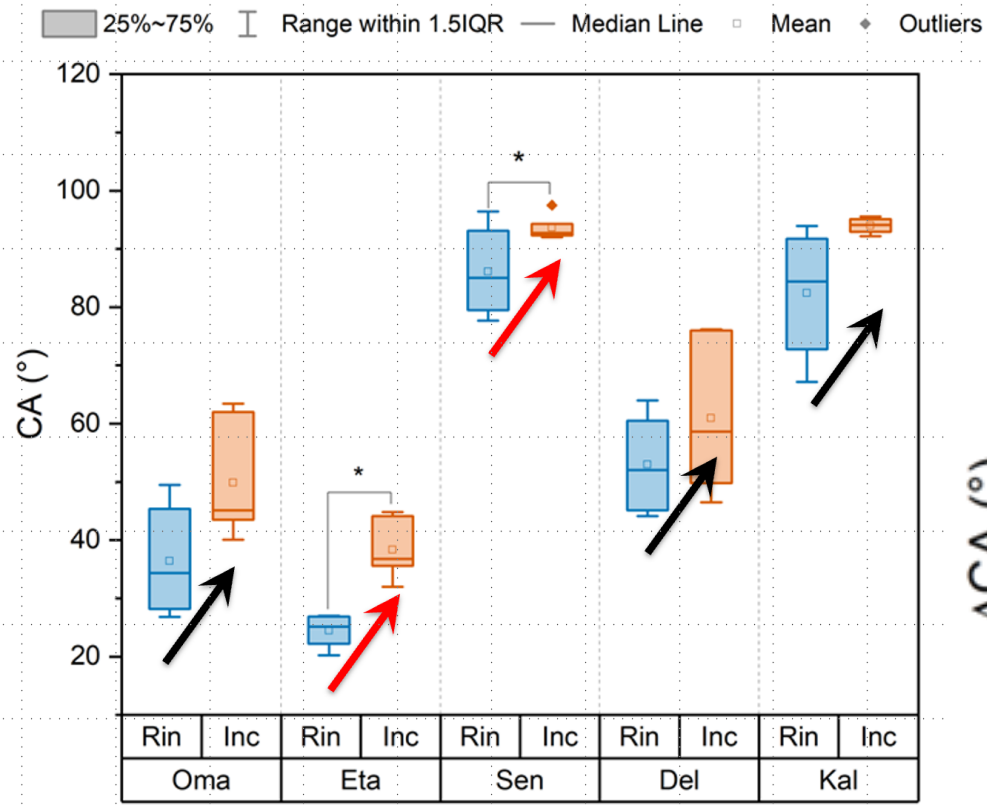


brief rinse ("Rin", blue boxes) in saline solution

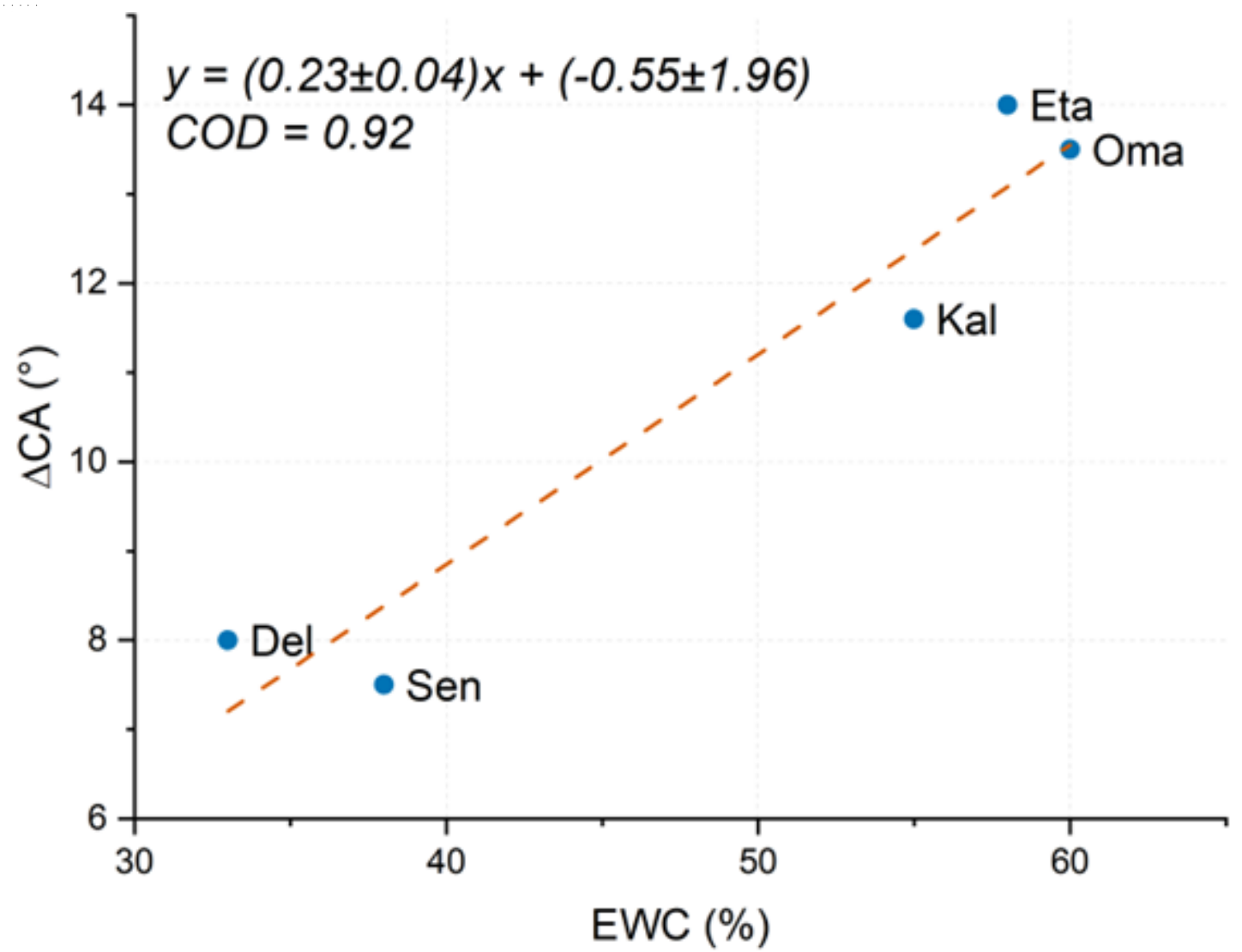
24-hour incubation ("Inc", orange boxes) in saline solution

Measurements carried out in the condition of **hydration corresponding to WC**

Wettability worsening after incubation

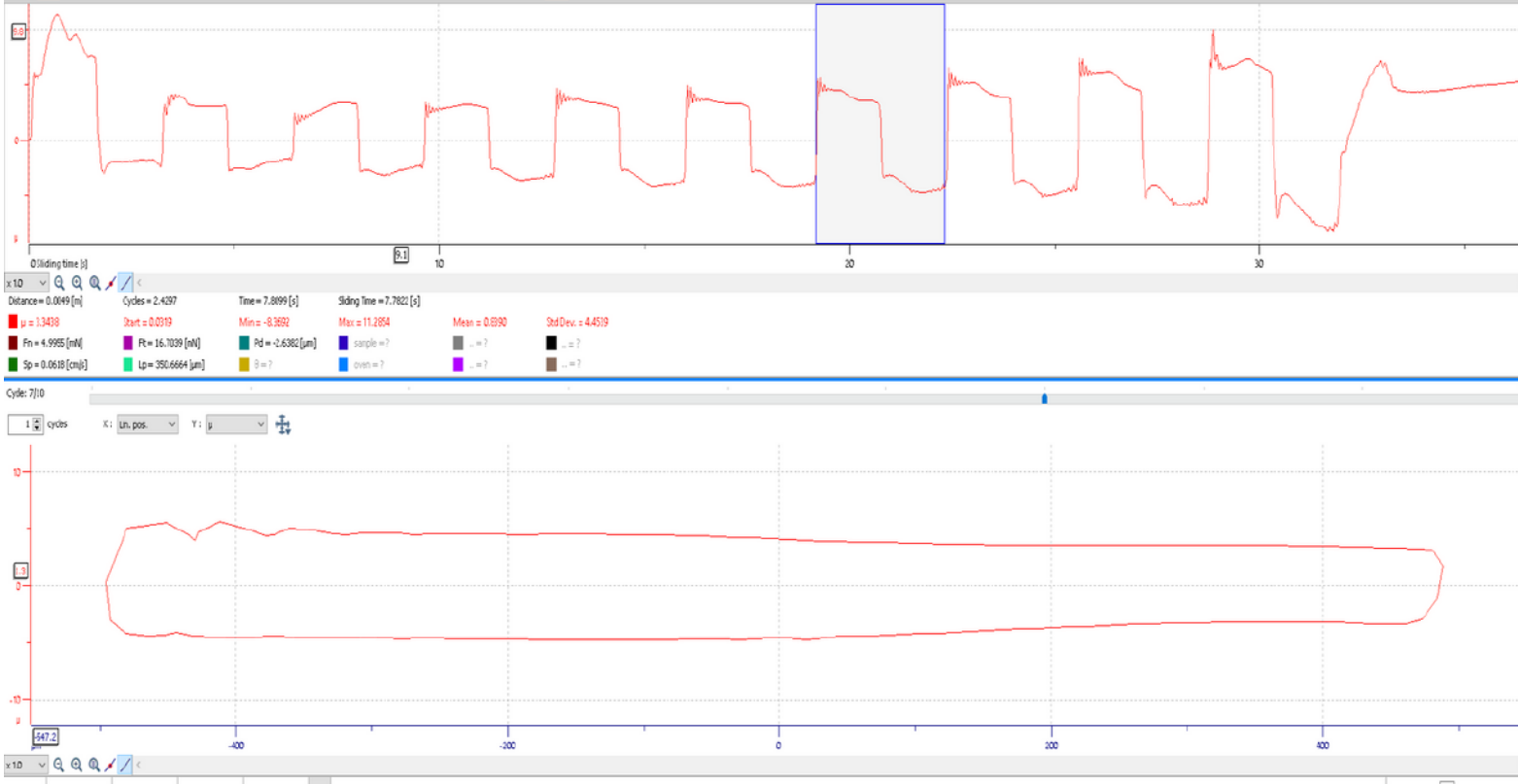
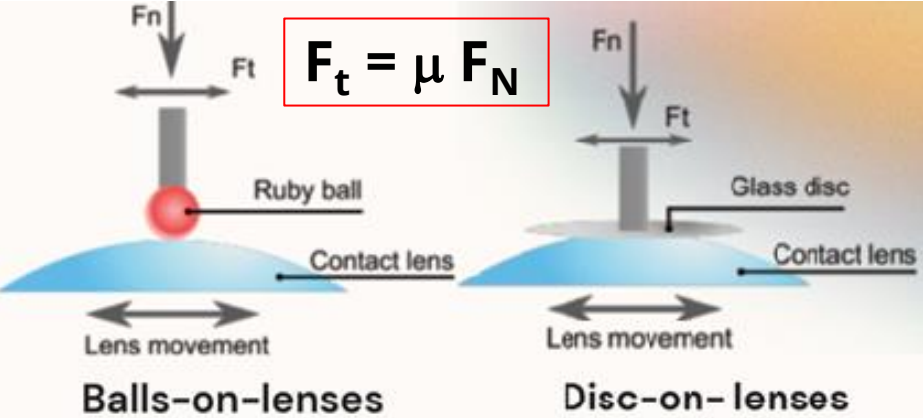


The worsening of wettability depends on the EWC.

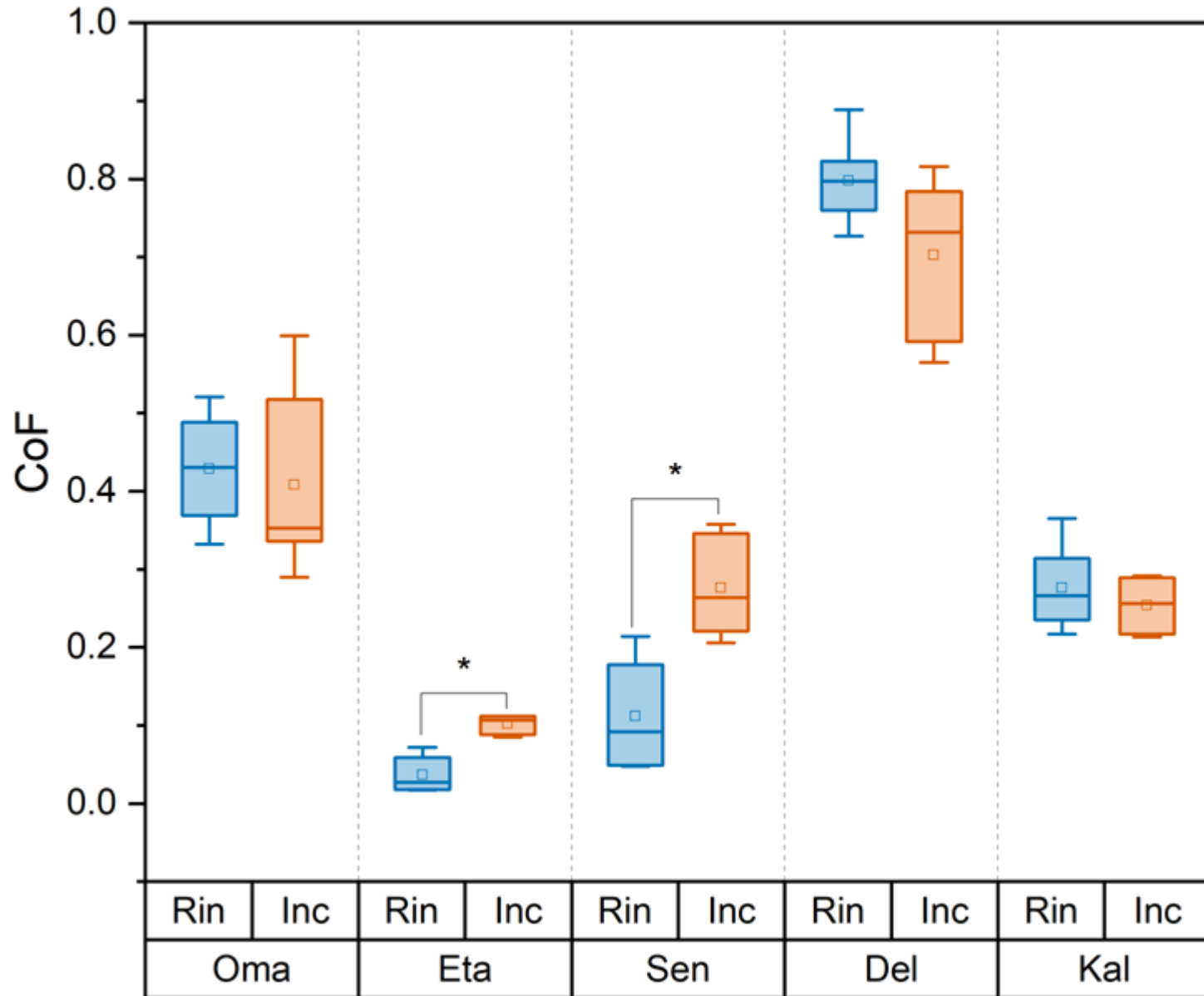


Friction

Friction is the force that opposes the relative motion of two components sliding against each other. The coefficient of friction (CoF) is the ratio of the frictional force (i.e., the force resisting relative motion) to the normal force (i.e., the net force pressing the two surfaces together).



25%~75%
 Range within 1.5IQR
 Median Line
 Mean
 Outliers



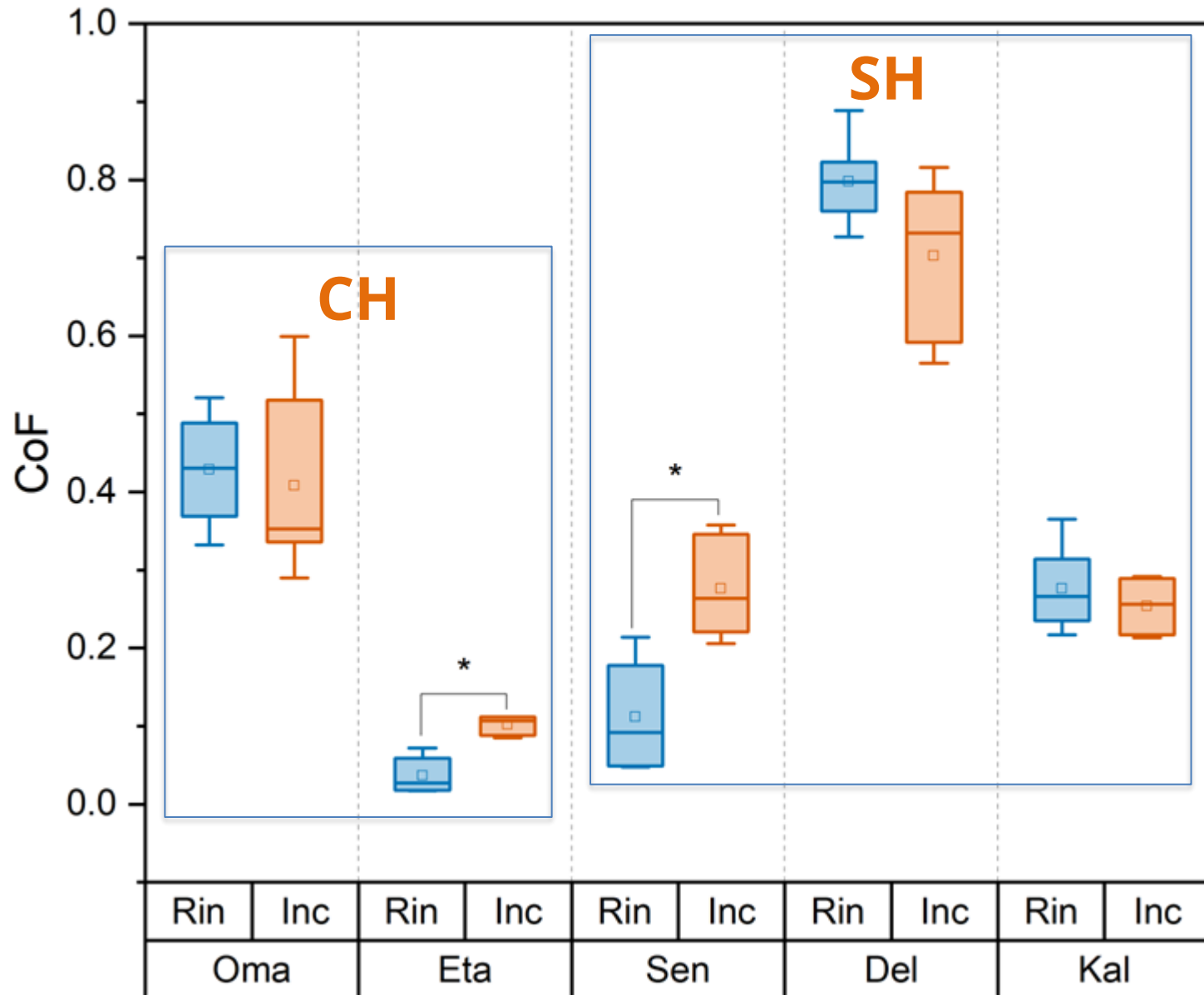
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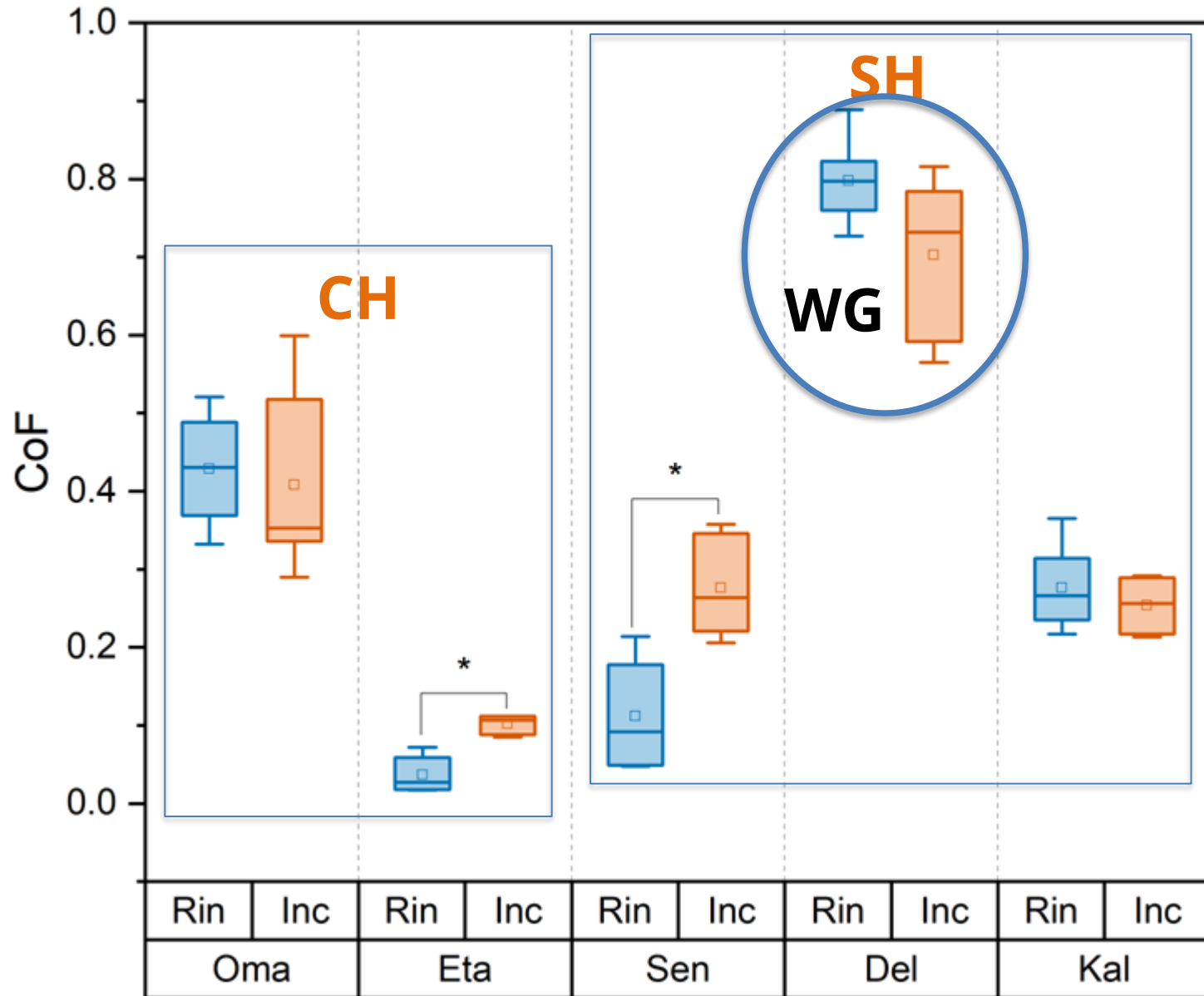
brief rinse ("Rin", blue boxes) in saline solution

24-hour incubation ("Inc", orange boxes) in saline solution

Measurements carried out in the condition of **hydration** corresponding to **WC**

NO clear difference between SH and CH and between rinsed and incubated CLs

25%~75%
 Range within 1.5IQR
 Median Line
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 Outliers



brief rinse ("Rin", blue boxes) in saline solution

24-hour incubation ("Inc", orange boxes) in saline solution

Measurements carried out in the condition of **hydration corresponding to WC**

Delefilcon A: relatively high CoF. A partial collapse of the outer layer probably needs to be taken into account due to the relatively high normal force and due to the CL hydration conditions of this work

CONCLUSIONS

DEHYDRATION:

- **DR slope** and **dehydration kinetics coefficient d** are correlated and describe the water diffusion during dehydration.
- The two Hs (Eta and Oma) showed a similar behavior, but different from Sen and Del (both SHs). Kal is a SH, **but it displayed a H-like dehydration kinetics.**

WETTABILITY:

- Wettability was found to be **better for the Hs** (Oma and Eta) compared to the three SHs (Sen, Del, kal).
- Wettability was **worse after incubation** than after a brief rinse.
- Although its very high-hydration (>80%) outer layer, **Del SH CLs showed an intermediate surface wettability** between SHs and Hs. A partial collapse of the outer layer probably needs to be taken into account due to the CL hydration conditions of this work.

FRICTION:

- **No clear differences** between SH and H and between rinsed and incubated CLs was found (Kal displays an intermediate behaviour among the investigated materials).
- **Relatively high CoF of Del:** a partial collapse of the outer layer probably needs to be taken into account due to the relatively high normal force and due to the hydration conditions of this work.

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DEHYDRATION:

- **DR slope** and **dehydration kinetics coefficient d** are correlated and describe the water diffusion during dehydration.
- The two CHs (Eta and Oma) showed a similar behavior, but different from Sen and Del (both SHs). Kal is a SH, **but it displayed a CH-like dehydration kinetics.**

WETTABILITY:

- Wettability was found to be **better for the CHs** (Oma and Eta) compared to the three SHs (Sen, Del, kal).
- Wettability was **worse after incubation** than after a brief rinse.
- **Although its very high-hydration (>80%) outer layer, Del SH CLs showed an intermediate surface wettability** between SHs and CHs. A partial collapse of the outer layer probably needs to be taken into account due to the CL hydration conditions of this work.

FRICITION:

- **No clear differences** between SH and CH and between rinsed and incubated CLs was found (Kal displays an intermediate behaviour among the investigated materials).
- **Relatively high CoF of Del:** a partial collapse of the outer layer probably needs to be taken into account due to the relatively high normal force and due to the hydration conditions of this work.

CONCLUSIONS

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Kalifilcon A

2-methacryloyloxyethyl phosphorylcholine (MPC), siloxane copolymer mainly composed of:

- 2-hydroxyethyl methacrylate (HEMA)
- N-vinylpyrrolidone (NVP)

Water content at equilibrium: 55%

Blister solution:

- Buffered saline solution with phosphate and potassium chloride
- Poloxamine 1107
- Poloxamer 181
- Glycerol and erythritol