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# In vitro uptake and release studies of ocular pharmaceutical agents by silicon-containing and p-HEMA hydrogel contact lens materials

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**Abstract**

The in vitro uptake and release behaviour of cromolyn sodium, ketotifen fumarate, ketorolac tromethamine and dexamethasone sodium phosphate with silicon-containing (lotrafilcon and balafilcon) and p-HEMA-containing (etafilcon, alphafilcon, polymacon, vifilcon and omafilcon) hydrogel contact lenses indicated that both drug and material affected the uptake and release behaviour. Rapid uptake and release (within 50 min) was observed for all drugs except ketotifen fumarate which was more gradual taking approximately 5 h. Furthermore, the maximum uptake differed significantly between drugs and materials. The highest average uptake (7879 ± 684 μg/lens) was cromolyn sodium and the lowest average uptake (67 ± 13 μg/lens) was dexamethasone sodium phosphate. Partial release of the drug taken up was observed for all drugs except dexamethasone sodium phosphate where no release was detected. Sustained release was demonstrated only by ketotifen fumarate. Drug uptake/release appeared to be a function of lens material ionicity, water and silicon content. The silicon-containing materials released less drug than the p-HEMA-containing materials. The lotrafilcon material demonstrated less interactions with the drugs than the balafilcon material which can be explained by their different bulk composition and surface treatment.
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## 1. Introduction

The potential for soft contact lenses to deliver drugs to the eye was first described by Sedlacek (1965). Since then, many studies have investigated the ability of contact lenses to improve the corneal penetration and bioavailability of topically applied pharmaceutical agents (Silbert, 1996). Two approaches are typically taken. In the first method, lenses are soaked in the drug solution for a period of time and then placed on the eye, resulting in a high initial release, followed by a slower, long-term release during the next hours to days of lens wearing time. This method is commonly employed with antibiotics and non-steroidal anti-inflammatory drugs (NSAIDs) postoperatively, and with antibiotics for severe infections (Silbert, 1996). Alternatively, a topical drug can be applied over the lens while the lens is in situ. This is often the

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approach taken when a patient is wearing a contact lens as a protective device (bandage lens) following a corneal injury or serious infective complication, in which case a lens is used as a shield or "bandage lens" to assist in corneal repair (Hovding, 1984; Lindahl et al., 1991; Tanner and DePaolis, 1992). The lens takes up some of the drug from the tear film and then acts as a reservoir, slowly releasing the drug into the tears as the overall concentration of the drug in the tear film declines (Lesher and Gunderson, 1993). Both these approaches prolong the contact time of the drug with the cornea (Hehl et al., 1999) and thus improve penetration of drugs through the cornea (Bawa, 1993).

Pre-soaking the lens in a drug solution, for a period from 2 min to 24 h, results in drug uptake varying from 0.02 to 2.3 mg/lens for ionic materials and 0.01–5.53 mg/lens for non-ionic materials (Lesher and Gunderson, 1993; Veys and Davies, 1996; Lumbroso et al., 1996; Momose et al., 1997). For poly-hydroxyethyl methacrylate (p-HEMA) lenses, the amount of drug uptake remains constant for soaking times above 10 min (Podos et al., 1972). While the drug uptake onto the lenses is generally rapid, the release occurs over differing time spans and at variable levels. For both in vitro and in vivo studies, a pulse-like (burst) or dose-dumping release of the drug from the lenses has generally been observed. For example, prednisolone was entirely released from helfilcon lenses within 1 h (Hull et al., 1974; Lesher and Gunderson, 1993). Pilocarpine release from lidofilcon lenses (Ruben and Watkins, 1975) and tobramycin from vifilcon lenses (Podos et al., 1972) occurred over an 8 h time period. Ciprofloxacin, cromolyn sodium, idoxuridine, pilocarpine and prednisolone release from vifilcon, etafilcon and polymacon materials was achieved after 15 min to 3 h. A partial release was observed for levocabastine and benzalkonium hydrochloride (BAK) from tefilcon and perfilcon lenses (Momose et al., 1997) and for BAK and chlorhexidine gluconate from polymacon (Lumbroso et al., 1996). Irreversible binding was observed for sulfacetamide and fluorescein from perfilcon lenses (Miranda and Garcia-Castineiras, 1983). A number of studies have demonstrated the value of combining drugs with hydrogel materials to enhance ocular drug delivery. Pre-soaked lenses were more effective in vivo than topical drops alone for a number of combinations, including pilocarpine/vifilcon (Podos et al., 1972), prednisolone sodium sulfate/helfilcon A (Hull et al., 1974), pilocarpine/lidofilcon (Hillman, 1974; Marmion and Jain, 1976) and ciprofloxacin/vifilcon (Kalayci et al., 1999). Pre-soaked lenses were more effective than topical drops with the lens already in situ for pilocarpine/lidofilcon and pilocarpine/p-HEMA (Ruben and Watkins, 1975).

Conventional soft lens materials based on poly-hydroxyethyl methacrylate (p-HEMA) have generally been selected as therapeutic/bandage lenses but have shown moderate success due to their limited wearing time and poor oxygen permeability. The recent introduction of silicon-containing hydrogel contact lens materials with significantly higher oxygen permeabilities than conventional p-HEMA-based materials has resulted in a new range of soft contact lens materials available to practioners (Tighe, 2000). These materials may represent a better option for practioners to use as bandage and therapeutic lenses, as these materials transmit significantly greater amounts of oxygen and are better suited to overnight use. To date, there exists no published data on uptake and release of ocular pharmaceuticals from these silicon-containing hydrogel contact lenses.

The aim of this study was to determine the feasibility of using silicon-containing hydrogel contact lenses as bandage and therapeutic lenses, when they would be used in combination with ocular pharmaceuticals. To achieve this, we evaluated the ability of two silicon-containing and five conventional p-HEMA containing commercial soft contact lenses to absorb and release four representative ocular medications through an in vitro study.

## 2. Materials and methods

### 2.1. Contact lenses and chemicals

Seven commercially available contact lenses (−3.00 diopter), described in Table 1, were used. The unpreserved borate buffered saline, Unisol4, was purchased from Alcon (Fort Worth, TX) and used to prepare the drug solutions. Drug release was also performed in Unisol4.

Cromolyn sodium, dexamethasone 21-phosphate disodium salt, ketotifen fumarate and ketorolac

Table 1
Contact lens material characteristics

| Commercial name (supplier) | Polymer composition | Listed water content (%) | Measured water volume[a] (ml) | Oxygen permeability (barrers[b]) | FDA category |
|---|---|---|---|---|---|
| Optima FW (Bausch & Lomb, Rochester, NY) | Polymacon p-HEMA/NVP/CMA | 38 | 0.01048 | 9 | Group I (non-ionic, low water content) |
| Focus Night & Day (Ciba Vision, Duluth, GA) | Lotrafilcon A DMA/Siloxane macromer | 24 | 0.00448 | 140 | Group I (non-ionic, low water content) |
| Soflens 66 (Bausch & Lomb, Rochester, NY) | Alphafilcon A p-HEMA/NVP/CMA | 66 | 0.0231 | 30 | Group II (non-ionic, high water content) |
| Proclear Compatibles (Biocompatibles, Norfolk, VA) | Omafilcon A p-HEMA/phosphorylcholine | 59 | 0.01741 | 22 | Group II (non-ionic, high water content) |
| PureVision (Bausch & Lomb, Rochester, NY) | Balafilcon A Siloxane macromer/NVP | 36 | 0.00956 | 99 | Group III (ionic, low water content) |
| Acuvue/Surevue (Johnson & Johnson, Jacksonville, FL) | Etafilcon A p-HEMA/MA | 58 | 0.01588 | 21 | Group IV (ionic, high water content) |
| Focus Monthly (Ciba Vision, Duluth, GA) | Vifilcon A p-HEMA/MA/NVP | 55 | 0.01588 | 19 | Group IV (ionic, high water content) |

p-HEMA, poly(hydroxy ethyl methacrylate); MA, methacrylic acid; NVP, *N*-vinyl pyrrolidone; CMA, cyclohexyl methacrylate; DMA, *N*,*N*-dimethyl acrylamide.

[a] Volume of water in the contact lens as obtained by subtracting the wet lens weight from the dry lens weight.

[b] 1 barrer $= 10^{-11}$ ($cm^3$ ml $O_2$)/(s ml mm Hg), obtained from the contact lens package inserts.

tromethamine were supplied by Sigma (Oakville, ON) and their properties are presented in Table 2. The octanol–water partition coefficient ($\log P$) for the non-ionic components of the various drugs was estimated using ACD/logD v5.0 from the ACD/I-labs service (Mississauga, ON).

### 2.2. Drug analysis

The drug concentrations were monitored by measuring the transmittance of drug solutions using a UV-visible spectrophotometer (Hitachi, Model U-2010, UV-Vis Spectrophotometer) for the appropriate wavelength (see Table 2). The wavelength was determined by choosing the most responsive and broadest peak over a full wavelength scan, which gave an appropriate calibration curve when tested over a range of drug concentrations.

### 2.3. Uptake and release studies

The uptake and release studies were performed at room temperature as follows. Each lens was removed from the packaging, dipped in saline and dabbed on a filter paper to remove excess fluid. The lens was then placed in an individual vial containing 2 ml of the uptake solution (drug). After the uptake studies the lens was removed from the vial, very gently dabbed a lens edge on a filter paper to remove excess fluid (but not to draw fluid away from the interior of the lens) and placed in 2 ml of release solution (saline). Samples were taken periodically (for at least 24 h) to produce a time-profile of drug uptake and release. The drug concentration of the uptake solution represented typical drug concentrations of ophthalmic solutions. All experiments were run in triplicate.

### 2.4. Data analysis

Statistical analysis consisted of comparison between lens materials performed using the Scheffe's multiple comparison test and comparison between groups of contact lenses performed within the multivariate analysis of variance (MANOVA) where differences were considered significant only if $P < 0.05$ (95% confidence).

## 3. Results and discussion

The pharmacological agents investigated, represent a range of drugs with different functional and physical properties as illustrated in Table 2.

### 3.1. Uptake and release kinetics

The time to reach maximum drug uptake/release was affected by the nature of the drug. Rapid uptake/release as a function of time was observed for cromolyn sodium, ketorolac tromethamine and dexamethasone sodium phosphate with all the lens materials investigated. A typical uptake/release profile is illustrated in Fig. 1. Although measurements were taken over a span of approximately 50 h, a maximum was reached within the first hour. The rapid kinetics (uptake/release) of the lens–drug systems is reasonable, since these three drugs are relatively small and the lenses have a relatively high water content. Similar rapid kinetics have been reported for vifilcon, etafilcon and polymacon lenses and cromolyn sodium, ciprofloxacin, idoxuridine, pilocarpine and prednisolone (Lesher and Gunderson, 1993).

A much more gradual uptake/release was observed for ketotifen fumarate with all the lens materials investigated. A typical uptake/release profile is illustrated in Fig. 2. Even though the same factors exist to promote fast kinetics as with the previous three drugs, the extremely dilute concentration of the drug solution (222 μg/ml) may have had an effect on the mass transfer rate of the drug to the surface of the lens. Maximum uptake occurred after approximately 5 h. Ketotifen fumarate and the various lens materials investigated in this study, constitute the only systems displaying some form of sustained drug release that would minimize the burst effect of a drug. The rate of ketotifen fumarate uptake and release was not readily modelled. Fig. 2 is representative of the behaviour of all lens materials and it is clear that the ketotifen uptake and release had a low time dependence, close to zero. This observation differs from the mechanisms reported for the release of drugs for systems where simultaneous drug uptake and hydrogel swelling was occurring. Fickian diffusion behaviour was observed for p-HEMA-co-MMA hydrogels while the Case II diffusion mechanism due to polymer relaxation (swelling) and anomalous transport (a situation involving both diffusion and polymer

Table 2
Drug characteristics

| Drug | Use | Commercial drug (concentration (mg/ml)) | Chemical formula (MW) | Aqueous solubility[a] (mg/ml) | Log $P$ (octanol/water) | Spectrophotometer absorbance wavelength (nm) |
|---|---|---|---|---|---|---|
| Cromolyn sodium | Anti-allergy | Opticrom (40) | $C_{23}H_{14}O_{11}Na_2$ (512.33) | 50 | −4.3 | 325 |
| Ketotifen fumarate | Anti-allergy | Zoditor (0.345) | $C_{19}H_{19}NOS$ (309.43) $C_4H_4O_4$ (116.07) | 0.01 | −4.5 (ketotifen) 3.2 (fumarate) | 300 |
| Ketorolac tromethamine | Non-steroid anti-inflammatory | Acular (5) | $C_{15}H_{13}NO_3$ (255.27) $C_4H_{11}NO_3$ (121.14) | 15 | −0.7 (ketorolac) −2.2 (tromethamine) | 323 |
| Dexamethasone sodium phosphate | Steroid | Maxidex (1) | $C_{22}H_{28}O_8PFNa_2$ (516.405) | 500 | N/A | 241 |

[a] Aqueous solubility was obtained from the supplier's MSDS sheets.

relaxation mechanisms) were observed for crosslinked PVA hydrogels (Brazel and Peppas, 1999a,b).

### 3.2. Uptake study

The maximum drug uptakes, presented in Table 3, indicate that both the drug and the material affected the uptake. The highest maximum uptakes were observed for cromolyn sodium, which also had the highest drug concentration in the soaking solution. The lowest maximum uptakes observed for dexamethasone sodium phosphate, may be due to the high aqueous solubility of dexamethasone sodium phosphate which would remain preferentially in solution rather than with the lens material. The maximum drug uptake for each of cromolyn sodium and dexamethasone sodium phosphate and any combination of two of the lens materials was not statistically different ($P > 0.1$). For ketotifen fumarate, there were statistical differences for the drug uptake between various combinations of two of the lens materials but no individual material was statistically different from all the other materials. For ketorolac tromethamine, the differences of uptake were significant only between the p-HEMA-containing hydrogel, alphafilcon, and the silicon-containing hydrogel, lotrafilcon ($P = 0.03$) which adsorbed the most and the least amount of ketorolac tromethamine, respectively. These differences can be explained by the water content of the two lens materials.

The uptake behaviour for each drug was also analyzed by grouping the materials according to the FDA classification (ionic/non-ionic and high/low water content) and with a third group, silicon/p-HEMA-containing materials as shown in Table 4. Similar uptake was observed for cromolyn sodium and all the groups of materials despite the hydrophilicity of cromolyn sodium. Differences were observed for dexamethasone sodium phosphate, ketorolac tromethamine and for ketotifen fumarate, where significantly higher uptake was demonstrated with the high water content materials ($P = 0.032$, $P = 0.04$ and $P < 0.000001$, respectively) and the p-HEMA-containing materials ($P = 0.002$, $P = 0.024$ and $P < 0.000001$, respectively). Furthermore, the ionic materials demonstrated a significantly higher uptake for ketotifen fumarate ($P < 0.00001$). The uptake of the silicon-containing materials was significantly lower

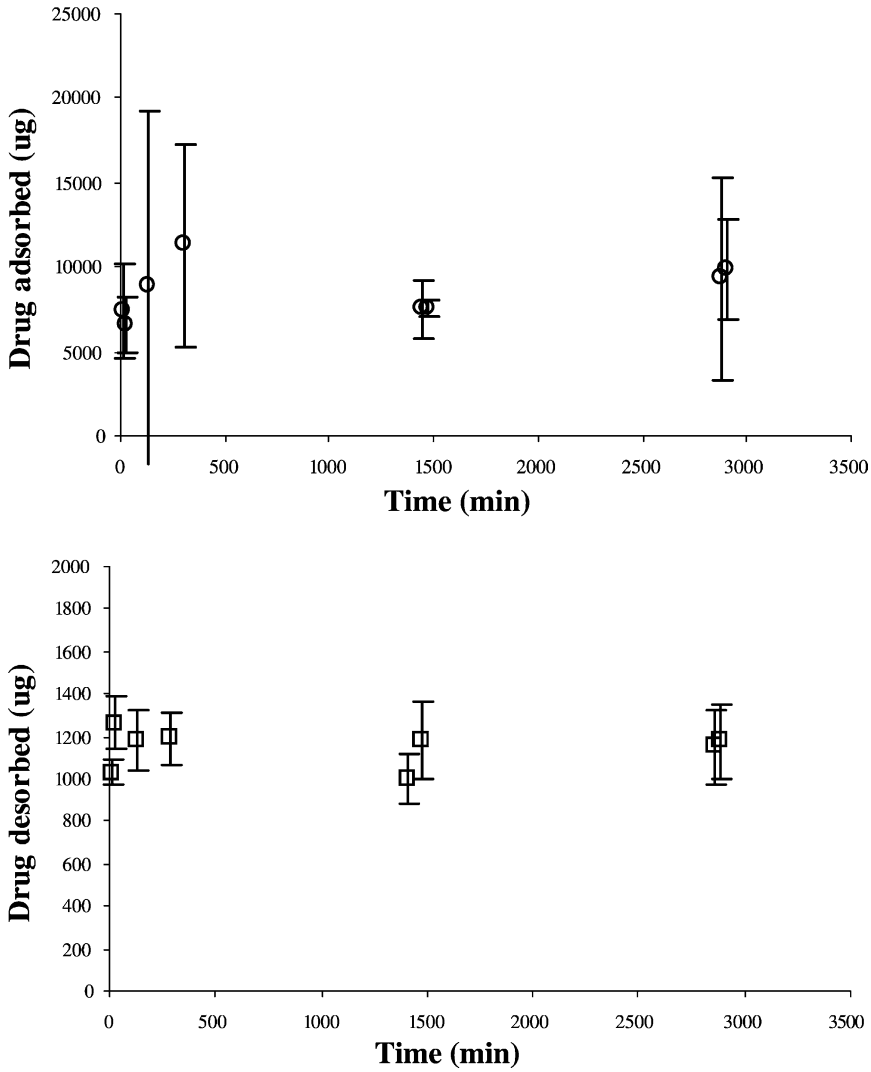


Fig. 1. Typical cromolyn sodium uptake (○) and release (□): alphafilcon.

for all of dexamethasone sodium phosphate, ketorolac tromethamine and ketotifen fumarate.

Analysis of the apparent concentrations of bound drug in the water phase of the lens materials showed that the alphafilcon material had the lowest concentration while the lotrafilcon material had the highest drug concentration regardless of the nature of the drug (Table 5). As one would expect, these materials have the highest and the lowest water content, respectively (Table 1). Furthermore, the lowest apparent concentration of cromolyn sodium and of ketotifen fumarate were higher than their reported solubility concentration (Table 2) indicating that some of the drug must be adsorbed on the material. Both dexamethasone sodium phosphate and ketorolac tromethamine, had apparent concentrations below their reported solubility concentration (Table 2). An analysis of the drug partition between the material and the soaking solution, as a measure of the material adsorption capacity for a given drug, the ratio between the maximum drug uptake and the remaining drug in the soaking solution, indicates that ketotifen fumarate has the highest

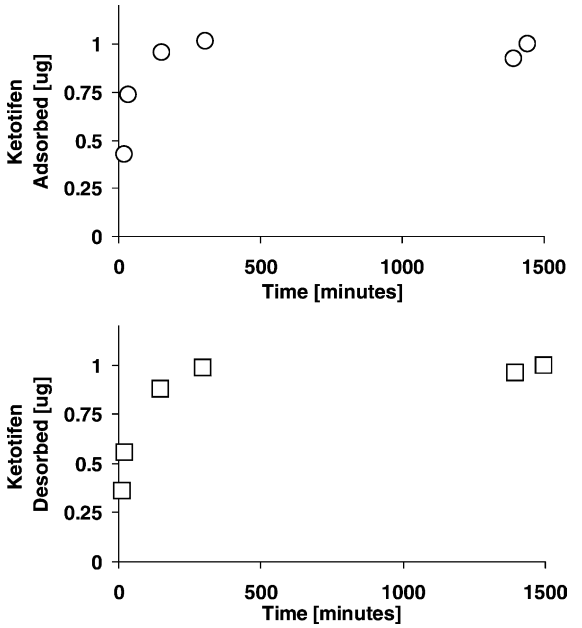


Fig. 2. Typical ketotifen fumarate uptake (○) and release (□): alphafilcon.

capacity while dexamethasone sodium phosphate has the lowest capacity. Cromolyn sodium and ketorolac tromethamine demonstrated similar intermediate partition coefficients. Previous studies for dexamethasone sodium phosphate uptake with intraocular lenses have shown a lower drug uptake for the hydrophobic polydimethylsiloxane lenses as compared to the more hydrophilic hydrogel lenses (Heyrman et al., 1989; Chapman et al., 1992).

### 3.3. Release studies

The maximum drug release, presented in Table 3, was also affected by the type of drug and the type of material both in absolute quantities and as fractional release. Only a fraction of the drug taken up was released, 12% maximum for cromolyn sodium, 1.5–28% for ketorolac tromethamine and 46–67% for ketotifen fumarate, indicating that the drugs were irreversibly bound to the lens materials. The release of dexamethasone sodium phosphate could not be evaluated due to the low concentration of drug released that was below the detection limit of the analytical technique used. A similar limitation of the analytical technique, was previously reported for the analysis of pilocarpine at low concentrations (Ruben and Watkins, 1975).

Cromolyn sodium release ranged from 125 μg/lens (lotrafilcon) to 1147 μg/lens (alphafilcon), with alphafilcon as the only material statistically different from all the other materials investigated ($P < 0.01$). The two silicon-containing hydrogel materials had significantly different release, with 125 μg/lens for lotrafilcon and 550 μg/lens for balafilcon. The cromolyn sodium release (Table 4) was significantly higher for the non-ionic materials ($P = 0.003$), p-HEMA-containing materials ($P = 0.0002$) and the high water content materials ($P = 0.000007$). The significantly higher release of cromolyn sodium

Table 3
Drug uptake and release with various lens materials over 50 h[a]

| Lens material | Drug (soaking solution concentration) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Cromolyn sodium (20 mg/ml) | | Ketotifen fumarate (0.20 mg/ml) | | Ketorolac tromethamine (0.30 mg/ml) | | Dexamethasone sodium phosphate (0.845 mg/ml) | |
| | Uptake[b] | Release[b] | Uptake[b] | Release[b] | Uptake[b] | Release[b] | Uptake[b] | Release[b] |
| Etafilcon | 7342 (2348) | 228 (65) | 213 (3) | 99 (3) | 90 (46) | 13 (10) | 67 (32) | N/A |
| Alphafilcon | 9301 (4934) | 1147 (146) | 133 (5) | 84 (2) | 123 (47) | 35 (11) | 76 (28) | N/A |
| Vifilcon | 7663 (2169) | 392 (51) | 227 (9) | 110 (2) | 107 (43) | 12 (4) | 67 (29) | N/A |
| Omafilcon | 7958 (3243) | 443 (58) | 105 (7) | 68 (2) | 110 (51) | 22 (6) | 88 (6) | N/A |
| Polymacon | 7264 (1911) | 373 (44) | 151 (2) | 87 (2) | 101 (31) | 21 (7) | 58 (21) | N/A |
| Balafilcon | 7640 (2603) | 550 (69) | 154 (3) | 99 (3) | 111 (69) | 25 (13) | 66 (33) | N/A |
| Lotrafilcon | 7981 (2031) | 125 (43) | 101 (9) | 68 (2) | 60 (42) | 0.9 (2) | 48 (25) | N/A |

[a] Maximum uptake and release values were often obtained at time much less than 50 h.
[b] μg/lens (standard deviation).

Table 4
Effect of contact lens properties on average maximum uptake and release

| Drug | Lens properties | Average uptake (μg/lens) | Average release (μg/lens) |
|---|---|---|---|
| Cromolyn sodium | Ionic vs. non-ionic | 7548 vs. 8126 | 390 vs. 522* |
| | Silicon vs. p-HEMA hydrogel | 7811 vs. 7906 | 338 vs. 517* |
| | High vs. low water content | 8066 vs. 8126 | 552 vs. 349* |
| Ketotifen fumarate | Ionic vs. non-ionic | 198 vs. 123* | 103 vs. 77* |
| | Silicon vs. p-HEMA hydrogel | 128 vs. 166* | 84 vs. 89* |
| | High vs. low water content | 170 vs. 135* | 90 vs. 85* |
| Ketorolac tromethamine | Ionic vs. non-ionic | 103 vs. 99 | 17 vs. 20* |
| | Silicon vs. p-HEMA hydrogel | 85 vs. 106* | 13 vs. 21* |
| | High vs. low water content | 108 vs. 90* | 20 vs. 16* |
| Dexamethasone sodium phosphate | Ionic vs. non-ionic | 67 vs. 68 | N/A |
| | Silicon vs. p-HEMA hydrogel | 57 vs. 71* | N/A |
| | High vs. low water content | 74 vs. 57* | N/A |

* Statistically different values at $P < 0.05$.

with non-ionic materials may be explained by the ionic nature of the drug that will not bind strongly to non-ionic materials.

Ketorolac tromethamine release was quite diverse (Table 3), with the lowest release, 0.9 μg/lens, for lotrafilcon, a silicon-containing material, and the highest release, 35 μg/lens, for alphafilcon, a p-HEMA-containing material. Both of these materials displayed significantly different release behavior than all the other materials ($P < 0.01$). The ketorolac release from balafilcon, the other silicon-containing material, was relatively high, 25 μg/lens. Significant differences of the release were observed for the ionic, the p-HEMA and the high water content materials releasing a significantly higher amount of drug (Table 4).

Ketotifen fumarate release (Table 3) ranged from 68 μg/lens (omafilcon) to 110 μg/lens (vifilcon) with the ionic, the p-HEMA and the high water content materials releasing a significantly higher amount of drug, $P < 0.00001$ (Table 4) as was observed for the uptake process.

If the drug uptake/release was affected only by the material properties, one should obtain similar differences between materials for the same experiment but using different drugs. Our experiments, however, show different trends and results for uptake and release of different drugs. This suggests that the drug properties have an effect on the mechanism of drug uptake and release. The uptake/release did not appear to be correlated with the drug hydrophilicity. Nonetheless, one observed common feature was a higher drug release for the high water content materials and the p-HEMA-containing material, regardless of the type of drug investigated. In other words, the silicon-containing materials consistently took up and released less drug. The silicon-containing material, lotrafilcon, consistently took up and released less drug than the other silicon-containing material, balafilcon. Furthermore, balafilcon displayed drug-interactions that mimic the p-HEMA-containing materials. This behaviour may be related to their differences in bulk composition and/or the surface treatment of the material. The balafilcon material is a homogeneous co-polymer. The lotrafilcon material has a core phase-separated structure, possibly resembling an inter-penetrating polymer network (IPN) with an exceedingly low water content. Further differences between the two materials reside in their surface coatings where the lotrafilcon has a chemically uniform plasma-deposited hydrophilic coating (trimethylsilane, methane, air/oxygen), while the balafilcon has a plasma-deposited coating (no precursors) displaying rounded silicate islands of varying depth, with no interconnection between the islands (Tighe, 2000). This surface heterogeneity may be responsible for the observed behaviour of balafilcon which resembles more the p-HEMA-containing materials, which also have irregular surfaces (Baguet et al., 1993; Bhatia et al., 1997). Despite their low release, the silicon-containing materials can still deliver the same amount for any of cromolyn sodium, ketotifen fumarate or ketorolac

Table 5
Drug partition coefficient[a] and drug concentration in the water phase of various lens materials

| Lens type | Cromolyn sodium | | Ketotifen fumarate | | Ketorolac tromethamine | | Dexamethasone sodium phosphate | |
|---|---|---|---|---|---|---|---|---|
| | Drug partition coefficient (mg drug/mg dry lens) | Apparent concentration of bound drug in the water phase of the lens (mg/ml) | Drug partition coefficient (mg drug/mg dry lens) | Apparent concentration of bound drug in the water phase of the lens (mg/ml) | Drug partition coefficient (mg drug/mg dry lens) | Apparent concentration of bound drug in the water phase of the lens (mg/ml) | Drug partition coefficient (mg drug/mg dry lens) | Apparent concentration of bound drug in the water phase of the lens (mg/ml) |
| Etafilcon | 0.223 | 462 | 0.922 | 13.4 | 0.1761 | 5.7 | 0.0413 | 4.2 |
| Alphafilcon | 0.301 | 402 | 0.428 | 5.8 | 0.258 | 5.3 | 0.0471 | 3.3 |
| Vifilcon | 0.235 | 482 | 1.046 | 14.3 | 0.217 | 6.7 | 0.0413 | 4.2 |
| Omafilcon | 0.246 | 457 | 0.310 | 6.0 | 0.224 | 6.3 | 0.0549 | 5.0 |
| Polymacon | 0.220 | 693 | 0.515 | 14.4 | 0.202 | 9.6 | 0.0355 | 5.5 |
| Balafilcon | 0.234 | 799 | 0.531 | 16.1 | 0.227 | 11.6 | 0.0406 | 6.9 |
| Lotrafilcon | 0.247 | 1781 | 0.294 | 22.5 | 0.111 | 13.4 | 0.0292 | 10.7 |

[a] The “drug partition coefficient” is a measure of the material adsorption capacity for a given drug and is calculated from the ratio between the maximum drug uptake and the remaining drug in the soaking solution.

tromethamine as would be obtained from a typical 50 μl eye-drop solution assuming a 7 μl tear volume.

## 4. Conclusion

The silicon-containing materials took up and released less cromolyn sodium, ketotifen fumarate, dexamethasone sodium phosphate and ketorolac tromethamine, than the p-HEMA-containing materials investigated in this study. Despite the lower uptake/release, the silicon-containing materials could release a higher amount of cromolyn sodium and ketotifen fumarate than if the drug would have been delivered by topical eye-drop solutions. Furthermore, the silicon-containing material, balafilcon displayed behaviour that is more comparable to p-HEMA-containing materials.

The drug uptake and release were affected by the type of drug and the type of material. Ketotifen fumarate, an amphiphilic antihistamine, was the only drug that demonstrated a sustained release with all the materials investigated. A wide spectrum of average drug uptake was observed with cromolyn sodium having the highest average uptake ($7879 \pm 684$ μg/lens) and dexamethasone sodium phosphate having the lowest average uptake ($67 \pm 13$ μg/lens). All drugs investigated displayed a partial release of the drug taken up except dexamethasone sodium phosphate where no release was detected.

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