

Development of a Poly-ε-Lysine Contact Lens as a Drug Delivery Device for the Treatment of Fungal Keratitis

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PURPOSE. The purpose of this study was to develop a more efficient drug delivery device to overcome the limitations of current drop therapy for the treatment of fungal keratitis.

METHODS. Amphotericin B (AmpB), 0 to 30 µg/mL, was associated with a poly-ε-lysine (pεK) hydrogel. Fungicidal effect against *Candida albicans* was assessed at 18 and 42 hours by optical density (OD₆₀₀) and growth on agar. Tear film dilution effect was mimicked by storage of AmpB pεK gels in 3.4 mL sterile PBS for 24 hours prior to fungal incubation. Drug elution over 96 hours was evaluated by HPLC, and drug stability was tested while associated with the gel by OD₆₀₀ up to 48 hours. Lack of cytotoxicity toward the HCE-T corneal epithelial cell line was assessed over 7 days.

RESULTS. AmpB pεK gels show fungicidal activity in normal conditions (0.057 OD₆₀₀, SD 0.003, $P < 0.005$) and in the presence of horse serum (0.048 OD₆₀₀, SD 0.028 $P < 0.005$) at 18 hours. The drug release profile was above therapeutic levels (0.188 µg/mL) for up to 72 hours. Tear dilution had no significant effect at higher concentrations of AmpB (3 to 10 µg/mL). AmpB pεK gels were not cytotoxic to the HCE-T cell line.

CONCLUSIONS. We demonstrated that AmpB pεK gels confer sustained therapeutic antifungal activity for at least 48 hours without corneal epithelial cell line cytotoxicity, suggesting their potential for in vivo use as an antifungal bandage contact lens. This could avoid the need for intensive topical medication in the treatment of fungal keratitis.

Keywords: hydrogel, drug delivery, antimicrobial, amphotericin, bandage lens, cornea, keratitis

Fungal keratitis (Fig. 1a) is a challenging condition to treat. Despite intensive topical antifungal therapy, it is not uncommon for systemic antifungal medication and emergency tectonic corneal grafts to be necessitated. The associated severe inflammation and scarring often leads to some permanent loss of vision, and if the infection is not controlled, it may lead to endophthalmitis.¹

There are two types of fungi that cause fungal keratitis: filamentous fungi such as *Fusarium* and *Aspergillus* spp. and yeast-like fungi such as *Candida*. Filamentous fungal keratitis tends to occur because of trauma involving vegetative matter.² *Candida* infections are more common in those with preexisting ocular surface disease, such as severe dry eye and/or exposure; topical steroid use; postocular surgery; or those with other systemic risk factors such as diabetes or immunosuppression.³

The mainstay of treatment for fungal keratitis is the use of topical antifungal drops. However, their efficacy is limited, with the majority of the drop immediately draining down the cheek or the nasolacrimal duct.⁴ The remainder is subject to nonspecific absorption and is continuously diluted by the tear film and reflex tearing or dispersed by blinking.^{5,6} Typically,

only 1% to 7% of the drug reaches the target tissue, and only a fraction will penetrate the deep layers of the corneal stroma where fungal infections may extend.^{5,7–9} To overcome these limitations, prolong contact time with the cornea, and achieve therapeutic stromal drug concentrations, regular (hourly or half-hourly) instillation of drops is required.⁷ Although drop frequency decreases as the infection improves, regimes typically last for months.^{2,10} Unsurprisingly, patient compliance is problematic.¹¹ Therefore, a drug release system that delivers sufficient quantities of drug to the cornea while increasing the contact time would improve drug efficacy, improve patient compliance, and limit the demands on nursing care.

A therapeutic contact lens is an ideal option for sustained-release drug delivery as it sits directly on the cornea and could help to limit tear dilution behind the lens and enable prolonged drug contact time with the tissue.^{12,13} A contact lens also provides protection to the cornea and may reduce associated pain. Furthermore, local drug concentrations could be supplemented by the addition of topical drug therapy.^{14–16}

Poly-ε-lysine (pεK) hydrogels are fully synthetic, transparent, high-water-content (70%) peptide gels manufactured using carbodiimide chemistry to cross-link the naturally occurring



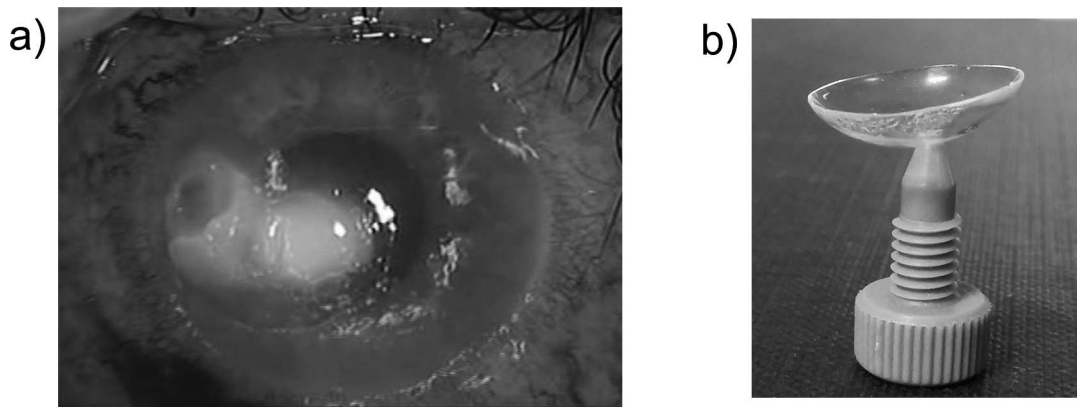


FIGURE 1. (a) Clinical photograph of fungal keratitis. Image courtesy of Stephen B. Kaye. (b) Example bandage contact lens material cast from hydrogel Su 60 14 (octanedioic acid cross-linker with a density of 0.071 g/mL and 60 mol% cross-linked).

components pEK and bis-carboxylic fatty acids (Fig. 1b). The high water content ensures excellent oxygen transmission to the avascular cornea reducing the risk of corneal hypoxia and vascularisation.¹⁷ The mechanical properties and optical transparency of these gels can be easily optimized by altering the cross-link density, the polymer density, and the molecular length of the bis-carboxylic fatty acid cross-linker. We demonstrated that pEK gels are noncytotoxic to a human corneal epithelial cell line (HCE-T).¹⁸ Furthermore, the amine functional groups in the polymer backbone can be used for the chemical attachment of a range of biomolecules to aid drug delivery. Amphotericin B (AmpB) is one of the first-line therapies against *C. albicans* keratitis.¹⁹ AmpB contains a 38-member lactone ring with amino and carboxyl moieties.^{20,21} These carboxyl moieties have the potential to interact with amine groups on pEK within the polymer matrix.

This study aimed to modify a pEK hydrogel (Su 60 15; octanedioic acid cross-linker with a density of 0.066 g/mL and 60 mol% cross-linked) by associating AmpB with the amine functional groups to provide an effective drug delivery mechanism against *C. albicans* under different growth conditions. An investigation of AmpB stability after associating it with the hydrogel and the subsequent toxicity of the AmpB hydrogels toward the HCE-T cell line was also investigated.

MATERIALS AND METHODS

Poly-ε-lysine, octanedioic acid, n-methylmorpholine (NMM), 1-ethyl-3-(3-dimethylaminopropyl) carbodiimide (EDCI), and n-hydroxysuccinimide (NHS) were supplied by SpheriTech Ltd. (Runcorn, UK). HCE-T cells were donated by Kaoru Araki-Sasaki (Itami City, Japan).²² All other reagents including AmpB (A2942, 250 μg/mL) stock were supplied by Sigma Aldrich (Gillingham, UK) unless otherwise stated.

Preparation of Hydrogel Su 60 15

Hydrogel Su 60 15 (30 mL) with 60% cross-linking and a polymer density of 0.07 g/mL was prepared. pEK (2.077 g) was dissolved in sterile distilled water (7.5 mL) in a 15-mL Falcon tube (Starlab Ltd., Blakelands, UK). An aliquot of 5% Tween 80 (0.25 mL) was added. Octanedioic acid (0.631 g) was dissolved in sterile distilled water (6.125 mL) with NMM (1.325 mL). This was sonicated until dissolved and added to the pEK solution. NHS and EDCI were measured into two separate 15-mL Falcon tubes and dissolved in PBS (7.5 mL PBS; Oxoid Ltd., Hampshire, UK). All solutions were filtered in a class II

microbiology hood using a 0.2-μm syringe filter. EDCI (3.471 g) and NHS (0.695 g) were mixed together and immediately added to the pEK/octanedioic acid solution. This was inverted five times. An aliquot of the polymer solution (5 mL) was pipetted into 63-cm² nontreated tissue culture dishes (Greiner Bio-One GmbH, Kremsmünster, Austria). These were incubated for at least 5 hours at room temperature until the gel had polymerized, followed by addition of PBS to prevent dehydration of the gel. Sheets of gel were washed five times with 10% NMM for 5 minutes, followed by thorough washing in dH₂O (10 × 5 minutes) to remove excess NMM. Gels were subsequently sterilized in 70% ethanol overnight before washing five times in sterile PBS and using them for experiments. Prior to commencing experiments, gels were cut into circular discs (0.36 cm²) using a metal trephine.

Culture of *C. albicans*

C. albicans strain SC5314 was revived from -80°C storage on potato dextrose agar (PD-agar; Formedium Ltd., Norfolk, UK) streak plates incubated at 37°C overnight.²³ *C. albicans* was subcultured by inoculating a PD agar streak plate with one colony taken from a previous PD agar plate and incubated overnight at 37°C. Colonies were maintained on PD agar stored at 5°C. Broth cultures were initiated by inoculating PD media (10 mL) with one colony of *C. albicans* taken from a PD agar plate. Cultures were incubated overnight at 37°C with constant shaking at 100 rpm. These were subcultured by taking an aliquot of *C. albicans* broth culture (0.5 mL) and diluting it in sterile PD broth (10 mL). For experiments, overnight broth culture (0.5 mL) was diluted with PD broth (10 mL), and optical density readings at 600 nm (OD₆₀₀) were measured hourly with a Jenway 6705 UV/Vis Spectrophotometer (Bibby Scientific Ltd., Staffordshire, UK). An initial OD₆₀₀ measured between 0.1 and 0.2 and was monitored until an OD₆₀₀ 0.5 to 0.6 was obtained. The culture was diluted 1:1 with sterile PD prior to experiments. *Candida* cultures were dispersed in an ultrasonic bath for 15 minutes prior to experiments to prevent aggregation.

Fungicidal Effects of AmpB-Loaded Gel

AmpB (250 μg/mL) was diluted in sterile PBS to concentrations of 30, 25, 20, 15, 10, 5, 3, and 0 μg/mL. Gels were incubated in the various concentrations of AmpB for 2 hours before being transferred to 96-well microtiter plates. Control wells containing PD only and PD with *C. albicans* were used throughout all these experiments. Wells containing PD (0.1 mL) were

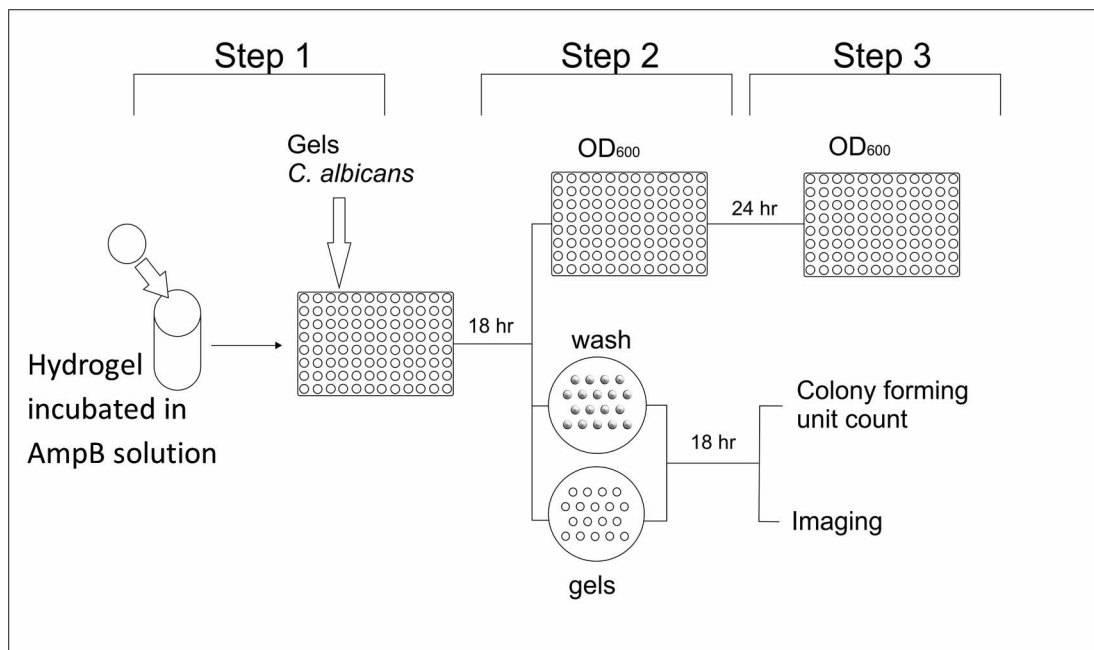


FIGURE 2. Schematic highlighting the various stages involved in monitoring the antifungal activity of hydrogel Su 60 15. Step 1: P&K gels were incubated with AmpB for 2 hours and then incubated overnight with *C. albicans*. Step 2: The optical density, OD₆₀₀, of *C. albicans* growth was measured; the gels were removed from the wells, washed in PBS to remove loosely adhered cells, and then placed on PD agar; and 0.02-mL samples of the PBS washes were pipetted onto PD-agar. Step 3: After another overnight incubation, further OD₆₀₀ readings, counts of colony forming units, and images were taken.

inoculated with *C. albicans* (0.0125 mL). Microtiter plates were incubated overnight at 37°C, and OD₆₀₀ readings were taken after 18 hours (Fig. 2, step 1).

This protocol was repeated to include *C. albicans* with the addition of horse serum (10% vol/vol) to PD broth to promote differentiation and upregulate the expression of virulence genes.^{24,25} After the gels were removed from the microtiter plate, they were individually washed in sterile PBS (5 mL) to remove any loosely attached fungi, and the wash solution was collected (Fig. 2, step 2). The gels were extracted using sterile forceps and placed on PD agar plates to identify the presence of viable fungi. An aliquot of each PBS wash solution (0.02 mL) was also plated (Fig. 2, step 2). The agar plates were incubated at 37°C overnight before imaging and counting the colony-forming units (Fig. 2, step 3). After the gels were removed, the plates were incubated at 37°C for a second night to establish whether there was any further growth of *C. albicans*. OD₆₀₀ readings were taken after 24 hours (Fig. 2, step 3).

Fungicidal Effect of the AmpB-Loaded Gel After 24-Hour Storage in PBS

Discs (0.36 cm²) of gel were incubated in various concentrations of AmpB (0.3, 3, 5, and 10 μg/mL) for 2 hours. Subsequently, the gel samples were individually incubated in 3.4 mL sterile PBS for 24 hours to mimic and assess the dilution effect of the tear film in vivo. Gels were then transferred to a 96-well microtiter plate containing PD (0.1 mL), and the PBS tear film solution was collected. The gels were inoculated with *C. albicans* (0.0125 mL) and incubated at 37°C overnight. OD₆₀₀ readings were taken after 18 hours with and without gels in the microtiter plate. After removal from the microtiter plate, gels were individually washed as described previously. The gels and an aliquot of the tear film wash solutions (0.02 mL) were plated onto PD agar. The agar plates were incubated

at 37°C overnight before imaging, and the number of colony-forming units was determined.

An aliquot of each PBS tear film solution (0.1 mL) was diluted with PD (0.1 mL) and added to a 96-well microtiter plate. The microtiter plate was then inoculated with *C. albicans* (0.0125 mL) and incubated overnight at 37°C. OD₆₀₀ readings were taken after 18 hours.

AmpB Elution From the Hydrogel

Discs of the gel (0.36 cm²) were incubated in a 30-μg/mL AmpB solution for 2 hours. The gels were removed and incubated in PBS at one gel per 0.1 mL for 24, 48, 72, and 96 hours. At each time point, the supernatant was removed and used to monitor AmpB elution via HPLC. Fresh PBS was added to the same gel samples prior to reincubation.

Reversed-phase HPLC (RP-HPLC) was performed on a SpectraSYSTEM AS3000 (Thermo Scientific, Waltham, MA, USA) with a C18 Vydac column (4.6 × 250 mm, 5 μm). The column temperature was set at room temperature, and 0.2 mL was the injection volume at a flow rate of 1 mL/min. The gradient was set to 40% to 100% B over 15 minutes with A: 0.1% TFA in H₂O, B: 0.1% trifluoroacetic acid (TFA) in MeCN and a detection wavelength of 380 nm.

AmpB Stability While Associated With the Hydrogel

Discs of the gel (0.36 cm²) were incubated in a 30-μg/mL AmpB solution for 2 hours. The gel was removed and incubated without media at 25°C for 1, 24, or 48 hours. The AmpB incubation solution was also stored for the same period. PD (0.1 mL) was added to each test well in a 96-well microtiter plate, and then a test gel or the corresponding AmpB incubation solution was added (0.0125 mL) and inoculated with *C. albicans* (0.0125 mL). Microtiter plates were incubated

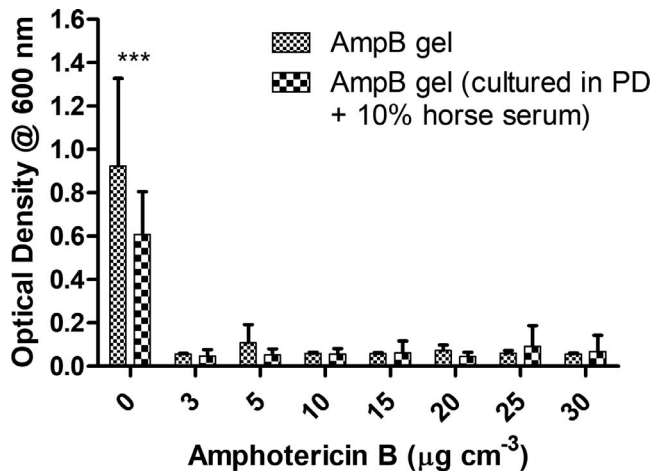


FIGURE 3. Bar chart demonstrating the fungicidal effects of gels preincubated in various concentrations of AmpB under different growth conditions. Error bars denote \pm SD, *** $P < 0.005$, $N = 9$.

overnight at 37°C , and OD_{600} readings were taken after 18 hours.

Cytotoxicity of AmpB-Loaded Gels

A cell counting kit-8 (CCK-8) assay kit (Dojindo Laboratories, Kumamoto, Japan) was used to monitor AmpB gel cytotoxicity toward the HCE-T cell line. Discs of the gel (0.36 cm^2) were incubated in a $30\text{-}\mu\text{g/mL}$ AmpB solution for 2 hours prior to incubating one gel per 0.1 mL in DMEM/F12 cell culture media at 37°C for 3 days. Media without gels was also incubated for the same period as a control. HCE-T cells were then seeded at a density of 2.5×10^4 in a 48-well microtiter plate and incubated with media from the preincubation with the gels or the control media (0.25 mL). At time points 4, 24, 48, 96, and 168 hours, CCK-8 (0.025 mL) was added to each well and incubated at 37°C for 2 hours. Aliquots ($2 \times 0.1\text{ mL}$) of media were removed and transferred to a 96-well microtiter plate, and the absorbance was read at 485 nm on a FLUOstar Omega microplate reader (BMG LABTECH GmbH, Ortenberg, Germany).

Statistical Analysis

GraphPad Prism version 5.03 for Windows (GraphPad Software, San Diego, CA, USA) was used to model 2-way univariate ANOVA with Tukey post hoc analysis, as well as model 1-way univariate ANOVAs to analyze data at the same concentrations or time points where appropriate. All the statistical data were presented as means \pm SD.

RESULTS

Fungicidal Effects of AmpB-Loaded Gels

The loading of AmpB and its release from the gels significantly reduced the growth of *C. albicans* compared with no AmpB, with no obvious changes in transparency (Fig. 3). However, there was no statistically significant difference between concentrations of AmpB or between the different culture conditions ($-\text{NH}_2$, $-\text{NH}_2$ gel cultured in PD + 10% horse serum) compared across all concentrations.

Viability of Cells Attached or Loosely Adhered to the Gel

No loosely attached viable fungi were recovered from the gel wash. Minimal *Candida* growth was also observed when gels preincubated with AmpB ($0.3\text{ }\mu\text{g/mL}$) were placed directly on PD agar (Fig. 4).

Viability of Fungi Remaining in the Wells

No further growth of *C. albicans* was observed in wells that previously contained the gel across all AmpB preincubation concentrations (Fig. 5).

Fungicidal Effect of AmpB-Loaded Gels After Storage in PBS

A statistically significant decrease in the growth of *C. albicans* was measured in wells treated with 3 to $10\text{ }\mu\text{g/mL}$ AmpB compared with those treated with $0.3\text{ }\mu\text{g/mL}$ (Fig. 6).

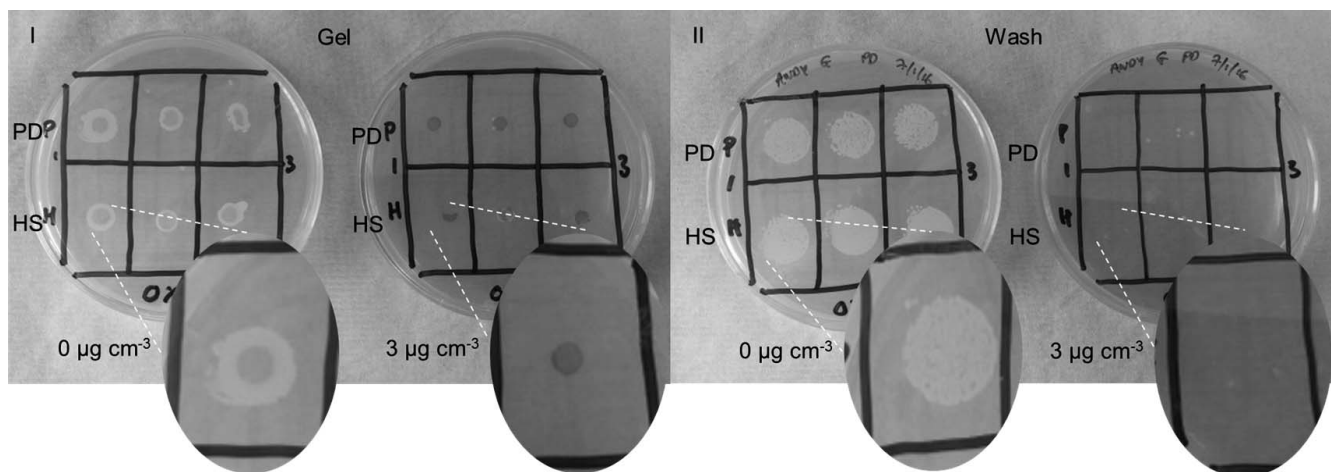


FIGURE 4. *C. albicans* viability assays on gels and from PBS washes with enhanced images of representative wells for each sample. (I) Gels plated on PD agar for 0 + $3\text{ }\mu\text{g/mL}$ AmpB gel cultured in PD broth and PD broth supplemented with 10% horse serum. (II) Washes plated on PD agar for 0 + $3\text{ }\mu\text{g/mL}$ AmpB gel cultured in PD broth and PD broth supplemented with 10% horse serum.

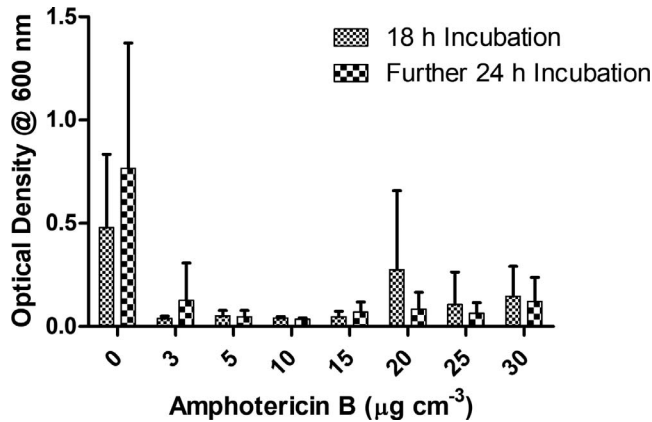


FIGURE 5. Investigation of further growth of *C. albicans* in wells that contained gels preincubated in different concentrations of AmpB; OD₆₀₀ after 18 hours with gels removed compared with OD₆₀₀ after a further 24-hour incubation. Error bars denote \pm SD. * $P < 0.05$, $N = 6$.

AmpB Elution From the Gels

A therapeutic dose of AmpB (see Supplementary Material S1) was eluted from the gel for a period of 72 hours with a smaller dose after 96 hours (Fig. 7). The dose at 96 hours is still relevant compared with minimum inhibitory concentration data from the literature.^{26,27}

AmpB Viability After Attachment to the Hydrogels

AmpB associated with the hydrogel remained stable and produced a killing effect against *C. albicans* for at least 48 hours (Fig. 8). There seemed to be less *C. albicans* killed at 48 hours compared with the earlier time points; however, this was not statistically significant. There was no difference between the efficacy of the AmpB gels and the 30- μ g/mL AmpB incubation solution at each time point in terms of the eradication of *C. albicans*.

Cytotoxicity of AmpB Gels

No cytotoxicity to the HCE-T cell line was observed when comparing gels incubated in AmpB (30 μ g/mL) with standard

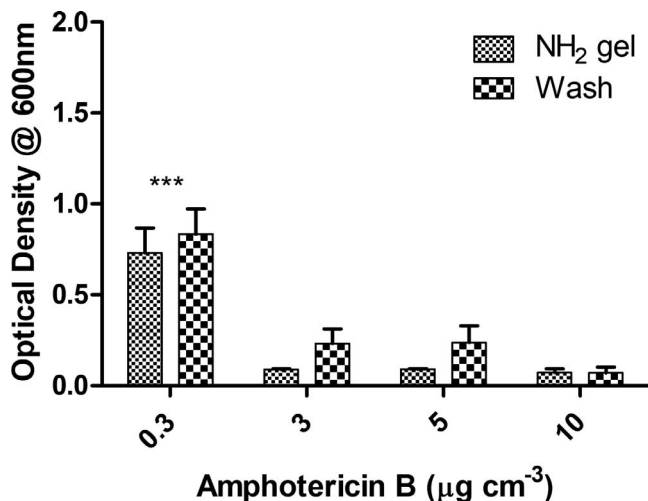


FIGURE 6. Antifungal effects of gels preincubated in various concentrations of AmpB prior to overnight storage in 3.4 mL sterile PBS tear film solution. Error bars denote \pm SD. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.005$, $N = 3$.

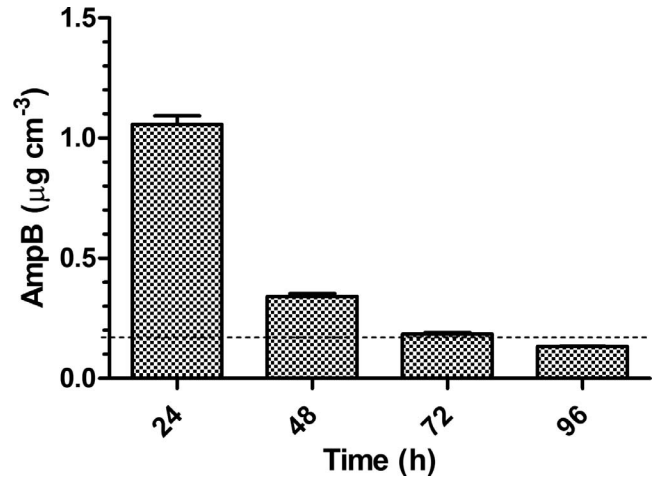


FIGURE 7. AmpB elution from gels over a 96-hour period as measured by RP-HPLC. Line denotes the MIC for *C. albicans* determined in this report (Supplementary Material). Error bars denote \pm SD. *** $P < 0.001$, $N = 4$.

cell culture media (Fig. 9). The positive control (Su PeK PO₄), a Su 60 14 gel loaded with phosphate, was cytotoxic toward the HCE-T cell line as already determined for this cell line.¹⁸

DISCUSSION

Development of a bandage contact lens as a drug delivery device for antifungal drugs overcomes the limitations of topical antifungal eye drops, with great potential benefit in the management of fungal keratitis. Ideally a bandage contact lens may be worn for extended periods of time, aiding ocular surface healing and comfort with less frequent need for medical review and lens change. The lens material in this situation must have excellent oxygen permeability to preserve the integrity of the avascular cornea. High-water-content hydrogels would allow significant oxygen permeability through the water phase of the gel. The advantage of hydrogels for drug delivery is the potential to incorporate biomolecules through-

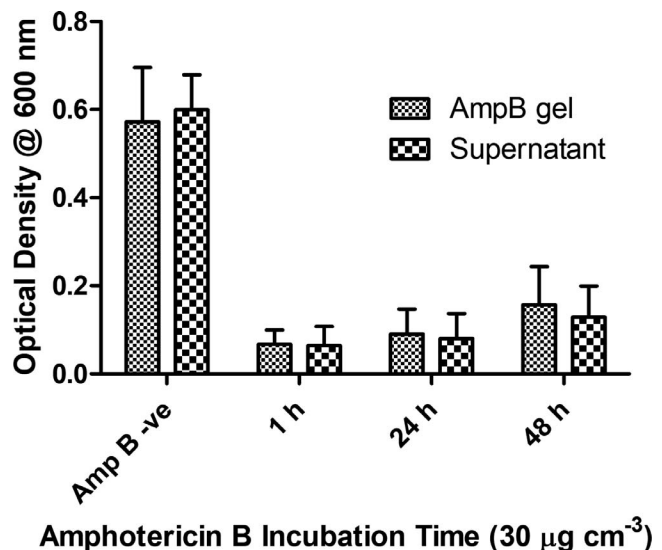


FIGURE 8. Effectiveness of AmpB gels at killing *C. albicans* after preincubation for set time points. Error bars denote \pm SD, *** $P < 0.001$, $N = 6$.

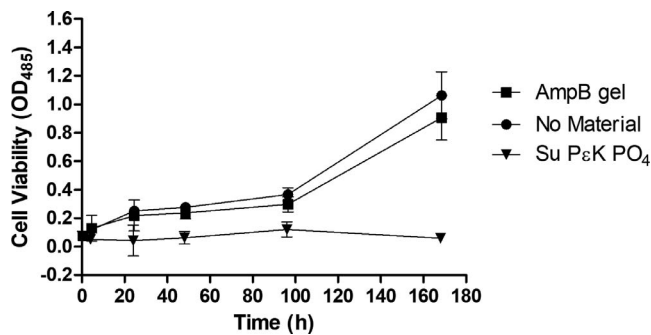


FIGURE 9. Cytotoxicity of AmpB gels toward the HCE-T cell line. Error bars denote \pm SD. $N = 8$.

out the gel during synthesis or attachment via charged functional groups after polymerization.

A hydrogel was synthesized from pεK and octanedioic acid using carbodiimide chemistry that was transparent, had similar mechanical properties to existing hydrogel contact lenses, and had a water content in the order of 70% that yields an oxygen permeability comparable to other short-term wear hydrogel lenses.¹⁸ Its excellent transparency would allow an ophthalmic review of the cornea without having to remove the lens, and this feature does not appear to be altered with the addition of AmpB. These hydrogels can be manufactured reproducibly and in an environmentally friendly way because they gel from aqueous solutions at room temperature requiring no harsh solvents, such as those used in the production of silicone hydrogel contact lenses. Furthermore, the mechanical and surface chemical properties can be tuned to optimize the mechanical properties and the number and character of the surface functional groups. We produced a lens material that has a 60% cross-link density using a pεK density of 0.07 g/mL (Su 60 15). This hydrogel has a positive charge due to the remaining uncross-linked amine groups within the polymer matrix.

C. albicans strain SC5314 was used to model a fungal keratitis infection as it is the most well-studied strain of *Candida* and is the organism that is most common in temperate climates.² AmpB was used as the antifungal agent, given that it is one of the first-line choices against *C. albicans* and has a carboxyl group that can promote attachment of the drug molecule to the free amine groups on hydrogel Su 60 15 and aid its uptake into the hydrogel.^{19,21} The MIC found in this report (see Supplementary Material S1) is between 0.094 and 0.188 μ g/mL for *C. albicans* cultured in both PD and PD with 10% horse serum and correlates with MIC data for ocular isolates from the literature of 0.06 to 1 μ g/mL.^{26,27} A concentration of AmpB, well above the MIC, is necessary to ensure adequate dosing to the cornea considering that $\leq 7\%$ reaches the target tissues. Using serial dilutions of the stock AmpB solution, we demonstrated that AmpB incorporated into the pεK hydrogels significantly reduced the growth of *C. albicans* compared with no AmpB, independent of the solution concentration over 18 hours. Generally, the gels preincubated in AmpB and cultured under both normal growth conditions (and when the PD was supplemented with 10% horse serum) had a similar efficacy on *C. albicans*. When the gels themselves were evaluated, it was clear that there was minimal fungi growth on the gels or loosely attached to the gels.

Once the gels had been removed from the wells, it was important to evaluate whether any fungi remaining could proliferate even if growth was low when the gels were present. This could model the situation where the medicated lens was

removed from the eye without knowing if all the infection had been eliminated. Over the subsequent 24 hours, minimal fungal growth was observed in the wells that contained the gels. These data suggest that the concentration of AmpB attached to, and released from, the gels is fungicidal.

The approximate volume of tear fluid produced over 24 hours is 1.7 mL in a normal eye.²⁸ When an eye is infected, however, there is often a considerable increase in tear volume. To mimic the dilution effect of the tear film, gels preincubated in AmpB were stored in 3.4 mL sterile PBS for 24 hours. Over this period, it is assumed that AmpB will diffuse out of the gel into the media. After incubation, both the gels and the tear fluid were evaluated for their antifungal activity. For the gels, the growth of *C. albicans* in any of the wells (3 to 10 μ g/mL) after storage was significantly reduced compared with the lowest concentration of AmpB (0.3 μ g/mL). Similarly, aliquots of the tear fluid from around these gels caused a significant reduction in fungi growth. Evaluation of the tear fluid from these gels demonstrated that only gels incubated in the greater concentrations of AmpB (3 to 10 μ g/mL) possessed a sufficient concentration of AmpB to cause a significant reduction in fungal growth. These data suggest that the effective antifungal dose of AmpB had been released from these gels in the 24-hour storage period but that this dose would be diluted too much in a watery eye at the lowest incubation concentration of AmpB (0.3 μ g/mL). In higher AmpB loading situations, 24 hours in a watery eye should allow sufficient release of AmpB to reduce *C. albicans* growth in the eye, as well as on the gel surface. It should be noted, however, that this model of tear film dilution does not take into consideration the turnover of the tear fluid and drainage of AmpB.

It is important to evaluate how much AmpB diffuses out of the gels over time to help optimize the drug loading regime. We demonstrated that after storage for all time points, the gel released a clinically relevant dose of AmpB for 72 hours, only falling below the MIC after 96 hours. These data demonstrate that the gels are effective at delivering a clinically relevant dose of AmpB. Furthermore, we could demonstrate that the dose of AmpB delivered by the gel was stable enough after 48-hour storage to kill *C. albicans* with a similar efficacy as a gel used immediately after preincubation in AmpB. Effective treatment of fungal keratitis will require the bandage contact lens to maintain the level of AmpB against the cornea at a therapeutic level to promote penetration of the drug into the corneal stroma. These data suggest that the gel may be an effective AmpB delivery device. It also suggests that the loading dose could be tailored to release the appropriate dose at different stages of the healing process.

The AmpB gel was also investigated for any cytotoxicity toward the HCE-T cell line. The gels, with AmpB, as expected and corroborated by previous work, were not cytotoxic toward the HCE-T cell line.¹⁸ An appropriate next step will be to investigate the AmpB gel in a diseased animal model or an ex vivo model of bacterial keratitis.

CONCLUSIONS

This study demonstrated the potential of pεK gels to act as a drug delivery bandage contact lens. The gels have a proven antifungal activity against *C. albicans* under normal growth conditions and in the presence of horse serum after preincubation with AmpB. A therapeutic amount of AmpB was released from the gel for a period of 48 to 72 hours, retaining its therapeutic fungicidal activity for at least 48 hours. The AmpB gels also proved noncytotoxic to the HCE-T cell line, further outlining its potential clinical use as a bandage

contact lens to replace the laborious AmpB administration by eye drops in the fight against fungal keratitis.

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