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Published in:
Clinical and Experimental Optometry

DOI:
10.1111/cxo.12518

Publication date:
2017

Document Version
Peer reviewed version

Care Solution Effects on Contact Lens *in-vivo* Wettability

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Number of figures: **9**

Number of tables: **4**

Key word: contact lens, wettability, interferometry, care solutions, in-vivo

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Background

The aim of study was to evaluate the effect of care solutions on contact lens (CL) *in-vivo* wettability using Doane's interferometer technique.

Methods

13 subjects (age 26.6 ± 6.3 years) were participated for CL wettability evaluation after soaking in five care solutions namely *Opti-Free EverMoist (now called puremoist), Opti-Free Express (Alcon), COMPLETE (AMO), ReNu and Biotrue (Bausch & Lomb)*. A new pair of lenses were soaked in the solutions for 8 hours (prior to wear) or taken directly from pack solutions (as control) and worn by the subjects. The total number of lenses tested was 13 x 6 = 78 lenses (13 pairs of lenses wetted in 5 care solutions + pack solution).

Doane's interferometer used to capture images of the pre-lens film on a single type of contact lens, ACUVUE OASYS (Johnson & Johnson). The lens *in-vivo* wettability was evaluated after 15 min and 8 hours of worn by each subject. 4 parameters: onset latency (OL), drying duration (DD), maximum speed (MS) and peak latency (PL) were used to assess the lens wettability.

Results

After 8 hours the solutions showed significant reduction in contact lens wettability were as the following; for OL: *Pack solution, Biotrue Opti-Free EverMoist* and *Express,* for DD: *Pack solution, ReNu and Opti-Free EverMoist*. For PL; *pack solution, Biotrue and Opti-Free EverMoist*. Regarding the MS, lenses soaked in *Pack solution*, *ReNu* and *Opti-Free EverMoist* showed a significant increase (worsening). The comparative study showed that there was significant difference among the performance of the care solutions.

Conclusion

This novel thin film interferometry technique was able to measure, objectively, contact lens *in-vivo* wettability following the use of care solutions. *COMPLETE* was the only solution that showed no significant change in the lens wettability (with the all parameters) between the initial and the end of day.

Contact lenses have seen many rapid developments over the last 15 years. These developments include the invention of silicone hydrogel contact lenses.(1) Silicone hydrogel materials have grown to dominate the contact lens market and have become widely used in the USA and Europe.(2)

The major advantage of silicone hydrogel materials over traditional hydrogels is their much improved oxygen permeability, which results in reduced corneal hypoxia.(3) However, the challenge of producing a wettable material is greatly increased with silicone hydrogel lenses, as the silicone component is highly hydrophobic.(4)

In 1977 Holly and Lemp stated that the two most important characteristics of contact lenses are oxygen permeability and surface wettability.(5) The wettability of a contact lens is thought to have an impact on in-eye comfort, due to its effect on tear film, ocular surface and lid to lens interactions.(6) Consequently, many contact lens manufacturers attempt to improve lens comfort by enhancing the lens wettability.(7-11) Inadequate contact lens wettability may affect the interaction between the tear film and the lens material. A material with good wetting characteristics will tend to support a stable pre-lens tear film. This, in turn, results in a lubricating effect, with smooth and comfortable lid movement over the lens.(12) It is likely that the performance of any contact lens is enhanced by the ability of the lens to form a stable pre and post lens tear film, which in turn is governed by its wettability. The contact lens care solutions play a vital rule in enhancing the lens wettability therefore, ocular comfort.

There are differences in clinical outcomes between contact lens care solution products, these difference are likely because of their different composition(13), the nature of contact lens materials, and interaction between care solution and lens material.(14-16) As a result of the unique nature of silicone hydrogel materials and the differences in their interaction with the widely available contact lens care products, it may be best to combine a particular type of lens with a specific form of lens care solution.(17)

The effect of contact lens care solutions on contact lens wettability has been evaluated by several authors. Yu *et al*.(18) utilized a sessile drop technique to investigate the wettability of four silicone hydrogel lenses: PureVision, Acuvue Advance', Night & Day and O2 Optix. These lenses were soaked in four care solution namely *COMPLETE MoisturePlus*, *ReNu* with MoistureLoc, *Opti-Free Express* and *Opti-Free RepleniSH.* Among these solutions, 'O2 Optix' and 'Night & Day' showed a lower contact angle (better wettability) after storage in *ReNu*.

Nichols *et al*.(19) compared the efficacy of the solutions '*COMPLETE', 'MoisturePlus'* and *Opti-Free Express* on the thickness of the tear film deposited on the hydrogel lens 'Etafilcon A' during lens wear. The pre-lens tear film (PLTF) thickness was slightly greater (but not significantly so) after *COMPLETE MoisturePlus* was used, compared to *Opti-Free Express*. Out of 31 subjects, twenty subjects (64.5%) preferred *COMPLETE MoisturePlus* compared to 11 subjects (35.5%) who preferred *Opti-Free Express*.

Contact lens wearers are often affected by decreasing comfort during contact lens wear, particularly toward the end of the day. A possible remedy for these complaints is to switch to another contact lens material. An alternative is to change the lens care products.(20, 21)

In the present project we assess the integrity and suitability of the care solutions on contact lens *in-vivo* wettability using Doane's interferometer technique

Materials and Methods

A single type of contact lens (Acuvue Oasys, Johnson & Johnson) (Table 1) was used, to avoid the different interaction between lens material and the care solutions. The Acuvue Oasys lens was chosen as it is known as one of the most commonly prescribed lenses.(22)

A variety of care solutions, including traditional solutions with wetting agents and new solutions with a novel agent were chosen for this study. These solutions were: *COMPLETE* (AMO, Santa Ana, CA), *ReNu, Biotrue*™ MPS (Baush&Lomb, Rochester, NY, USA), *Opti-Free EverMoist* (now called puremoist) and *Opti-Free Express* (Alcon Inc., Fort Worth, TX). Details of their compositions are shown in Table 2.

Study design

Thirteen habitual contact lens wearers (age 26.6 ± 6.3 years) with no known ocular disease were recruited for this study. The contact lens (CL) worn by the subjects were tested for CL wettability after soaking (for 8 hours prior to wear) in each of the five care solutions listed in table 2 or from pack solution (control). The pair of lenses were soaked in the care solutions + pack solutions and worn by the subjects. The total number of lenses tested was 13 x 6 = 78 lenses, and 13 pairs of lenses wetted in each solution.

The study was conducted according to the principles contained in the Declaration of Helsinki(23) and ethical approval was obtained from Ethics Committee. Written informed consent was obtained from each participant prior to taking part in the study.

As a control, the Acuvue Oasys lenses were tested directly from the pack solution (i.e. taking the lens directly from the sealed container used by the manufacturers to supply lenses) and observed after 15 min and 8 hours wear (Figure 1 A). Care solutions influence on lens wettability was assessed by soaking a new pair of lenses overnight for eight hours in each one of the five care solutions listed in Table 2 (Figure 1 B). A 48 hours washout period was allowed between each solution use. It was a participant-masked (to the care solutions) study and the order of solutions testing was chosen randomly.

Doane's interferometer

Thin-film interferometry, a non-invasive technique, was used to assess the tear film structure and stability through observation the interference fringes. A CMEX-1301 camera was attached to a Doane interferometer and linked to its associated image capture software (ImageFocus®, Euromex). With this arrangement, a sequence of high definition images of the tear film interference pattern could be recorded. The sequence of still images were converted to a video-clip (ImageToAVI), and MATLAB software version 7.7.0.471 (R2008b) (Mathworks, Natick, MA) used for their analysis.

The subject was asked to sit in front of the interferometer, they were asked to blink and then refrain from blinking until the contact lens surface became completely dry (fringes disappear) (Figure 2). Images of the pre-lens tear film were captured. The tear film over the contact lens was illuminated with monochromatic light (λ = 546 nm) from a source within the thin film interferometry device. Fringes were observed, being produced by the constructive and destructive interference of light reflected from the anterior surface of the tear film and that of the contact lens.(24) (25).

Analysis of the Interferometry Images

The analysis procedure has been described previously in details elsewhere.(25) In brief the pre-lens captured images where converted into a video clip. MATLAB software was used to analyze the clip tracking the drying dynamics. This program analyzed each clip, frame by frame. The dry areas on the lens surface were detected by the absence of interference fringes (Figure 3). The drying dynamics of the soft contact lenses were described by the following four parameters:

Onset latency (OL): Time to first break-up. Drying duration (DD): stability of a liquid on lens surface. Maximum speed of drying (MS): this parameter showing the speed of dry area appearing. (In square millimetres per second). Peak latency (PL) is a measure of the time until the MS of drying was reached.

Results

This was a crossover design study, with each subject using all five care solutions in addition to the original lens pack solution. Each subject was observed wearing a new lens of the same type, taken either directly from pack solution or following an 8 hour soak in each of the five solutions. The mean of contact lens wettability parameters after it has been soaked in each solution is shown in (Table 3). A test of normality showed that some of the contact lens wettability parameters were not normally distributed (Kolmogorov–Smirnov test, $p < 0.05$). Therefore, non-parametric tests (Friedman and Wilcoxon signed-rank tests) were applied throughout.

Change in contact lens wettability soaked in each solution after 15 minutes and 8 hours of lens wear

Onset latency (OL) observed with each solution after 15 minutes of wear was compared to that observed after 8 hours of lens wear (Figure 4). Lenses worn straight from the pack solution or after they had been soaked in *Biotrue*, *Opti-Free EverMoist* and *Opti-Free Express* all showed a significant reduction in OL following 8 hours of lens wear ($p = 0.028$, 0.005, 0.017, 0.047 respectively). The OL evaluated when the subjects were wearing lenses soaked in *COMPLETE* and *ReNu* solutions did not show a significant reduction in performance following eight hours of lens wear ($p = 0.093$ and 0.445 respectively).

The comparison between drying duration (DD) mean (Figure 5) of the lenses worn by subjects from the pack solution and those which were soaked in the care solutions showed that *Opti-Free EverMoist* and *ReNu* solutions both showed a significant reduction (worse) in *in-vivo* drying duration when the eight hours' performance was compared with that seen after 15 minutes of lens wear ($p < 0.017$). The in-vivo DD evaluated in subjects wearing lenses soaked in Biotrue, Opti-Free Express and COMPLETE solutions did not significantly change when the lens DD means following 8 hours of lens wear were compared with values obtained after 15 minutes of lens wear ($p=0.646$, $p= 0.059$ and $p= 0.799$ respectively).

For peak latency (PL) (Figure 6), only 3 solutions suffered a significant reduction (worse) in *in-vivo* PL after eight hours of lens wear compared to values seen after 15 minutes of lens wear. These were the pack solutions, *Biotrue* and *Opti-Free EverMoist* ($p= 0.017$, 0.028 and 0.005 respectively). In contrast subjects wearing lenses soaked in *ReNu*, *Opti-Free Express* and *COMPLETE* solutions showed no apparent change in PL between 15 minutes performance compared with that seen after 8 hours of lens wear ($p= 0.508$, 0.139 and 0.878 respectively).

For lenses maximum speed of drying (MS) (Figure 7) the comparison between the subjects wearing lenses directly from pack solution or soaked in *ReNu* and *Opti-Free EverMoist* showed a statistically significant increase (worsening) in the MS after 8 hours of lens wear compared to that seen after 15 minutes of lens wear ($p= 0.047$, 0.017 and 0.037 respectively). The subjects wearing lenses soaked in *Biotrue*, *Opti-Free Express* and *COMPLETE* MPS did not show any significant change in the drying speed between the two time points.

Comparison between the solution effects on contact lens wettability

Onset latency

OL observed after 15 minutes wear is shown in Figure 8 A. The Friedman test showed that there were significant differences between solutions when onset latency was measured at 15 minutes after lens insertion ($p < 0.001$). Post-hoc Wilcoxon signed-rank test showed that the OL observed in the participants wearing lenses soaked in *ReNu* was found to be significantly shorter when compared with *Opti-Free EverMoist, Opti-Free Express ,COMPLETE* and *Biotrue* ($p = 0.013$ and $p = 0.025$, $p = 0.022$ and $p = 0.005$ respectively). A significantly longer OL was found for the subjects wearing lenses soaked in *Biotrue* compared to those wearing the lenses soaked in *Opti-Free Express* ($p = 0.005$). However, no significant difference was found between the OL of subjects wearing lenses soaked in *Biotrue* and *Opti-Free EverMoist* or *Biotrue* and *COMPLETE* ($p > 0.074$). Also, no significant differences were found between participants wearing lenses soaked in *Opti-Free EverMoist*, *Opti-Free Express* and *COMPLETE* ($p > 0.139$).

The Friedman test showed that there were no significant differences between the OL evaluated in subjects wearing the lenses soaked in any of the care solutions or worn directly from pack solution following 8 hour of wear (Figure 8 B).

Drying duration

Drying duration (DD) of the CLs observed in the 13 subjects did not differ significantly between solutions when measured after15 minutes of lens wear. This was also true when measured after 8 hours of lens wear (Friedman test, $p= 0.323$ and $p= 0.127$ respectively.

Peak latency

The different care solutions did not induce differences in contact lens wettability (PL) measured after15 minutes of lens wear. Also, after 8 hours of lens wear, no significant difference was observed in the test population irrespective of which solution was used (Friedman test, p= 0.347 and p= 0.366 respectively).

Maximum speed

No significant differences were observed between the MS evaluated in subjects wearing lenses soaked in the MPSs following 15 minutes of wear (p= 0.740). This was also true when MS was evaluated after 8 hours of lens wear (p= 0.455).

Discussion

Giannoni and Nichols investigated the importance of the care solutions by means of a survey in which practitioners were asked about their most frequent ways of managing contact lens induced dry eye (Figure 9).(26) Changing the care solution was the third most frequent means of managing contact lens induced dry eye. Several studies have investigated the *in-vivo* stability of the pre-contact lens tear film. Some of these studies use it as an indicator of contact lens wettability.(27-33)

Our study showed that the Interferometric technique is a good method which can be used to compare the effect of different care solutions on contact lens *in-vivo* wettability.(34) Our comparative study of the care solutions showed that onset latency (OL) observed in care solutions, *in-vivo* lens wettability was not different to those observed in the pack solutions (control) after 15 minutes as well as 8 hours of lens wear (Figure 8 A). This could be the result of the relatively small sample size recruited for this study. To test this, a power calculation based on the OL result was carried out. The assumptions were as follows: standard deviation 14.42 sec, observed difference 13 sec and a power of 0.8. It showed that another 13 participants would be required to have an 80% chance of detecting a difference between lens pack solution and care solutions.

The absence of a significant difference between the effect of the lens pack solution and the care solutions on lens wettability might be the result of a number of factors. The lens's pack solution has been formulated with many of the same types of components found in care solutions. Recently, manufacturers have incorporated water soluble polymers, surfactants and unnamed wetting agents or surface-active agents into the blister pack solution of the lenses.(35) These are added to aid in preventing the lenses from sticking to the blister, enhance lens wettability, and improve initial comfort of the lens in the eye.(35) So the treatment of lenses in the pack solution is not a true inactive control. Saline may be better control but would still interact with the tear film due to the envelope of saline instilled in the eye as the lens is put in.

Our study showed that soaking the lenses in some of the care solutions did not show a significant reduction in the lens *in-vivo* wettability after 8 hours of wear compared to that found at insertion (Table 3). This was unlike that observed when the lenses were worn directly from the pack solution. There were some possibilities of a reduction in wettability when the lens was worn directly from the pack solution compared to wearing lens soaked in care solutions. First, the wetting agents associated with the lens pack solution are no longer available at the end of the day.(36) Secondly, wettability can be positively influenced by care solutions which contain active wetting agents that have the ability to keep the lens surface hydrophilic for a longer period of time.(37) Thirdly, the care solutions stop deposits that reduce lens wettability.

The constancy in lens wettability observed with some care solutions after 8 hours of lens wear may be because of an initially poor performance of the solutions that remains poor after 8 hours e.g. *ReNu* effect on OL. The subjects wearing lenses soaked in *COMPLETE* solution did not show a significant reduction in *in-vivo* lens wettability evaluated with all four of the wetting parameters at both time points. Some solutions without comfort/wetting ingredient included another ingredient which may help in improving CL wear comfort and wettability. E.g. the *COMPLETE* solution contains hydroxypropyl methylcellulose (HPMC) which is designed to increase the wettability of the lenses.(40) In 2000 Donshik *et al*.(38) reported that a multipurpose solution (MPS) containing HPMC resulted in increased comfort and wettability of the contact lenses *in-vivo*. Other solution properties may also have influences on the contact lens in-vivo wettability such as solution viscosity and surface tension.(35, 39)

The onset latency of the lenses worn by the 10 subjects was not significantly changed after these lenses had been stored in the *ReNu* and *COMPLETE* solution. *ReNu* was the only MPS that showed an increase in the lens *in-vivo* onset latency after 8 hours of wear compared to those measured after 15 minutes (Figure 4). However, the *in-vivo* onset latency measured after soaking the lens in *ReNu* was initially (after 15 min) poor compared to the other solutions, this might be the reason for observing the increase in onset latency after 8 hours of lens wear. This could be due to deposition of tear components on the lens or due to the dilution of ReNu within the lens matrix.

In addition to *COMPLETE*, both *Opti-Free Express* and *Biotrue* showed no significant reduction in lens *in-vivo* DD after 8 hours of wear compared to that observed after 15 min of lens wear. The *Opti-Free Express* solution contains Tetronic 1304 as a conditioning agent,(41) Tetronics are octablock star copolymers and contain hydrophilic terminal blocks having poly (ethylene oxide)/poly(propylene oxide) (PEO/PPO in different ratios) arms attached to an ethylenediamine core.(42) These copolymers show excellent surfactant properties.(42) The amine groups in the Tetronic chains provide more hydrophilicity to the molecule.(43) The results presented in this study agree with those of Meadows(36) who investigated the effect of Tetronic 1304 (as used in Opti-Free Express) and Tetronic 1107 (as used in *ReNu* MPS) on the Acuvue 2 lens (Etafilcon A). The lenses were soaked in the solutions for 12 hours, and the *in-vitro* contact angle measured (the smaller the angle, the better the lens wettability). The contact angle measured after the lens was soaked in *ReNu* was 100° and after the lens was soaked in *Opti-Free Express* it reduced to 10°. This change is in agreement with our study findings.

Some solutions (Pack solution, *ReNu*, Opti-Free EverMoist) showed a significant reduction in the lens *in-vivo* drying duration between that observed after 8 hours of lens wear compared with that seen after 15 minutes. For both DD and MS, soaking the lenses in *Biotrue*, *Opti-Free Express* and the *COMPLETE* solution did not result in a significant reduction in *in-vivo* drying duration after 8 hours of lens wear. The *Biotrue* solution contains hyaluronan, which acts to improve the wettability of the contact lens. Hyaluronan is a member of the glycosaminoglycan family of biological polysaccharides and it is a high molecular weight polysaccharide polymer found throughout the human body, particularly in the eye.(44, 45) Solutions of hyaluronan are viscoelastic and also its viscosity is shear rate dependent. In the condition of a low-pressure force, hyaluronan is randomly arranged and highly viscous, while under a high shear force, such as eye-blinking, the hyaluronan polymers align; subsequently, viscosity is reduced, allowing water to flow between the chains.(46) This low viscosity allows the polymers to spread across the ocular surface, acting as a lubricant. Hyaluronan has strong water retention and viscoelastic properties and enhances water retention on the corneal/lens surface and therefore increases its wettability.(47) These properties may help to explain *Biotrue's* performance *in-vivo*.

It has been noticed that the wetting agents in some solutions did not result in improved wetting compared to the lens pack solution, this might be because the contact lens manufacturer, such as Acuvue Oasys, have, undoubtedly, incorporated ingredients into the blister pack solution to prevent the lens sticking to the blister, enhance lens wettability and improve lens wearing comfort. These ingredients include water soluble polymers, wetting agents and surface active agents. These pack solution ingredients may transcend some MPS while other solutions perform better. An alternative approach would be to soak the lenses in saline solution as a control instead of wearing lens directly from the pack solution. Then treat the lens in MPSs to investigate it effect on contact lens wettability. But the aim was to investigate the real life situation of contact lens wearers, who usually insert their lenses directly from the pack solution.

The role of contact lens care systems in conditioning lens surfaces, to enhance lens surface wetting, has recently earned renewed interest and may prove an important contributing factor in sustained contact lens comfort.(48-50) However, although it is clear that lens wettability OL, DD, PL and MS are very useful measurements, a variety of other factors are also likely to contribute to contact lens wearer comfort after storage in care solutions, such as: lens lubricity, deposit accumulation(51) and contact lens modulus(52).

It would be benefit also if appropriate questionnaire was used to reflect the subjective response to the different solutions. A report by the International Workshop on Contact Lens Discomfort reported that the contact lens dry eye questionnaire (CLDEQ) is the only tool validated for the evaluation of contact lens induced discomfort.(53) But this questionnaire is long, as it contains 36 questions specific to symptoms of contact lens-related dry eye.(54) A shorter form of this questionnaire known as CLDEQ-8 was evaluated by Chalmers et al.(55) Unfortunately this short form of CLDEQ was not validated at the time of data collection of this study.

For practitioners who want to choose the optimum care system that enhances contact lens wettability, two conditions should be considered before recommending a contact lens care solution. Firstly, does the solution significantly improve wettability over the pack solution at 15 min i.e. at insertion? Secondly, is the wettability sustained until the end of the day? No significant change was observed between wettability after 15 minutes versus 8 hours lens wear for the solutions listed in Table 4.

Although the present study has certain limitations with regard to the number of subjects, it showed a statistically significant difference in the performance of the care solutions. Further larger scale studies, with inclusion of a CL dry eye questionnaire, would obviously be needed to ascertain if this was the case. It also leads a significant difference in clinical practice.

Conclusion

This novel thin film interferometry technique was able to measure, objectively, contact lens *in-vivo* wettability following the use of contact lens care solutions. *COMPLETE* MPS was the only solution which showed no significant change in the lens wettability (with the 4 parameters) between that evaluated after 15 minutes and 8 hours of lens wear (Table 4). However, one lens material only was investigated in this study. Evaluation of different lens materials would be required for a full judgment.

All the care solutions and the lens pack solution suffered from a reduction in lens wettability at the end of day (after 8 hours of lens wear). None of the care solutions tested showed a significant improvement in the *in-vivo* lens wettability compared to wearing the lens directly from the pack solution. The manufacturers have incorporated water soluble polymers, surfactants and wetting agents to aid in enhance lens wettability, and improve initial comfort of the lens on eye.(35) This is likely to make the lens pack solution perform similarly to the care solutions and make distinguishing between their performances more difficult.

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Acknowledgment

The authors extend their appreciation to the college of Applied Medical Sciences Research Centre and Deanship of Scientific Research at King Saud University for its funding for this research.

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Figure 1

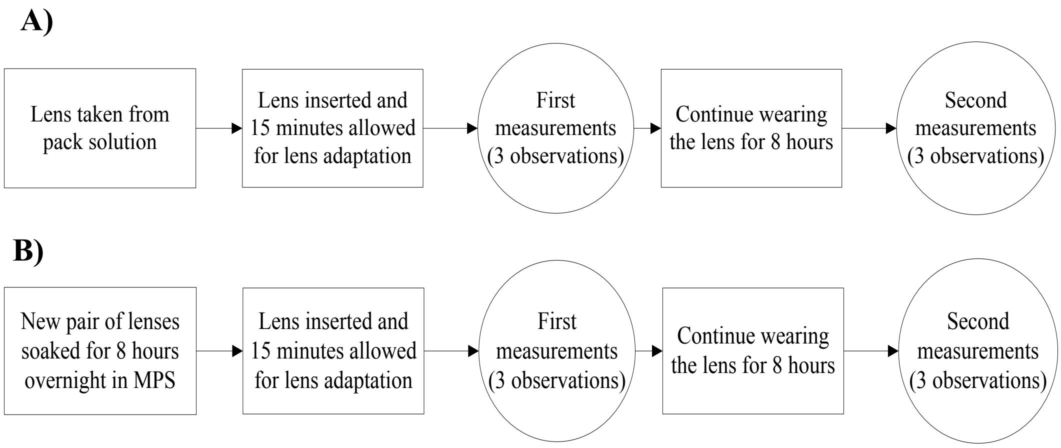
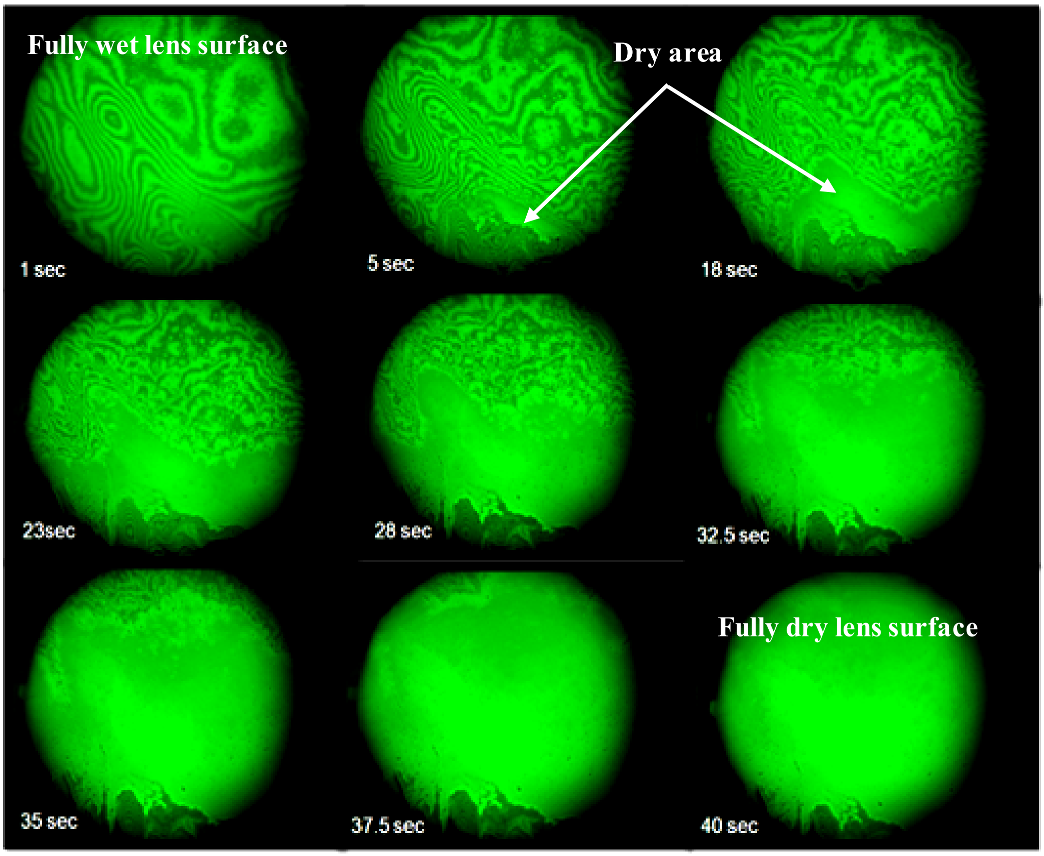

A)
Lens taken from pack solution
Lens inserted and 15 minutes allowed for lens adaptation
First measurements (3 observations)
Continue wearing the lens for 8 hours
Second measurements (3 observations)
B)
New pair of lenses soaked for 8 hours overnight in MPS
Lens inserted and 15 minutes allowed for lens adaptation
First measurements (3 observations)
Continue wearing the lens for 8 hours
Second measurements (3 observations)

Figure 2



Fully wet lens surface
Dry area
Fully dry lens surface
1 sec
5 sec
18 sec
23sec
28 sec
32.5 sec
35 sec
37.5 sec
40 sec

Figure 3

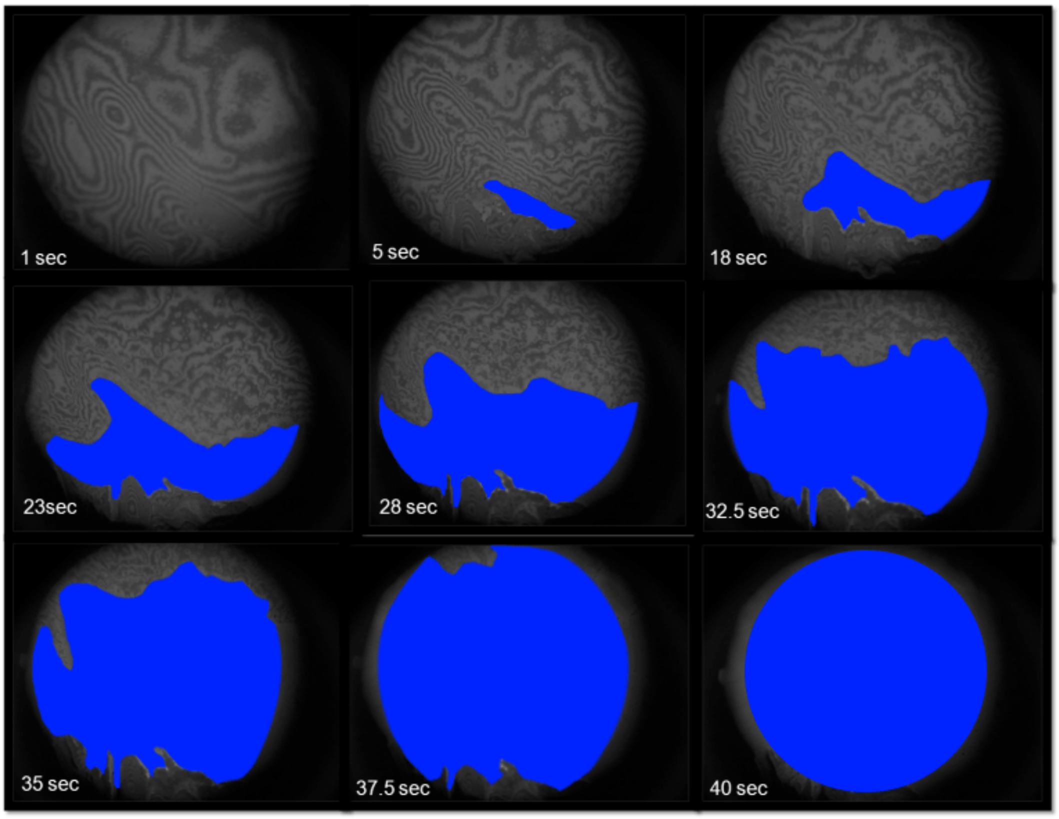


Figure 4

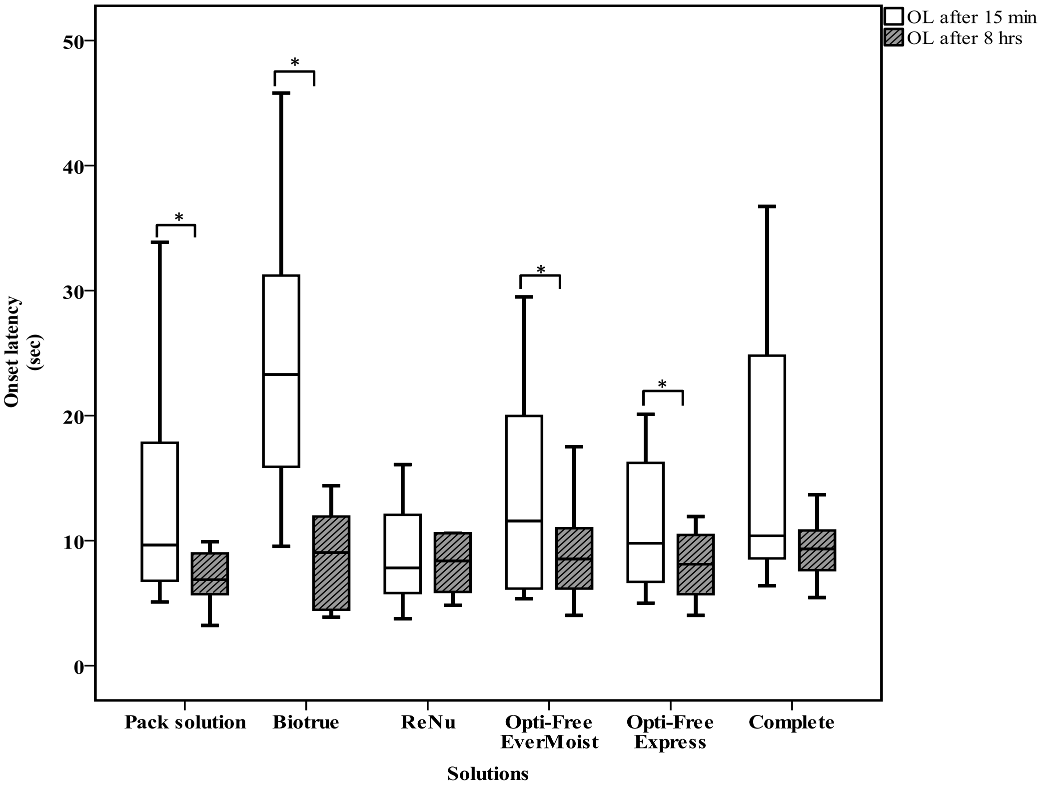

OL after 15 min
OL after 8 hrs
Onset latency
(sec)
50
40
30
20
10
0
*
*
*
*
Pack solution
Biotrue
ReNu
Opti-Free
EverMoist
Opti-Free
Express
Complete
Solutions

Figure 5

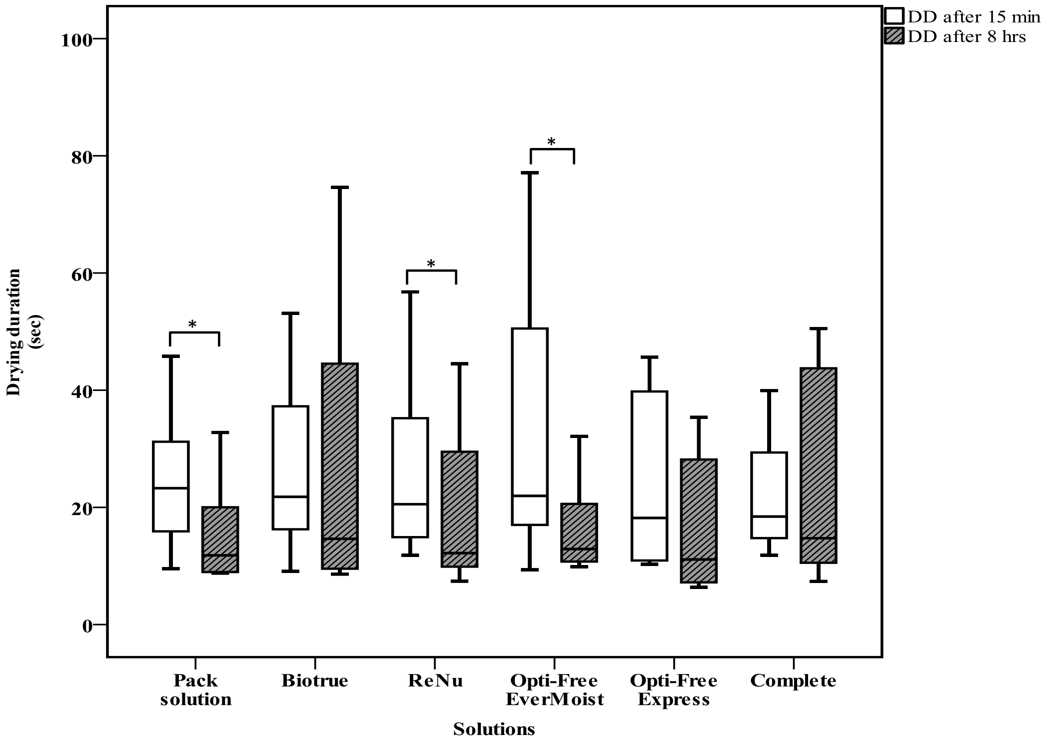

DD after 15 min
DD after 8 hrs
Drying duration (sec)
100
80
60
40
20
0
*
*
*
Pack solution
Biotrue
ReNu
Opti-Free EverMoist
Opti-Free Express
Complete
Solutions

Figure 6

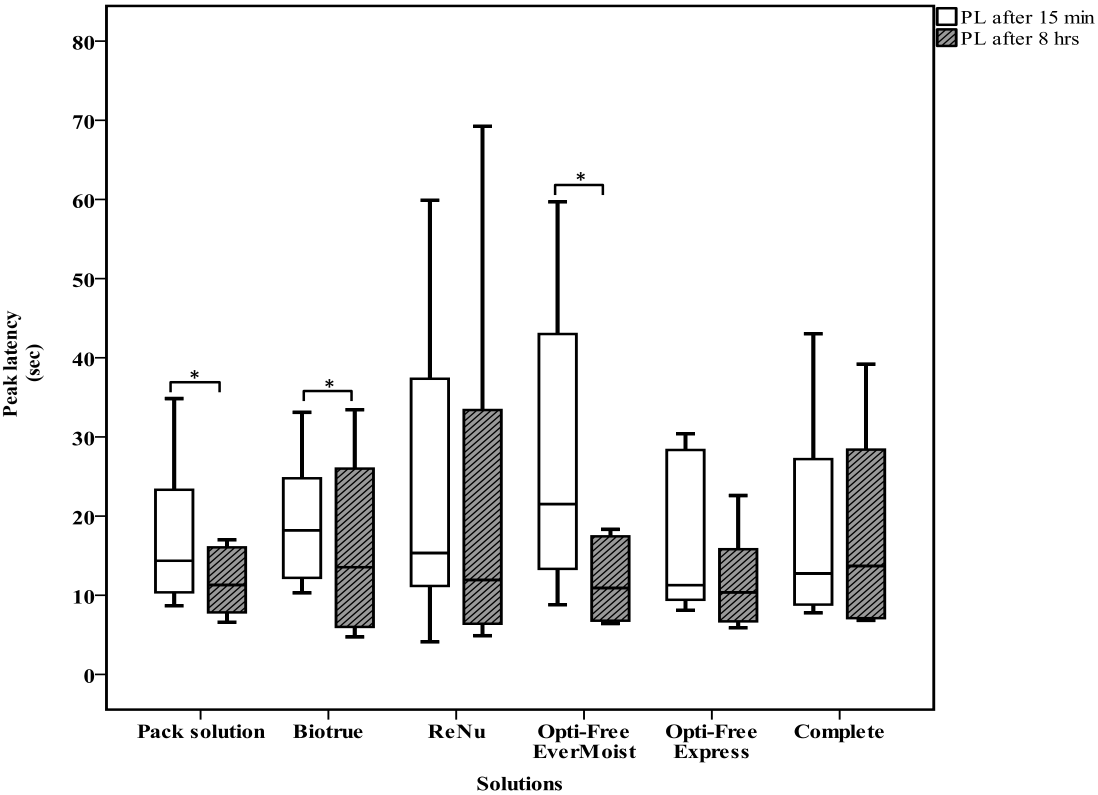
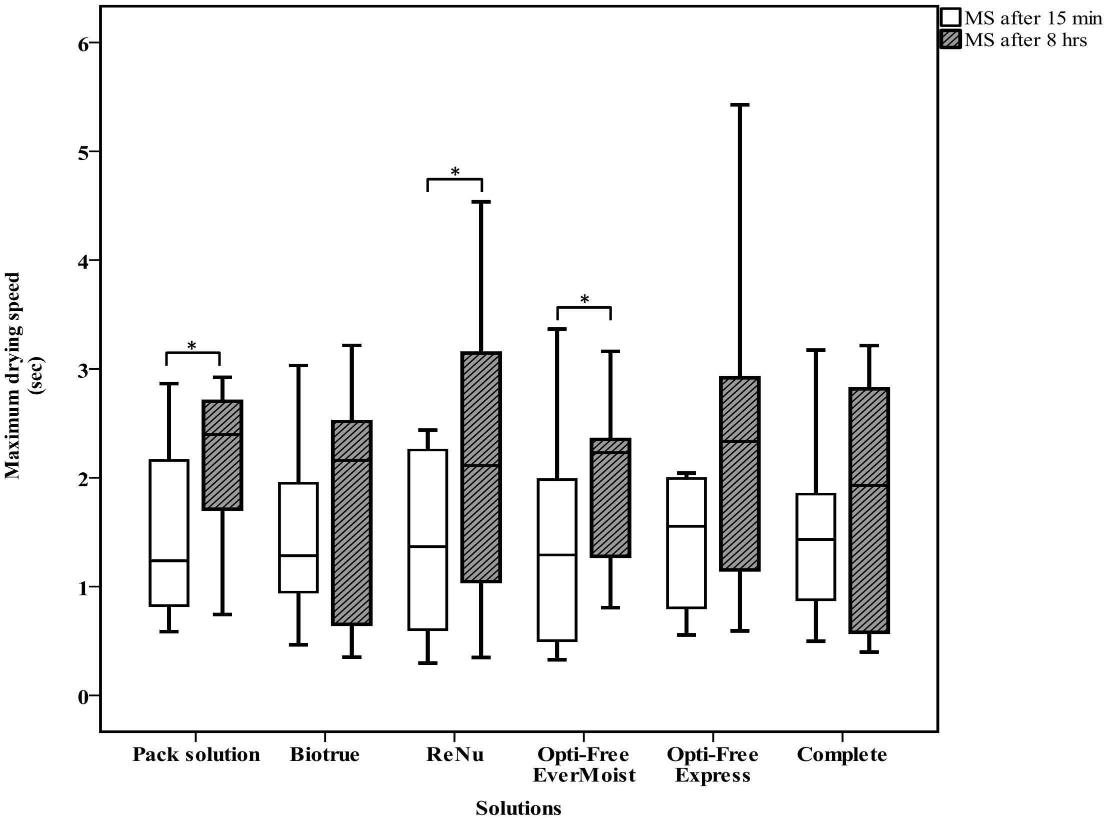

PL after 15 min
PL after 8 hrs
Peak latency (sec)
80
70
60
50
40
30
20
10
0
*
*
*
Pack solution
Biotrue
ReNu
Opti-Free EverMoist
Opti-Free Express
Complete
Solutions

Figure 7



MS after 15 min
MS after 8 hrs
Maximum drying speed
(sec)
6
5
4
3
2
1
0
*
*
*
Pack solution
Biotrue
ReNu
Opti-Free
EverMoist
Opti-Free
Express
Complete
Solutions

Figure 8

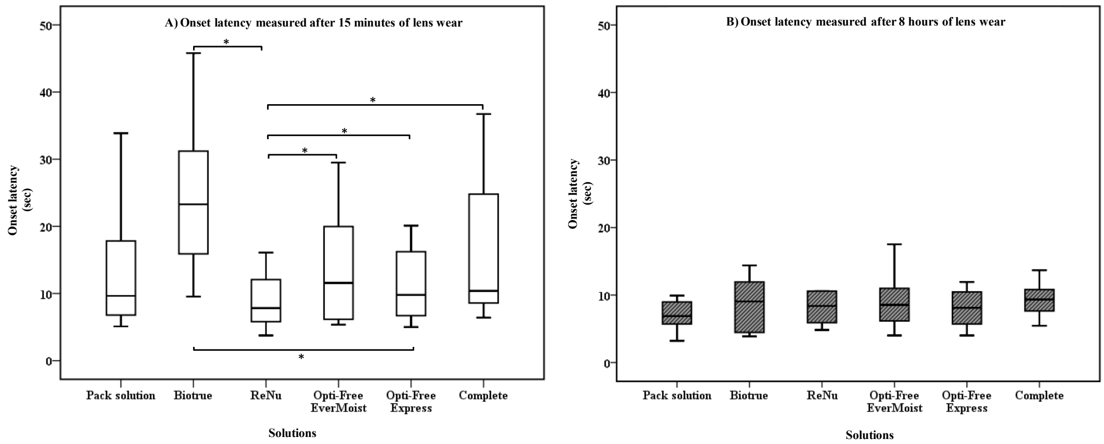

A) Onset latency measured after 15 minutes of lens wear
Onset latency (sec)
50
40
30
20
10
0
*
*
*
*
*
Pack solution
Biotrue
ReNu
Opti-Free EverMoist
Opti-Free Express
Complete
Solutions
B) Onset latency measured after 8 hours of lens wear
Onset latency (sec)
50
40
30
20
10
0
Pack solution
Biotrue
ReNu
Opti-Free EverMoist
Opti-Free Express
Complete
Solutions

Figure 9

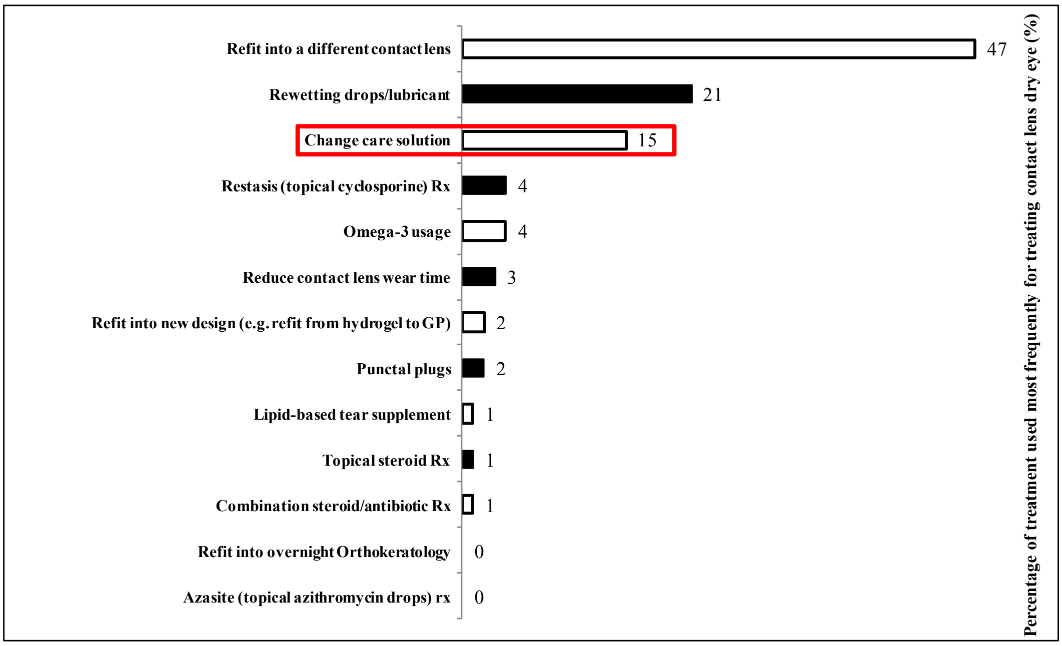

Refit into a different contact lens
47
Rewetting drops/lubricant
21
Change care solution
15
Restasis (topical cyclosporine) Rx
4
Omega-3 usage
4
Reduce contact lens wear time
3
Refit into new design (e.g. refit from hydrogel to GP)
2
Punctal plugs
2
Lipid-based tear supplement
1
Topical steroid Rx
1
Combination steroid/antibiotic Rx
1
Refit into overnight Orthokeratology
0
Azasite (topical azithromycin drops) rx
0
Percentage of treatment used most frequently for treating contact lens dry eye (%)

Table 1

Brand Name	USAN	FDA group	Water content (%)	Dk (Fatt/ISO)	Modulus	Surface treatment	Principal monomers
Acuvue Oasys (Johnson &Johnson Vision Care)	**Senofilcon A** **(silicone hydrogel)**	1	38	103/77	0.72	None (However, internal wetting agent, PVP used)	MPDMS, DMA,HEM, siloxane macromer, TEGDMA, PVP

Key: PVP, polyvinyl pyrrolidone; MPDMS, monofunctional polydimethylsiloxane; DMA, N, N-dimethylacrylamide; HEMA, hydroxyethyl methacrylate; TEGDMA, tetraethyleneglycol dimethacrylate.
(Fatt/ISO): The International Organization for Standardization has been chose the Fatt method as the international standard for all contact lens material manufacturers to state the permeability of their materials.[1]

Table 2

Solution	Manufacturer	Ingredients	Active Agent	Comfort/wettability ingredient	Buffer
COMPLETE MPS AMO	Abbott Medical Optics	Purified water, Hydroxypropyl methylcellulose (HPMC), sodium chloride, potassium chloride, sodium phosphate dibasic (heptahydrate), poloxamer 237, 0.05%, edetate disodium, sodium phosphate monobasic (monohydrate) and preserved with polyhexamethylene biguanide 0.0001%	Poloxamer 0.05%	----	Phosphate
Opti-Free Evermoist (Renamed puremoist)	Alcon	POLYQUAD® (polyquaternium-1) 0.001% and ALDOX® (myristamidopropyl dimethylamine) 0.0006% preservatives.	Poloxamine,Citrate, Polyoxyethylene, Polyoxybutylene	TETRONIC®1304 and HydraGlyde® Moisture Matrix	Borate/Sorbitol/ Aminomethyl-propanol
Opti-Free Express	Alcon	Polyquaternium-1 (Polyquad) 0.001%, Myristamidopropyldimethylamine (Aldox) 0.0005%, Poloxamine, Sodium citrate, Boric acid, Sorbitol, Aminomethyl-propanol, Edetate disodium	Poloxamine, Citrate	TETRONIC®1304 (Poloxamine)	Borate/Sorbitol/ Aminomethyl-propanol
ReNu® MPS	Bausch & Lomb	Polyaminopropyl biguanide 0.0001% (PHMB), Poloxamine Hydroxyalklphosphonate, Edetate disodium, Borate and Boric acid, Sodium chloride	Poloxamine (1.0%) and Hydronate®	TETRONIC®1107	Sodium Borate & Boric Acid
Biotrue™ MPS	Bausch & Lomb	A sterile isotonic solution that contains hyaluronan, sulfobetaine, poloxamine, boric acid, sodium borate, edetate disodium and sodium chloride preserved with a dual disinfection system (polyaminopropyl biguanide 0.00013% and polyquaternium 0.0001%).	Sulfobetain, Ploxamine, sodium borate.	Hyaluronan	Boric Acid, Sodium Borate

Table 3

	Solutions	Wettability parameter mean ± SD OL (sec)	DD (sec)	PL (sec)	MS (mm²/sec)
After 15 minutes	Pack solution	17.4±19.1*	24.6±10.9*	16.8±8.6*	1.5±0.83*
	Biotrue	16.6±19.0*	26.6±14.8	23.016.6±*	1.5±1.03
	ReNu	8.81±3.9	29.1±25.2*	23.0±18.4	1.3±0.83*
	Opti-Free EverMoist	18.5±19.6*	33.9±23.2*	27.16±17.9*	1.39±0.98*
	Opti-Free Express	11.3±5.5*	24.3±14.5	17.0±9.6	1.5±1.01
	COMPLETE	16.0±10.2	21.5±8.9	18.8±12.1	1.5±0.76
After 8 hours	Pack solution	7.0±2.0*	14.9±7.9*	11.5±4.1*	2.4±1.19*
	Biotrue	8.7±4.0*	25.3±22.4	16.3±10.5*	1.8±1.06
	ReNu	13.4±12.7	22.6±19.3*	21.0±21.4	2.2±1.4*
	Opti-Free EverMoist	9.2±3.9*	16.8±8.4*	11.7±4.8*	1.9±0.75*
	Opti-Free Express	7.7±4.8*	16.4±10.4	11.5±5.5	2.3±1.4
	COMPLETE	10.0±3.8	23.5±16.8	17.6±11.4	1.8±1.14

* Significant difference between the lens wettability measured after 15 minutes and 8 hours of wear.

Table 4

Wettability parameter	Solutions
Onset latency	*ReNu* ***COMPLETE***
Drying duration	*Biotrue* *Opti-Free Express* ***COMPLETE***
Peak latency	*ReNu* *Opti-Free Express* ***COMPLETE***
Maximum speed	*Biotrue* *Opti-Free Express* ***COMPLETE***