The Effect of Tear Components on the *in vitro* Wettability of Silicone Hydrogel Lenses

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Alcon ARVO 2005

INTRODUCTION

- An important element towards the success of contact lens materials is the in-eye wettability for extended time periods. This has a significant impact on the lens comfort and ocular dryness sensitivity.[1,2,3,4] See Figure 1.
- The surface properties of silicone hydrogel (SiH) materials have undergone significant improvements in the last few years.[5,6,7,8]
- The wettability of hydrogel materials exposed to air is poor due to the thermodynamic driving force of the hydrophobic groups migrating to the hydrogel-air interface.[9,10,11]
- Variables such as surface wettability along with lipid and protein deposition can influence the on-eye comfort of the SiH lens materials.[12,13,14] Recent work using a captive bubble contact angle method has indicated that lysozyme and mucin improved the wettability of the SiH lens surfaces under hydrated conditions.[9]

PURPOSE

- To compare the surface wettability and water content of Acuvue 2 lenses that have been exposed to various conditions in order to prove that water content is not related to surface wettability.
- To use a sessile drop technique to measure *in vitro* advancing contact angles as an indicator of silicone hydrogel lens wettability in the presence of artificial tear solutions (ATS) containing lysozyme, albumin and mucin.

MATERIALS

Table 1. Description of Contact Lens Materials.

Lens	Acuvue 2™ etafilcon A	Acuvue Advance™ galyfilcon A	O_2OPTIX™ lotrafilcon B
Water Content	58%	47%	33%
Dk/t	35	85	138
Lens Diameter (mm)	14.0	14.0	14.2
Base Curve	8.7	8.7	8.6
Power	-2.00	-2.00	-2.00
Manufacturer	Vistakon®	Vistakon®	Ciba Vision®

Table 2. Description of composition of disinfection solutions.

	Solution contents as listed by the Manufacturer		
MPDS Products	**Biocides and Preservatives**	**Buffers, Tonicity and Protein Cleaning Agents and Salts**	**Surfactants and Polymers**
Opti-Free® Express® (Alcon)	POLYQUAD®, ALDOX® and EDTA	Sodium citrate, NaCl, boric acid, sorbitol, and AMP-95	Tetronic® 1304
Renu MultiPlus® (Bausch & Lomb)	DYMED	HYDRANATE®, boric acid, sodium borate and sodium chloride	Poloxamine
Renu® MoistureLoc™ (Bausch & Lomb)	Alexidine	HYDRANATE®, boric acid, sodium phosphate and sodium chloride	MoistureLoc™ (polyquaternium-10 and poloxamer) and poloxamine.
Aquify® (CIBA Vision)	Polyhexanide and EDTA	Tromethamine, sorbitol, sodium phosphate, dexpanthenol	Pluronic F-127
Unisol® 4	none	NaCl, boric acid and sodium borate	none

Table 3. Artificial Tear Solutions used in Lens Cycling Experiments.

Components	Without albumin (%)	With albumin (%)
KCl	0.172%	0.172%
$NaHCO_3$	0.168	0.168
$CaCl_2$	0.0147	0.0147
NaCl	0.663	0.663
HEPES	0.59575	0.59575
albumin	-	0.2
lysozyme	0.018	0.018
mucin	0.015	0.015
pH	7.4	7.4

METHODS

Diameter was measured on the Optimec JCF Soft Contact Lens Dimension Analyser. The water content was measured on the Sartorius MA100 Moisture Analyzer. The following procedures were used:

- Lenses were soaked in Unisol saline solution overnight to remove packaging artifacts. Then the lenses were exposed to Unisol solutions at pH 4, 7.4 and 11. After overnight exposure to these solutions, the lens parameters (base curve, diameter and water content) were measured and compared to a control lens. Wetting angles on similarly conditioned lenses were also performed.
- Lenses were soaked in pure water (low osmolality) or a saline or propylene glycol solution (High osmolality: > 400 mOsm) overnight. After exposure to these solutions, the lens parameters were measured and compared to the control lens (lens soaked in Unisol). Wetting angles were also obtained.
- The above experiments were repeated using the same solutions as described above except that 0.05% Tetronic 1304 (surfactant) was added to the solutions.

Wetting angles were determined using the sessile drop technique (OCA 20, Future Digital Scientific Inc., NY)

- A sequential cycling methodology using ATS solution (with and without albumin) (5 min) and air (1.5 min) exposures were used to simulate blinking conditions. See Table 3. A curved baseline profile-detection fitting algorithm resident in the software was used (OCA 20 software) for determining the best fit to the contact angle drop profile. The software automatically corrected the best fit calculation (based on a least square difference method) to cover all the points.

RESULTS

Figure 1 shows the measurements of advancing contact angle, water content and lens diameter of Acuvue 2 hydrogel lenses exposed to various pHs and osmolalities, with and without the presence of 0.05% Tetronic 1304. By changing the pH of Unisol (pH 7.4) to either 4 or 11 or by changing the osmolality of Unisol (292 mOsm) by either adding or removing NaCl, the bulk water content of the lenses is altered dramatically. However, the contact angle of a sessile water droplet placed on the lens is not affected by the change in bulk water content of the lens. Upon addition of Tetronic 1304 to the conditioning solution, contact angles are reduced to 0° (complete wetting) regardless of the bulk water content of the lenses.

Figure 2 shows the same experiment from Figure 1 except that AA SiH lenses are used in place of AV2 hydrogel lenses. As can be seen in Figure 2, the diameter and water content of the AA lenses are not affected by changes in osmolality and pH as much as AV2 lenses. However, advancing contact angles of sessile water droplets on AA lenses are significantly affected by the addition of Tetronic 1304, despite the fact that lens diameter and water content are not altered by the surfactant. This suggests that changes in the surface play an important role in determining wettability, whereas bulk water content is not at all related to surface wettability. AA lenses do not experience the same magnitude of contact angle reduction as AV2 lenses.

Figure 3 and **Figure 4** show the advancing contact angles of water droplets on preconditioned AV2 lenses as a function of cycles using ATS, with and without the presence of albumin, as the cycling solution. Albumin, a major tear film component, plays an important role in assisting with the wettability of AV2 lenses as can be seen by comparing the contact angle profiles of the disinfection products tested here. Note that the contact angles with albumin are generally lower than those without albumin. However, the figures also show that OFXP, the only solution containing Tetronic 1304, provides complete wettability for AV2 lenses, regardless of the presence of albumin.

Figure 5 and **Figure 6** show the influence of using ATS with and without albumin on the wettability of the AA lenses (preconditioned using the disinfection products). In the absence of albumin (Figure 5), the wetting angles showed a trend towards high values indicating poor wettability. The changes in wetting angles at earlier cycling times are believed to be a reflection of protein desorption and adsorption. OFXP showed the lowest angles at higher cycles in the absence of albumin. In the presence of albumin (Figure 6) the wetting angles were lower for all the pre-soaked lenses. Aquify and OFXP showed the lowest wetting angles (best wettability) and OFXP continued to maintain low wetting angles throughout the cycling experiments.

Figure 7 and **Figure 8** show the influence of using ATS with and without albumin on the wettability of the O2Optix lenses (preconditioned using the disinfection products). In the absence of albumin (Figure 7), the wetting angles showed a trend towards low values indicating good wettability except for the lens presoaked with Renu MultiPlus which showed wetting angles of 50-60°. OFXP and Aquify showed the lowest angles towards higher cycles and these were generally better than the control lens (no presoaking). In the presence of albumin (Figure 8) the wetting angles were significantly lower for all the pre-soaked lenses and the control. The O2Optix lens displayed excellent wetting properties in the ATS containing albumin especially when the lenses were presoaked in OFXP.

Figure 1. Effect of pH and osmolality on the Acuvue 2 lens diameter, wetting angle and water content with and without surfactant (Tetronic 1304) pretreatment.

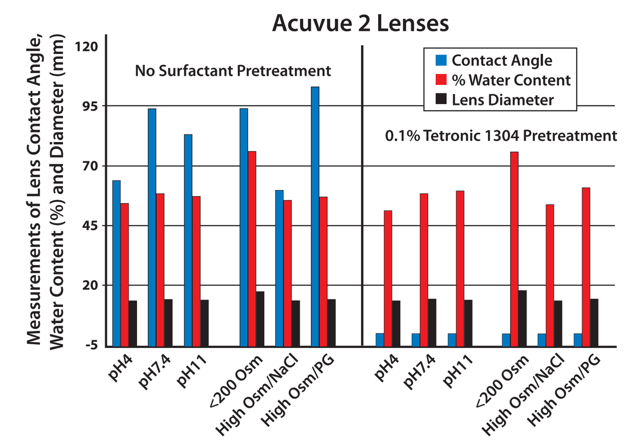


Figure 2. Effect of pH and osmolality on the Acuvue Advance lens diameter, wetting angle and water content with and without surfactant (Tetronic 1304) pretreatment.

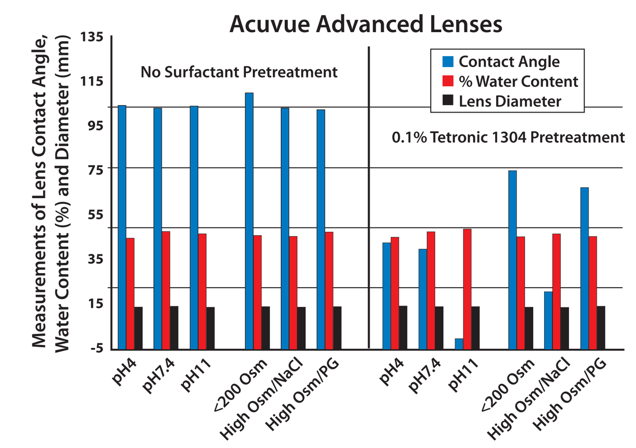


Figure 3. Wetting Angles for Acuvue 2 (pHEMA-MAA) presoaked in marketed disinfection solutions. Artificial tear cycling solutions **without** albumin.

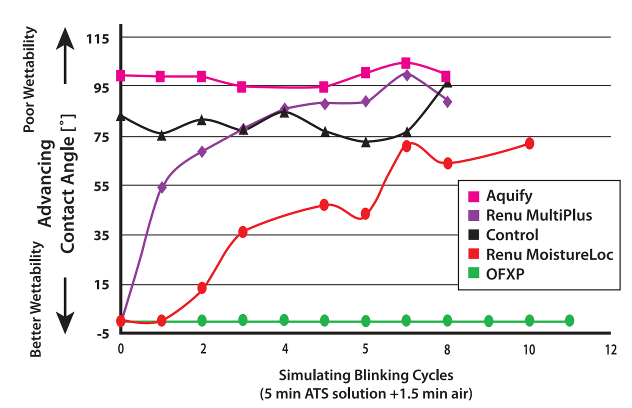


Figure 4. Wetting Angles for Acuvue 2 (pHEMA-MAA) presoaked in marketed disinfection solutions. Artificial tear cycling solutions **with** albumin.

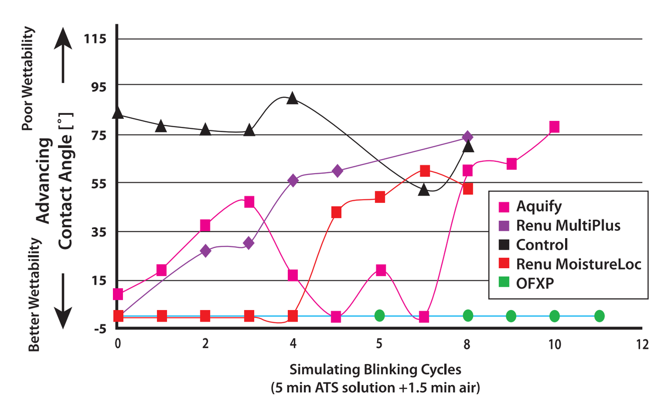


Figure 5. Wetting Angles for Acuvue Advance (SiH) presoaked in marketed disinfection solutions. Artificial tear cycling solutions **without** albumin.

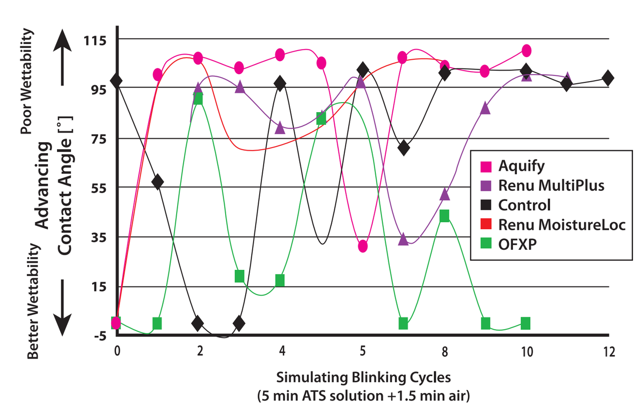


Figure 6. Wetting Angles for Acuvue Advance (SiH) presoaked in marketed disinfection solutions. Artificial tear cycling solutions **with** albumin.

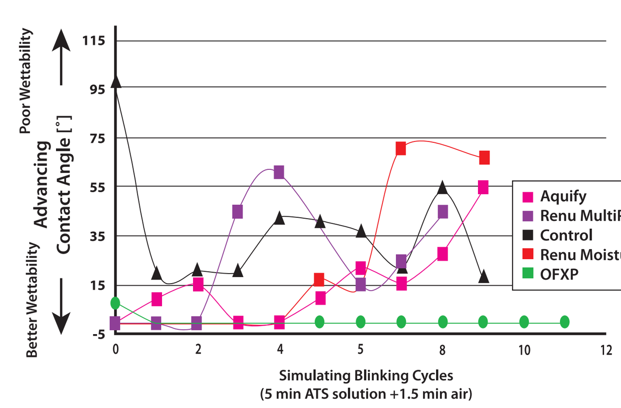


Figure 7. Wetting Angles for O2Optix (SiH) presoaked in marketed disinfection solutions. Artificial tear cycling solutions **without** albumin.

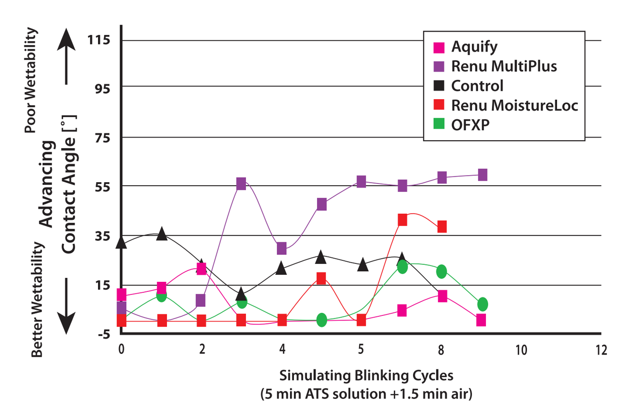
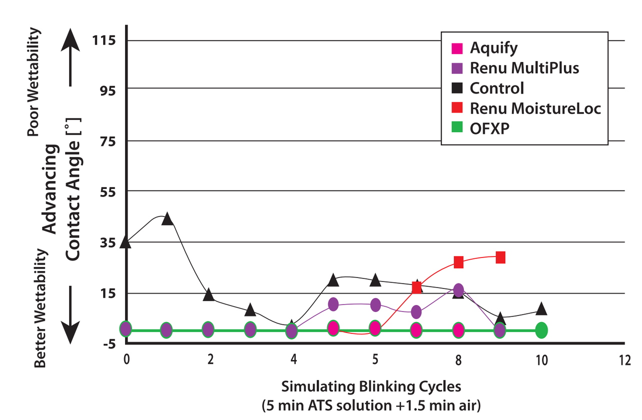


Figure 8. Wetting Angles for O2Optix (SiH) presoaked in marketed disinfection solutions. Artificial tear cycling solutions **with** albumin.



CONCLUSION

(1) The diameter and water content of contact lenses are significantly affected by physical changes in their environment such as pH and osmolality. However, these changes do not affect the wettability of the lens. The results suggest that there is no relationship between the bulk water content and the *in vitro* wettability of a contact lens. Rather, wettability of a contact lens is more likely to be determined by surface changes, wholly independent of the bulk water content of the lens.

(2) The wetting studies showed that the O2Optix SiH lens material had significantly improved *in vitro* wetting properties compared to the non-surface treated SiH lens (Acuvue Advance) and a Group IV soft lens with no preconditioning of the lenses. This suggests that surface modification creates a more hydrophilic surface for SiH lenses.

(3) Lysozyme and mucin do not contribute significant wetting properties to AV2 or AA lens materials under the sessile drop sequential cycling conditions at the concentrations tested. Albumin provides improved *in vitro* wettability for AV2 lenses when added to ATS regardless of the preconditioning solution used. These effects were greater with Aquify than for ReNu Multiplus and ReNu MoistureLoc. A similar result was not found for lenses that were not preconditioned in disinfection solution. OFXP showed no difference as it provided complete wetting throughout the cycling protocol, with and without albumin.

(4) Albumin plays a role in improving the wetting behavior of the AA lens material when Aquify or OFXP was used to presoak the lenses. The Tetronic 1304 block copolymer in OFXP appears to interact favorably with tear components such as albumin and improve or retain the wetting properties of the Acuvue 2, Acuvue Advance and O2Optix lenses. The wetting studies indicated that the OFXP formulation provides wetting under multiple conditions and also with both hydrogel and SiH lens materials.

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