Contact Lens and Anterior Eye 41 (2018) 362–368

Contents lists available at ScienceDirect

Contact Lens and Anterior Eye

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

The influence of lens care systems on eyelid tissue changes during silicone hydrogel contact lens wear

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ARTICLE INFO

Keywords:
Silicone hydrogel
Contact lens
Eyelid
Peroxide

ABSTRACT

Purpose: To compare the effects of a hydrogen peroxide (H_2O_2)-based lens care solution and a polyhexamethylene biguanide (PHMB) multi-purpose solution on the eyelids when used with silicone hydrogel (SiHy) contact lenses.

Methods: A total of 74 symptomatic wearers of ACUVUE® OASYS® (senofilcon A; n = 39) or PureVision® (balafilcon A; n = 35) contact lenses were randomised 1:1 to either CLEAR CARE® Cleaning & Disinfecting Solution or renu® fresh™ multi-purpose solution (n = 37 each). Assessments of hyperaemia, papillae and lid margin staining of eyelid tissue were evaluated subjectively by a masked investigator at enrolment (with the subjects' habitual SiHy contact lenses and PHMB-preserved care systems), at dispensing visit (when no lenses were worn) and at 3-months' follow-up.

Results: There were no differences in eyelid assessments between the two lens care groups at dispensing visit ($p = 0.086$ to 0.947). After 3 months, the papillae response was significantly less marked with H2O2-based solution than with PHMB-based solution ($p = 0.017$). Lid hyperaemia ($p < 0.001$) and papillae ($p = 0.002$) were also significantly reduced. Although lid hyperaemia was also reduced with PHMB-based solution ($p < 0.001$), there was no concurrent decrease in papillae response ($p = 0.051$). No improvements were found in eyelid margin staining either over time or between the two lens care groups.

Conclusion: In symptomatic contact lens wearers, a H_2O_2-based lens care solution used with senofilcon A and balafilcon A lenses was better tolerated by eyelid tissues than was a PHMB-based solution and led to a decrease in clinical markers of eyelid inflammation.

1. Introduction

Unwanted eyelid changes have been reported with daily and extended wear silicone hydrogel contact lenses [1]. The changes may be associated with the mechanical interaction between the contact lens front surface and eyelid tissue and, as such, are specific to the contact lens material and design rather than a general effect of the lens category [2]. Changes in ocular surface physiology have been associated with lens material characteristics [3,4], and are thought to be exacerbated by the presence of deposits, lipids in particular, at the contact lens surface [5,6].

The use of a hydrogen peroxide (H_2O_2) lens care solution in combination with silicone hydrogel contact lenses has been associated with a low level of corneal staining, one which is significantly lower than that observed with polyhexamethylene biguanide (PHMB)-preserved multipurpose solutions (MPS) [7–10]. PHMB-based systems have also been associated with undesirable palpebral changes [9,11,12]. H_2O_2-based lens care systems may therefore have a favourable impact on interactions between silicone hydrogel contact lenses and eyelid tissue by facilitating better wetting of the lens surface by the tear film [10,13,14]. CLEAR CARE®, an H_2O_2-based lens care system, has been reported to provide effective cleaning of the lens surface [10].

The primary objective of this investigation was to measure the effects of two different lens care systems – one H_2O_2-based, the other PHMB-based – on the integrity of eyelid tissue after 3 months' wear of daily silicone hydrogel contact lenses. A previous report assessed the effects of two lens care solutions on silicone hydrogel contact lens wettability [14]; the present article reports on the effects of the two lens care solutions on hyperaemia, papillae and lid-margin staining of the eyelid tissue when used with silicone hydrogel contact lenses.

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https://doi.org/10.1016/j.clae.2018.02.141
Received 9 October 2017; Received in revised form 28 February 2018; Accepted 28 February 2018
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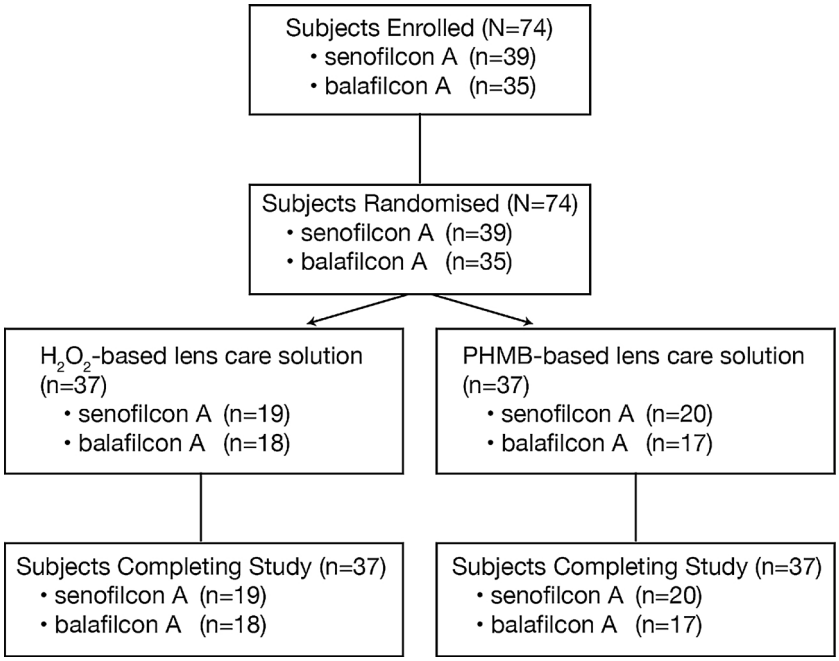

Fig. 1. Study design.

2. Materials and methods

2.1. Study products

The study methods have been described previously [14]. Briefly, this study evaluated CLEAR CARE (AOSEPT® Plus® in the UK) 3% H_2O_2 Cleaning & Disinfecting Solution (Alcon Laboratories, Inc., Fort Worth, TX, USA) and renu® fresh™ multi-purpose PHMB-containing solution (Renu MultiPlus® Fresh™ in the UK; Bausch + Lomb Incorporated, Rochester, NY, USA) in habitual wearers of silicone hydrogel contact lenses. Subjects were allowed the use of Minims® unpreserved single-dose saline (Chauvin Pharmaceuticals, Ltd, Kingston-Upon-Thames, UK) as contact lens re-wetting drops. Frequency of use was not delimited, but drop usage during contact lens wear was monitored and recorded at all follow-up visits.

2.2. Study population

The study was conducted at a single site in the UK (OCULAR TECHNOLOGY GROUP – *International*, London). The target population consisted of symptomatic daily wearers of silicone hydrogel contact lenses, aged ≥18 years, who were current users of various PHMB–preserved lens care systems. Habitual lenses worn were either ACUVUE® OASYS® (senofilcon A; Johnson & Johnson Vision Care, Inc., Jacksonville, FL, USA) replaced every 2 weeks or PureVision® (balafilcon A; Bausch + Lomb Incorporated, Rochester, NY, USA) replaced monthly.

Subjects were classified as symptomatic if they reported an average daily wear time of less than 10 h or a difference of at least 2 h between their total daily wear time and comfortable wear time at the end of the contact-lens–wear period prior to lens replacement [15]. The end of the wear period was determined to be 11 to 17 days after replacement for the 2-week contact lenses and 25 to 35 days after replacement for the monthly replacement contact lenses.

2.3. Study design

This was a two-arm, prospective, randomised, investigator-masked, controlled, bilateral interventional study in which the H_2O_2-based solution served as the test component and the PHMB-based solution as the control.

Based on the results of a Phase 1 pilot section of this study and the ensuing sample size calculations summarised below, a total of 80 subjects (40 subjects in each lens care group) was enrolled with a view to achieve a cohort population of 70 (35 in each group). The recommended sample size will achieve: (i) a differentiation of 20% incidence in slight or less median hyperaemia, mild or less maximum hyperaemia for the effect of the study lens care system after three months of use and between the test and reference lens care systems after three month of use; (ii) a differentiation of 1 mm^2 staining of the lower eyelid for the effect of the study lens care system after three months of use and of 2 mm^2 staining of the lower eyelid between the test and reference lens care systems after three month of use.

At the enrolment visit, subjects were assessed for their eligibility to participate in the study while wearing their habitual silicone hydrogel contact lenses for at least six hours and having been using their habitual PHMB-based lens care system. Clinical measurements were conducted by an investigator masked to the lens care system. If the criteria were met, baseline measurements were performed and subjects were scheduled to attend the dispensing and remaining study visits.

For the dispensing visit, subjects were instructed to not wear their habitual contact lenses on the day prior to, or the day of the visit. After this 1 day washout or recovery period without contact lens wear and prior to insertion of the new lenses, subjects were provided with a new pair of senofilcon A or balafilcon A silicone hydrogel contact lenses (with updated prescription if required) and randomised 1:1 to exclusive use of one of the two study lens care systems (Fig. 1). Measurements were carried out with the new contact lenses, and all subjects were instructed to wear the dispensed contact lenses daily for a minimum of 6 h per day every day for the duration of the period of wear if possible (minimum 5 days per week). This approach was adopted to reproduce current clinical practice. During the study, subjects continued to wear their habitual senofilcon A or balafilcon A contact lenses daily, replacing them every 2 weeks or monthly as applicable.

All subjects were scheduled to attend four follow-up visits: after 2 weeks, 1 month, 2 months, and 3 months. Lenses were replaced at all follow-up visits and in between the visits to ensure that the 2-week replacement lenses had been worn for 14 ± 3 days and the monthly

replacement lenses for 30 ± 5 days. At each follow-up visit, subjects were required to have worn the study contact lenses at least 6 h on that day [12].

2.4. Measurement procedures

Measurements were performed at enrolment (baseline), dispensing and each of the scheduled follow-up visits. Eyelid tissue was assessed at 25× magnification with a slit-lamp biomicroscope. Three parameters were recorded: hyperaemia, papillae and lid-margin staining. Hyperaemia was evaluated independently in three zones of the upper lid and overall for the lower lid under white diffuse lighting and classified on a five-point scale (0 = Clear; 1 = Slight redness; 2 = Mild redness; 3 = Moderate redness; 4 = Severe redness). Median hyperaemia, representing the overall response, was based on grading of each of the four zones. Measurements of maximum hyperaemia represented the worst responses, as they are often used as the basis of clinical management. Upper and lower lid-margin staining was evaluated under the same lighting conditions after the instillation of lissamine green dye. Two staining parameters were recorded to describe the staining: *type* of staining, using a four-point scale (0 = None; 1 = Broken line; 2 = Thin line; 3 = Thick line/Patch) and *severity* of staining, using a five-point scale (0 = None; 1 = Slight; 2 = Mild; 3 = Moderate; 4 = Severe). Papillae were assessed under blue cobalt lighting after the instillation of sodium fluorescein dye. The severity of papillae was recorded on a five-point scale (0 = None; 1 = Slight [diffuse papillae]; 2 = Mild [diffuse and tufts papillae]; 3 = Moderate [moderate and tufts papillae]; 4 = Severe [giant papillae]) independently for three zones of the upper lid and overall for the lower lid. Papillae were reported as the median number of papillae in each of the four zones, representing the overall response, and as maximum papillae, representing the worst response.

Safety assessments included Snellen distance visual acuity, slit-lamp biomicroscopy of other ocular tissues and adverse events.

2.5. Study endpoints

The primary clinical efficacy endpoint was eyelid tissue integrity, assessed as redness (hyperaemia), papillae and lid-margin staining.

2.6. Statistical method

The data analysis was carried out using SPSS 19.0 (IBM UK Ltd., Portsmouth, UK). The data recorded at the enrolment visit, with the subjects' habitual contact lenses and PHMB-based care system, and at the dispensing visit, when no lenses had been worn for 24 h, were the reference data used to determine the efficacy of the two study lens care systems. For each parameter of interest, comparative statistical analyses were performed on the change from enrolment and from dispensing, using Wilcoxon signed-ranks tests with a 0.050 significance level, to test the alternate hypothesis that the changes observed between the time points were significant. Further, comparisons of the data collected at the 3-month visit with the test lens care system (H_2O_2-based) and the data gathered at the 3-month visit with the control lens care system (PHMB-based) were compared by independent-sample Mann-Whitney U-Tests to assess the relative performance of the two lens care systems.

The experimental protocol was reviewed and approved by the Independent Ophthalmic Ethics Committee in London, UK. The study complied with the requirements of the Declaration of Helsinki and the Data Protection Act in the UK. All subjects were given written information about the study and signed the consent form at the enrolment visit, prior to any assessment being carried out.

3. Results

3.1. Study population

A total of 74 subjects were enrolled according to the protocol and randomly allocated 1:1 to either the test H_2O_2-based solution or the control PHMB-based solution (n = 37 each). The two study groups were well matched for age and gender. The mean ages of subjects in the H_2O_2-based and the PHMB-based groups were 34.8 ± 9.8 years and 35.5 ± 10.5 years, respectively, and 57% and 68%, respectively, of the subjects in these two groups were women.

All subjects were habitual, symptomatic wearers of senofilcon A (n = 39) or balafilcon A (n = 35) silicone hydrogel soft contact lenses. The distribution of lens brands was close to 1:1, with slightly more senofilcon A wearers in both the H_2O_2 (n = 19; 51%) and PHMB (n = 20; 54%) groups. The mean wear times (11.5 vs. 11.4 h) and the mean comfortable wear times (8.0 h vs. 8.5 h) were similar in both groups.

Two subjects were discontinued prematurely for non-study–product related reasons: one due to a non-ocular event and one (prior to randomization) due to relocation. Sixteen adverse events were recorded during the study, as previously described [14]. Six events were non-ocular, of which two were serious adverse events, and ten were ocular, of which seven were study product related: six were in the CLEAR CARE® group (four toxic reaction and two bacterial conjunctivitis) and one in the renu® fresh™ group (corneal erosion). All adverse events resolved prior to study exit and all the subjects completed the study. None of the adverse events reported invalidated the data recorded.

The daily contact lens wear times for subjects in both lens care groups were similar and remained unchanged throughout the study period. The average number of days of contact lens wear ranged from 6.0 and 6.4 days per week, and the average daily wear time ranged from 11.6 to 12.0 h per day. In the senofilcon A group (2-week planned replacement), the average lens age at follow-up visits varied from 12.9 to 13.6 days. For the balafilcon A group (monthly planned replacement), the mean lens age at all but the 2-week follow-up visit was between 27.4 and 28.7 days. None of the subjects in the two groups reported using rewetting eye drops after the 2-week visit (data not shown).

3.2. The effects of lens care solutions on eyelid tissue

3.2.1. Hyperaemia

In the H_2O_2 group, both median and maximum eyelid hyperaemia responses ($p < 0.001$ each) were significantly lower at 3 months than at baseline. These decreases were associated with changes in the distribution of both the median and maximum responses. Assessments of the median hyperaemia response showed that more eyes were graded as 1/slight hyperaemia (baseline, 28%; 3 months, 43%) and fewer eyes were graded as > 2/mild or moderate hyperaemia (baseline, 22%; 3 months, 3%) at 3 months than at baseline. Similarly, evaluation of the maximum hyperaemia response resulted in more eyes being graded as 1 (baseline, 12%; 3 months, 23%) and fewer eyes as > 2 (baseline, 42%; 3 months, 23%; Fig. 2). Remarkably, the median ($p = 0.016$) and maximum ($p < 0.001$) hyperaemia ratings were significantly lower at 3 months than at the dispensing visit (i.e., after 1 day without lens wear or habitual PHMB-based solution use) and were again associated with similar changes in median and maximum hyperaemia. For the median response, there was a decrease in the percentage of grades ≥ 2 (dispensing, 56%; 3 months, 46%). For the maximum response, there was a decrease in the percentage of eyes graded as ≥ 3 (dispensing, 43%; 3 months, 23%; see Fig. 2).

In the group that received the control PHMB-based MPS, eyelid hyperaemia was also significantly lower at 3 months follow-up than at baseline (median, $p = 0.03$; maximum, $p < 0.001$). This decrease was associated with changes in the distribution of both the median and maximum responses. The change in median response was principally

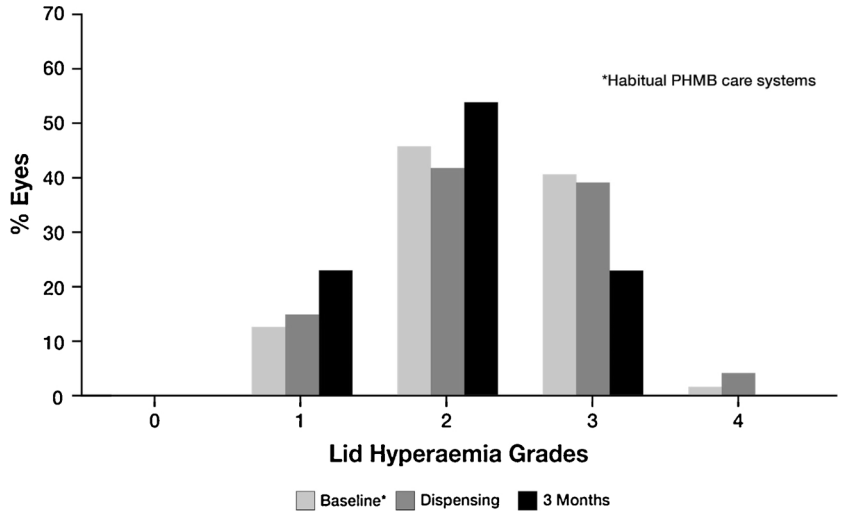

Fig. 2. Maximum lid hyperaemia distribution at enrolment, dispensing, and 3-month follow-up visits with the H_2O_2-based lens care system.

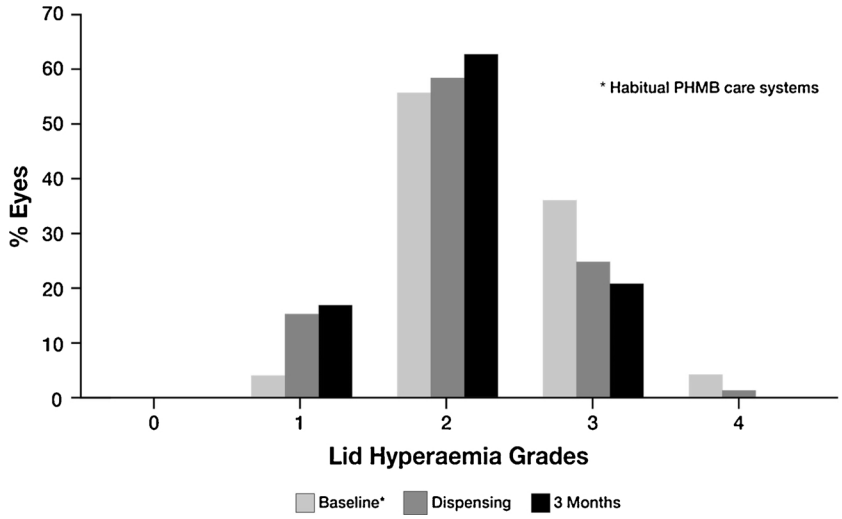

Fig. 3. Maximum lid hyperaemia distribution at enrolment, dispensing, and 3-month follow-up visits with the PHMB-based lens care system.

due to a reduction in the percentage of eyes graded as > 2 at 3 months than at baseline (18% vs 8%, respectively). Evaluation of the maximum hyperaemia response showed that more eyes were graded as 1 (baseline, 4%; 3 months, 17%) and fewer eyes as > 2 (baseline, 40%; 3 months, 21%; Fig. 3). However, there were no significant differences between the hyperaemia response at 3 months and at dispensing (median, $p = 0.506$; maximum, $p = 0.289$).

3.3. Lid-margin staining

The use of the H_2O_2-based solution for 3 months did not alter the type or severity of upper or lower eyelid-margin staining compared with eyelid-margin staining at baseline (staining type: $p = 0.180$ and 0.317 for upper and lower eyelids, respectively; staining severity: $p = 0.483$ and 0.515 for upper and lower eyelids, respectively) or at dispensing (staining type: $p = 0.257$ and 0.405; staining severity: $p = 0.780$ and 0.317 for upper and lower eyelids, respectively). At all visits, the type of staining observed was overwhelmingly a "Thick line/Patch" staining (upper lid: 88% to 97%; lower lid: 78% to 93%) and the severity of staining was, in the majority of cases, rated as ≥ 3/moderate-severe (upper lid: 83% to 92%; lower lid: 78% to 88%) across all follow-up visits and dispensing.

Similarly, the use of the control PHMB-based solution for 3 months was not associated with changes in either the type or severity of upper or lower eyelid-margin staining compared with staining at baseline (staining type: $p = 1.000$ and 0.509; staining severity: $p = 0.171$ and 0.144 for upper and lower eyelids, respectively). Comparisons of eyelid-margin staining at 3 months and at dispensing showed that staining type differed significantly in the lower lid ($p = 0.031$) but not the upper lid ($p = 0.317$), whereas staining severity was similar in both the upper ($p = 0.562$) and lower ($p = 0.086$) eyelids. The difference in staining type of the lower lid was due to the difference in "Thick line/Patch" staining at dispensing (79%) and at 3 months (92%). The severity of staining was generally rated as moderate or severe (≥ grade 3; upper lid: 77% to 92%; lower lid: 69% to 89%) across all follow-up visits.

3.4. Papillae

For the group that received the tested H_2O_2-based solution, the median papillae grades recorded at baseline and 3 months were similar ($p = 0.178$); however, grading of the maximum (worst) papillae decreased significantly ($p = 0.002$). The latter effect was associated with changes in the distribution of the maximum responses, including an increase in the percentage of eyelids graded as ≤ 1/slight or no papillae (baseline, 34%; 3 months, 41%) and a decrease in the percentage of eyelids graded as ≥ 2/mild, moderate or severe papillae (baseline, 30%; 3 months, 15%; Fig. 4). Further, the median and maximum grades of papillae at the 3-month follow-up visit were significantly lower

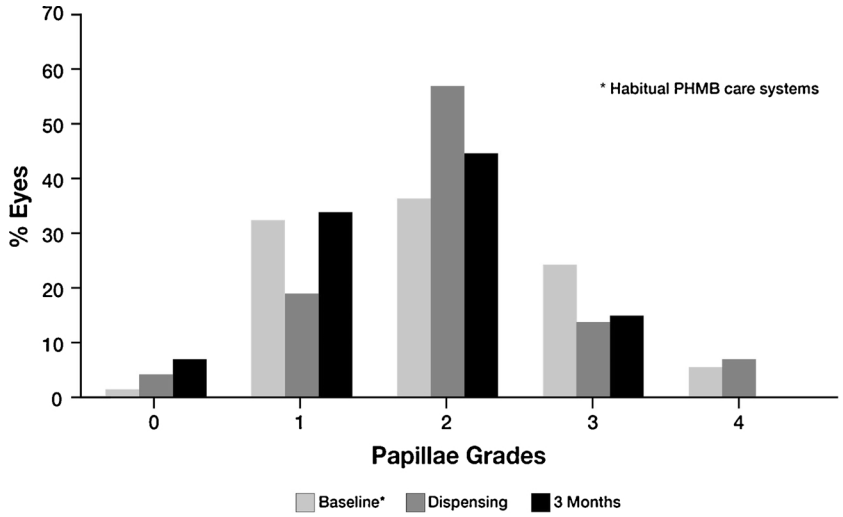

Fig. 4. Maximum papillae distribution at enrolment, dispensing, and 3-month follow-up visits in patients using the H_2O_2-based lens care system.

(median, $p = 0.012$; maximum, $p = 0.001$) than they were at dispensing and were associated with changes in the distribution of median and maximum responses. The percentage of eyelids with median papillae grades of ≤ 1 was higher at 3 months (dispensing, 23%; 3 months, 41%), and for papillae grades of ≥ 2 (dispensing, 26%; 3 months, 8%) was lower at 3 months than at dispensing. For the maximum response at 3 months, more eyelids were graded as ≤ 1 (dispensing, 23%; 3 months, 41%) and fewer eyelids as ≥ 2 (dispensing, 77%; 3 months, 59%; see Fig. 4).

By contrast, use of the control PHMB-based solution for 3 months did not produce significant improvement in the appearance of papillae compared with papillae at baseline (median, $p = 0.062$; maximum, $p = 0.051$) or at dispensing (median, $p = 0.727$; maximum, $p = 0.400$). Throughout the 3-month study, the most commonly observed maximum papillae in the control PHMB group was grade 2 (mild).

3.5. Relative performance of lens care solutions

At the dispensing visit, a comparison of the eyelid status prior to contact lens insertion revealed no significant differences between the H_2O_2-based and PHMB-based groups for hyperaemia (median, $p = 0.634$; maximum, $p = 0.086$), lid-margin staining ($p = 0.628$ to 0.914) or papillae (median, $p = 0.832$; maximum, $p = 0.515$). These findings indicate that the eyelid status of the two lens care solution groups was similar before dispensing of the study solutions and that any difference at the end of the 3 months could be due to the differential effect of the two study solutions.

At the 3-month follow-up visit, hyperaemia (median, $p = 0.837$; maximum, $p = 0.706$) and lid-margin staining ($p = 0.071$ to 0.616) were similar in the two lens care groups. However, the median papillae response was significantly less marked with the H_2O_2-based solution than with the PHMB-based solution ($p = 0.017$); the difference was associated with a higher rate of non-clinically significant papillae (grades 0.0 and 0.5: H_2O_2-based, 24%; PHMB-based, 10%) and a lower rate of mild or more severe papillae (grades ≥ 2: H_2O_2-based 8%; PHMB-based 20%; Fig. 5).

4. Discussion

The objective of the study was to investigate the potential benefits on eyelid tissues of using a preservative free H_2O_2 based lens care system relative to using PHMB-preserved lens care system for current symptomatic silicone hydrogel contact lens wearers. The effect on the eyelid tissues, which was assessed by rating hyperaemia, lid-margin staining and papillae, clearly supported the working hypothesis for this study that three months use of H_2O_2 would improve the eyelid tissue status. The improvements observed were principally inflammatory with a significant decrease in eyelid hyperaemia and papillae, but no change in lid-margin staining, though to be a marker of mechanical damage. In contrast, only a small improvement in hyperaemia was recorded by the PHMB users in the control group who showed no improvement in either papillae or staining.

The present study hypothesized that the use of an H_2O_2-based lens care system without preservatives would have beneficial effects on the eyelid tissue of current symptomatic silicone hydrogel contact lens wearers who had previously used a range of PHMB-preserved lens care systems. The findings of the current study clearly support the hypothesis that 3 months' use of the H_2O_2-based lens care system can produce significant improvements in the appearance of eyelid tissue. One possible confounding explanation could be a Hawthorne effect; that is, subjects are liable to modify their behaviour (e.g., follow the lens care system more rigorously than habitually) when they are aware that they are part of an experiment. For this reason, a PHMB contemporaneous control, renu® fresh™, was introduced into this study. Although the latter solution showed limited positive effects, the improvement with the H_2O_2-based system was substantially greater; hence, supporting the hypothesis.

Hyperaemia and papillae are two clinical markers of eyelid inflammation [16]. Use of H_2O_2-based lens care for 3 months positively modified both markers. Overall (median) eyelid hyperaemia was judged to be no more than "slight" in one-half of all eyes compared with one-third of eyes at the study outset. In addition, the presence of hyperaemia graded as "moderate" or worse was practically eliminated (3%) after 3 months compared with approximately 20% at the study outset. Both the median and maximum (worst) levels of hyperaemia that were observed in any eyelid region were significantly lower at 3 months than at the (non-lens–wearing) dispensing visit. The reason for this difference may be attributed to more time being required for the resolution of this chronic condition. Eyelid papillae were significantly less marked at 3 months than at both the enrolment and the dispensing visits; specifically, the percentages of eyelids with at least "moderate" papillae at the 3-month visit were one-half and one-quarter that at baseline and dispensing, respectively.

By contrast, the use of the control PHMB-based system was associated with decreases in moderate or worse median hyperaemia from 18% to 8% and moderate or worse maximum hyperaemia from 40% to 21% between the dispensing and 3-month visits, with neither of these decreases being statistically significant. In addition, 3 months' use of the PHMB-based lens care did not result in changes in median or maximum papillae compared with both the enrolment and the

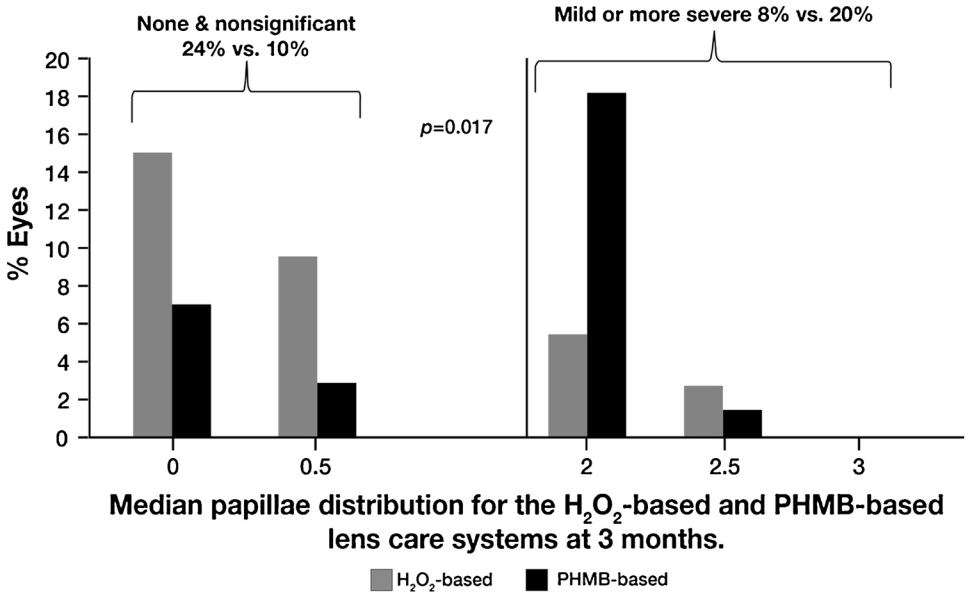

Fig. 5. Median papillae distribution at 3-month follow-up visit in patients using the H_2O_2-based and PHMB-based lens care systems.

dispensing visits. These findings also were supported by the significantly less marked papillae response at 3 months in users of the H_2O_2-based lens care system compared with users of the PHMB-based system.

In previous studies, palpebral changes have been associated with the use of MPSs containing PHMB [9,11,12]. Early preservatives in contact lens solutions, such as thimerosal and chlorhexidine, have a causative role in the development of papillary lid changes [17,18].

Several earlier studies evaluated the effects of silicone hydrogel contact lenses and H_2O_2-containing lens care systems on eyelid tissue. For example, a 2-year prospective study evaluated the effects on eyelid tissue of senofilcon A lenses, worn daily and replaced every 2 weeks, and four lens care systems in 58 wearers of soft contact lenses and 32 previous non-wearers, with 42 and 22, respectively, completing the study [19]. Lid hyperaemia in both previous contact lens wearers and non-wearers was significantly different at 2 years compared with baseline, indicating improved lid responses. Papillae differed significantly at baseline and at 24 months in contact lens wearers, but were similar in non-wearers. There were no differences reported among the four lens care systems.

A second study tested the effects of 3 months' use of an H_2O_2-based lens care solution on lid papillae and symptoms in symptomatic soft contact lens wearers with at least mild papillae who used a PHMB-containing lens care solution routinely [20]. Subjects were randomised to lens care solutions containing H_2O_2 or biguanide. The H_2O_2 group showed significantly greater improvements in lid papillae and significantly lower frequency and intensity of symptoms, including grittiness, end-of-day dryness, irritation, burning/stinging, itchiness, and blurry vision than did the biguanide-preserved group. A recent analysis utilised in vivo confocal microscopy to assess the effects on corneal epithelium of lens care solutions on wearers of lotrafilcon A contact lenses for 5 months [21]. That study found that significantly fewer subjects randomised to the H_2O_2 solution had ≥ 1 visible hyper-reflective cells compared with those randomised to the biguanide solution.

No differences in either upper or lower eyelid-margin staining were found during the study. Eyelid-margin staining has been reported to be more prevalent in symptomatic contact lens wearers. Because the aetiology of this staining is most likely to be mechanical in nature, it is not surprising that eyelid staining did not change in this group of symptomatic silicone hydrogel lens wearers, as the contact lenses worn during the study were the same as those worn habitually. Consistent with the findings in the present study, Schulze et al. found no clinically meaningful differences in lid wiper epitheliopathy (marginal conjunctiva of the lid) between the multi-purpose solutions and hydrogen peroxide solution for the contact lens types studied [22].

In an analysis of lens wettability in wearers of senofilcon A and balafilcon A contact lenses who habitually used a biguanide-containing lens care solution, subjects were randomised into two groups [14]. One group continued to use with their habitual lens care solution, while the other used an H_2O_2-containing solution, for 3 months. Pre-lens non-invasive break-up time and visible deposits were assessed with the Tearscope. After 3 months, the H_2O_2-containing solution showed a significant improvement in lens wettability compared with the biguanide solution and compared with baseline. In contrast, use of the biguanide solution for 3 months did not improve wettability over baseline. Moreover, use of the H_2O_2-containing solution for 3 months resulted in a cleaner contact lens surface than at baseline, with significant reductions in lipid and mucus deposits. In contrast, the biguanide solution did not significantly reduce lipid or mucus deposits [14]. The association of the findings of the current study with those of the analysis of the contact lens wettability of the same group of subjects is the first set of evidence that links better on eye contact lens wettability with lesser papillary changes. The combination of the two sets of data supports the hypothesis that improving on eye wettability, minimizes the mechanical interaction between the contact lens anterior surface and the palpebral tissue leading to better tissue tolerance.

5. Conclusion

The silicone hydrogel contact lenses senofilcon A and balafilcon A were apparently better tolerated by eyelid tissue when used in conjunction with the H_2O_2-based than with the PHMB-based MPS lens care solution. After 3 months, fewer papillae were observed with the H_2O_2-based lens care solution than with the PHMB-based MPS, and the H_2O_2 lens care solution was associated with a decrease in the investigator-graded subjective ratings of eyelid hyperaemia and papillae compared with the subjects' habitual PHMB-based care systems measured at enrolment and prior to insertion of the study contact lenses at dispensing. Together, these findings suggest a decrease in eyelid inflammation. Although the use of the PHMB-based solution also improved hyperaemia, there was no concurrent decrease in papillae response. These findings strongly suggest that symptomatic wearers of silicone hydrogel contact lens who use a PHMB-preserved lens care solution may benefit

from changing to a preservative-free H_2O_2-based lens care system, as shown by improvements in the inflammatory status of their eyelid tissue. Conjunctival physiology, including eyelid papillae and hyperaemia, may be important factors to consider for successful contact lens wear.

Acknowledgements

The authors wish to acknowledge the contribution of Kathryn Dumbleton in developing this manuscript. Editorial support was provided by BelMed Professional Resources, Inc.

References

[1] C.C. Skotnitsky, T.J. Naduvilath, D.F. Sweeney, P.R. Sankaridurg, Two presentations of contact lens-induced papillary conjunctivitis (CLPC) in hydrogel lens wear: local and general, Optom Vis Sci 83 (2006) 27–36.
[2] M.C. Lin, T.N. Yeh, Mechanical complications induced by silicone hydrogel contact lenses, Eye Contact Lens 39 (2013) 115–124.
[3] K. Sapkota, S. Franco, M. Lira, Daily versus monthly disposable contact lens: which is better for ocular surface physiology and comfort, Contact Lens Anterior Eye (December) (2017) 0484–S1367, http://dx.doi.org/10.1016/j.clae.2017.12.005.
[4] C. Maldonado-Codina, P.B. Morgan, C.M. Schnider, N. Efron, Short-term physiologic response in neophyte subjects fitted with hydrogel and silicone hydrogel contact lenses, Optom Vis Sci 81 (12) (2004) 911–921.
[5] P. Ramamoorthy, J. Nichols, Clinical and contact lens deposition characteristics of contact lens wearers with and without dry eye, Optom Vis Sci 92 (2014) e–140056.
[6] M. Glasson, F. Stapleton, M. Willcox, Lipid, lipase and lipocalin differences between tolerant and intolerant contact lens wearers, Curr Eye Res 25 (2002) 227–235.
[7] G. Andrasko, K. Ryen, Corneal staining and comfort observed with traditional and silicone hydrogel lenses and multipurpose solution combinations, Optometry 79 (2008) 444–454.
[8] N. Carnt, M.D.P. Willcox, V. Evans, T.J. Naduvilath, D. Tilia, E.B. Papas, et al., Corneal staining: the IER matrix study, Contact Lens Spectrum 22 (2007) 142.
[9] G. Young, N. Keir, C. Hunt, C.A. Woods, Clinical evaluation of long-term users of two contact lens care preservative systems, Eye Contact Lens 35 (2009) 50–58.
[10] C. Amos, Comparing lens care systems for silicone hydrogel contact lenses, Contact Lens Spectrum 22 (2007) 145.
[11] T. Lofstrom, J.S. Anderson, A. Kruse, Tarsal abnormalities: a new grading system, CLAO J 24 (1998) 210–215.
[12] L.A. Hall, R.J. Garofalo, G. Young, A clinical comparison of three contact lens care system used in conjunction with senofilcon A, lotrafilcon A, and comfilcon A daily wear lenses, Optom Vis Sci 87 (2010) e–105358.
[13] R. Chalmers, B. Long, S. Dillehay, C. Begley, Improving contact-lens related dryness symptoms with silicone hydrogel lenses, Optom Vis Sci 85 (2008) 778–784.
[14] M. Guillon, C. Maissa, S. Wong, T. Patel, R. Garofalo, Effect of lens care system on silicone hydrogel contact lens wettability, Contact Lens Anterior Eye 38 (2015) 435–441.
[15] K.A. Dumbleton, M. Guillon, P. Theodoratos, T. Patel, Diurnal variation in comfort in contact lens and non-contact lens wearers, Optom Vis Sci 93 (2016) 820–827.
[16] C. Kilduff, C. Luis, Red eyes and red-flags: improving assessments and referral in primary care, BMJ Qual Improv Rep 1 (2016) 1–8.
[17] H.W. Roth, Studies on the etiology and treatment of giant papillary conjunctivitis in contact lens wearers, CLAO J 18 (1992) 72.
[18] L. Jones, C.H. Powell, Uptake and release phenomena in contact lens care by silicone hydrogel lenses, Eye Contact Lens 39 (2013) 29–36.
[19] M. Guillon, C. Maissa, Long term effects of the daily wear of senofilcon A silicone hydrogel contact lenses on eyelid tissues, Contact Lens Anterior Eye 35 (2012) 112–117.
[20] C.S. Lievens, S. Kannarr, L. Zoota, J. Lemp, Lid papillae improvement with hydrogen peroxide lens care solution use, Optom Vis Sci 93 (2016) 933–942.
[21] X. Zhang, C. Marchetti, J. Lee, Y. Sun, S. Debanne, Y. Jiang, et al., The impact of lens care solutions on corneal epithelial changes during daily silicone hydrogel contact lens wear as measured by in vivo confocal microscopy, Contact Lens Anterior Eye 40 (2017) 33–41.
[22] M.M. Schulze, S. Srinivasan, S.B. Hickson-Curran, et al., Lid wiper epitheliopathy in soft contact lens wearers, Optom Vis Sci 93 (2016) 943–954.