Development and Characterization of Voriconazole Loaded In Situ Gel Formulations for Ophthalmic Application

Oküler Uygulama için Vorikonazol Yükü In Situ Jel Formülasyonlarının Geliştirilmesi ve Karakterizasyonu

Neslihan ÜSTÜNDAĞ OKUR*, Ayşegül YOLTAŞ, Vildan YOZGATLI

1İstanbul Medipol University, Faculty of Pharmacy, Department of Pharmaceutical Technology, Beykoz, 34810, İstanbul, TURKEY
2Ege University, Faculty of Science, Department of Biology, Fundamental and Industrial Microbiology Division, Bornova, 35100, İzmir, TURKEY

ABSTRACT

The aim of the this research was to prepare and evaluate the potential use of in situ gel formulations for ocular delivery of voriconazole for the treatment of fungal keratitis. An in situ gelling system was used to increase the residence time and thus the bioavailability of voriconazole in ocular mucosa. Temperature triggered in situ gel formulations were prepared by cold method using polymers like poloxamer 188, poloxamer 407 and sodium alginate. Finally, concentration of voriconazole in formulations was 0.1% (w/w). These formulations were evaluated for clarity, sol-gel transition temperature, gelling capacity, pH, viscosity and drug content. The gelation temperatures of all the formulations were within the range of 32-34°C. All the formulations exhibited fairly uniform drug content. Furthermore in vitro drug release and antifungal activity of these formulations were also evaluated. Drug release study of all the formulations showed sustained release properties. In conclusion, voriconazole loaded in situ gels could be offered as a promising strategy for ocular drug delivery for the treatment of fungal keratitis.

Key words: Voriconazole, In situ gel, Ocular drug delivery, Characterization, Microbiological study

INTRODUCTION

The eye is unique in terms of its anatomical and physiological nature and defence mechanisms, which make the targeting of drugs to eye tissues one of the greatest challenges in drug delivery (1,2). One of the major limitations faced in ophthalmic delivery is the attainment and retention of optimum drug concentration at the site of action within the eye (3,4,5). Poor bioavailability of drugs from conventional ocular dosage forms in mainly due to tear production, nasolacrimal drainage and transient residence time, drainage of the instilled solution, tear turnover and limited corneal area (6). Various ophthalmic vehicles such as inserts, ointments, suspensions and aqueous gels, have been developed in order to lengthen the residence time of instilled dose and enhance the ophthalmic bioavailability. These ocular drug delivery systems, however, have not been used extensively because of some drawbacks such as blurred vision from ointments or lack of patient compliance are the main reasons that they have not universally accepted (6,8,9). The effective dose administered may be altered by increasing the retention time of medication into the eye by using in situ gel forming systems (10). In situ gel forming systems are liquid aqueous solutions...
before administration but turn to gel under physiological conditions. There are several possible mechanisms that lead to in situ gel formation, such as pH change, ionic cross-linkage, and temperature modulation (11,12).

Several in situ gel forming systems have been developed to prolong the precorneal residence time of a drug and improve ocular bioavailability. Polymers are employed in such delivery systems to carry various drugs and they may demonstrate a transition from sol(liquid) to gel state once instilled in the cul-de-sac of the eye (13). In situ gel forming formulations current a novel idea of deliver drugs to patients as a liquid dosage form, yet achieve sustained release of drug for the desired period. Different delivery systems based on polymers have been developed, which are able to increase the residence time of the formulation at absorption site of drugs. In recent years, there has been an increasing interest in water-soluble polymers are highly advantageous compared with other polymers because, in contrast to very strong gels, they can be easily applied in liquid form to the site of drug absorption. At the site of drug absorption, they swell to form a strong gel that is capable of prolonging the residence time of drug (14).

Keratitis, a disease of the cornea, results from direct infection with viruses, bacteria, fungi, yeast, and amoebae or from immune-related complications (4). Fungal keratitis is a leading cause of serious ocular morbidity and blindness. It is worldwide in distribution, but is more common in the tropics and subtropical regions. In fungal keratitis, early diagnosis and antifungal therapy is necessary in preventing further complications such as hypopyon formation, endophthalmitis, or loss of vision (15).

Voriconazole (VCZ), C_{16}H_{14}F_{3}N_{5}O, a second generation antifungal agent possesses phenomenal characteristics like broad-spectrum activity, activity against resistant fungal species, and acceptable tolerability. Almost 100% in vitro susceptibility was observed against various fungal isolates associated with keratitis and endophthalmitis. Moreover, studies suggested an excellent efficacy of voriconazole against several ocular mycoses following topical administration (16).

In this study, a new ocular drug delivery system based on the dispersion of voriconazole loaded in situ gels coating into sodium alginate was proposed. The characterization properties of the system were investigated, including clarity, gelling capacity, pH, viscosity and drug content. In vitro drug release and antifungal activity of these formulations were also evaluated.

**EXPERIMENTAL**

**Materials**

VCZ and sodium alginate were purchased from Sigma, Germany. Poloxamer 407 and poloxamer 188 were kind gift from BASF, Turkey. Distilled water was used throughout the study. High pressure liquid chromatography (HPLC) grade acetonitrile (Sigma, Germany) was used for HPLC studies. Roswell Park Memorial Institute (RPMI 1640) medium was purchased from Sigma-Aldrich, Germany (R65504). All the other chemicals and solvents were of analytical or HPLC grade. Dialysis membrane (Spectro/por Dialysis Membrane, Spectra/por 4, diameter 16 mm, molecular weight of 12-14 kDa) was purchased from Spectrum.

**Preparation of in situ gel formulations**

Poloxamer analogs were used as the gelling agents, and the in situ gels were prepared by using a cold method (17). The polymeric solutions were prepared by dispersing required quantity of Poloxamer 407 and Poloxamer 188 in cold water (5 °C) using a magnetic stirrer until the poloxamer completely dissolve (approximately 2 hours). The dispersion was kept in a refrigerator for 48 hours to get clear solution.

**Determination of sol-gel temperature (Tsol-gel)**

20 g of cold sample solution were put into a beaker and placed in a temperature-controlled stirrer. A thermometer was immersed into the sample solution for constant monitoring. The solution was heated at the rate of 2 °C/min with the continuous with stirring at 200rpm. The temperature at which the magnetic bar stopped moving due to gelation was reported as the gelation temperature. The maximum limit for gelation was checked up to 60 °C. Optimum poloxamer ratios were determined and selected with sol-gel temperature as 32-33 °C which is the eye surface temperature (18). The experiments were repeated four times.

---

**Table 1. Poloxamers concentrations, gelling temperature and pH of the formulations**

| Codes | Poloxamer 407 (%) | Poloxamer 188 (%) | Gelling temperature (°C) | pH   |
|-------|------------------|------------------|-------------------------|------|
| F1    | 15               | 10               | 42-43                   | 7.15 |
| F2    | 15               | 15               | 39-40                   | 7.31 |
| F3    | 15               | 20               | 35-36                   | 7.44 |
| F4    | 15               | 23               | 34-35                   | 7.53 |
| F5    | 15               | 25               | 30-32                   | 7.63 |
| F6    | 18               | 15               | 41-42                   | 7.51 |
| F7    | 18               | 18               | 38-39                   | 7.57 |
| F8    | 18               | 20               | 33-34                   | 7.53 |
| F9    | 18               | 22               | 32-33                   | 7.63 |
| F10   | 18               | 25               | 28-29                   | 7.85 |
| F11   | 20               | 5                | 30-32                   | 7.07 |
| F12   | 20               | 10               | 33-34                   | 7.22 |
| F13   | 20               | 15               | 36-37                   | 7.30 |
| F14   | 20               | 20               | 32-33                   | 7.34 |
| F15   | 20               | 23               | 32-33                   | 7.67 |
Preparation of voriconazole loaded in situ gel formulations

In situ gels were selected according to pH values and gelling temperatures of formulations. F11 (ratio of P407 and P188 were 20% and 5%, respectively) was selected as optimum formulation for preparation an ocular formulation. After detection of the optimum in situ gel compositions sodium alginate of different concentrations (0.1%, 0.3%, and 0.5%) and for each formulations same concentration of VCZ were added in poloxamer solutions with continuous stirring until completely dissolved. Benzalkonium chloride (0.02% w/w) was added as a preservative to the solutions. Sufficient amount of sodium chloride (0.9% w/w) was added to the mixture to maintain the isotonicity. The effect of drug and the other compositions of formulations on gel temperature were also evaluated.

Characterization of in situ gels

The prepared ocular formulations were characterized such as clarity, gelling capacity, pH, viscosity and drug content. In addition gelling temperature of formulations was determined and statistical analysis was performed using t-test. Data were considered statistically significant at p<0.05. The experiments were repeated four times.

Clarity of formulations

The clarity of formulations was determined by visual inspection under black and white background, and it was graded as follows: turbid, +; clear, ++; and very clear (glassy), +++.

Gelling capacity

The gelling capacity of the prepared formulation was determined by placing a drop of the formulation in a beaker at 32-34°C and it was visually observed for gelling time. It was graded as follows: +; gel after few minutes dissolves rapidly, ++; immediate gelation remains for few mins, +++; immediate gelation remains for nearly an hour.

Determination of pH

The pH of the gel was determined using calibrated pH meter (Mettler Toledo, Switzerland). Determinations were carried out four times and an average of these determinations was taken as the pH of the prepared gels.

Determination of viscosity

The viscosity of the developed formulations was performed with a digital viscometer (Brookfield) equipped with spindle RV2 with 50 rpm at 32±2°C.

Drug content

1 mL of the developed in situ gel formulation was dissolved in 100 mL pH 7.4 simulated tear fluid buffer (NaCl: 0.670g, NaHCO3: 0.200g, CaCl2.2H2O: 0.008 g and distilled water q.s. to 100 g) (19) followed by HPLC estimation of the aliquot to determine drug concentration. The experiments were repeated four times.

HLPC analysis

The HPLC system consisted of a gradient pump and a UV detector supplied by Agilent 1100. C18 column (150x4.6mm,5µm) (GL Sciences, Japan) was used. The samples were analyzed at 256 nm with a 1 mL/min flow rate at 25°C. The mobile phase was a mixture of acetoniitrile: ultrapure water (50:50). Retention time of drug was 4.098 min. The method was validated partially linearity, limit of detection (LOD) and limit of quantitation (LOQ), precision, accuracy and specificity, selectivity and stability.

In vitro drug release study

The in vitro drug release study was performed using the dialysis bag method (5). In vitro release study of in situ gel formulations was carried out in simulated tear fluid (pH=7.4) at 50 rpm. The temperature was maintained at 33±1°C to mimic eye surface temperature. 5 g formulation was separated from release media by means of dialysis membrane (Spectra/por, MW of 12-14 kDa) and capped with closures. The membrane was heated 33±1°C for 30 min in bidistilled water before use. 0.5 mL of sample was withdrawn at a predetermined time interval of 1 h to 8 h and the same volume of fresh medium was replaced. The samples were analyzed with HPLC for the drug content. The experiments were repeated three times.

Stability of the in situ gels

In physical stability studies, VCZ loaded in situ gels were stored at 5±1°C in the refrigerator and 25±2°C and 40±2°C for 3 months in the stability cabinets (Nüve, Turkey). After storage for 3 months visual appearance, clarity, pH, gelation time of in situ gels and VCZ content were investigated. The experiments were repeated three times.

Microbiological studies

Sterility studies

In situ gel formulations in the presence or absence of VCZ were prepared at Laminar air flow Cabinet (Haier HR40-IIIA2). To check the sterility of the prepared ocular formulations sterility control testing were performed. Sterility testing of the in situ gel formulations with or without VCZ was carried out under aseptic conditions according to the international pharmacopoeia. For anaerobic bacteria Fluid thioglycollate medium was used. For fungi and aerobic bacteria soya-bean casein digest medium was used. 1 mL of formulation solution was added to each medium and incubated at 35°C for bacteria and 25°C for fungi for 14 days.

To check the suitability of the used mediums for the sterility testing promotion test were performed. For growth promotion test of aerobes, anaerobes and fungi, fluid thioglycollate media (using separate portion of media for each microorganism) were inoculated with 100 CFU of Staphylococcus aureus ATCC 6538, Clostridium sporogenes ATCC 19404 and Candida albicans ATCC 10231. Media were incubated at 35°C for 48 h.
**Determination of MIC of VCZ**

The broth microdilution test was done in accordance with CLSI guidelines for filamentous fungi (20) and yeasts (21). VCZ was dissolved in dimethyl sulfoxide, final dilutions were made in RPMI 1640 medium buffered to pH 7.0 with 0.165 M MOPS buffer [3-[(N-morpholino) propanesulfonic acid] and final concentrations were 500-0.125 µg/mL. Using the spectrophotometric method of inoculum preparation, an inoculum concentration of 1.5±1.0x10^2 cells/mL for yeasts and 0.4-5x10^4 spores/mL for moulds, and RPMI 1640 medium buffered with MOPS were used. *C. albicans* ATCC 10231, *C. tropicalis* RSKK 2412, *A. fumigatus* ATCC 204305 and *A. flavus* ATCC 204304 which may be possible causes of fungal keratitis were used to evaluate antifungal activity of developed formulations (22,23). A 0.1 mL inoculum was added to each well of the microdilution trays. The MICs were determined after 48 h of incubation. The MIC endpoints were evaluated for the lowest drug concentration that showed a prominent reduction (50%) of the growth in the control well.

**Disk diffusion testing**

Disk diffusion testing was performed according to CLSI standard. Mueller-Hinton agar (Difco) supplemented with 2% glucose and 0.5 µg/mL methylene blue dye (SSI Diagnostica, Hillerød, Denmark) was used. Blank disks that were 12.1 mm in diameter were impregnated with 20 µL of formulations at final concentration of 1 µg/disk and allowed to dry at room temperature. *C. albicans* ATCC 10231 and *C. tropicalis* RSKK 2412, *A. fumigatus* ATCC 204305 and *A. flavus* ATCC 204304 which may be possible causes of fungal keratitis were used to evaluate antifungal activity of developed formulations (22,23). A 0.1 mL inoculum was added to each well of the microdilution trays. The MICs were determined after 48 h of incubation. The MIC endpoints were evaluated for the lowest drug concentration that showed a prominent reduction (50%) of the growth in the control well.

**RESULTS AND DISCUSSION**

**Preparation of in situ gel formulations**

Preliminary studies were carried out using different concentrations of polymers evaluated for their gelling temperature in order to identify the compositions suitable for use in the in situ gelling system for ocular drug delivery. Temperature sensitive in situ gels were successfully prepared by cold method using poloxamer 407, poloxamer 188. Cold method is one of the preferred methods due to providing clear solution for in situ gel while hot process causes formation of lumps of polymer as reported and observed in literature (24).

Poloxamer 407 (ethylene oxide and propylene oxide blocks) has excellent thermo-sensitive gelling properties, which is of the most interest in optimising drug formulation. Poloxamer 407 formulations led to enhanced solubilization of poorly water-soluble drugs and prolonged release profile for many applications (e.g., ophthalmic, oral, rectal, topical, nasal and injectable preparations) but did not clearly show any relevant advantages when used alone. Combination with other excipients like Poloxamer 188 or mucoadhesive polymers promotes the action of Poloxamer 407 by optimising sol–gel transition temperature or increasing bioadhesive properties (25). For this purpose poloxamer 188 and poloxamer 407 mixture were used to develop in situ gels.

To find out optimum gelling temperature (32±2°C), the poloxamer 407 and poloxamer 188 were mixed various concentrations. Table 1 shows poloxamer concentrations, gelling temperature and pH of the prepared formulations. F11 was selected optimum composition which contains poloxamer 407 (20%) and poloxamer 188 (5%).

After selecting F11 formulation, benzalkonium chloride (0.02%, w/w) was added as a preservative to the solution. Sufficient amount of sodium chloride (0.9% w/w) was added as a preservative to the solution. The clarity of all the formulations was found to be satisfactory, the poloxamer 407 and poloxamer 188 were mixed various concentrations. Table 1 shows poloxamer concentrations, gelling temperature and pH of the prepared formulations. F11 was selected optimum composition which contains poloxamer 407 (20%) and poloxamer 188 (5%).

After selecting F11 formulation, benzalkonium chloride (0.02%, w/w) was added as a preservative to the solution. The clarity of all the formulations was found to be satisfactory, the poloxamer 407 and poloxamer 188 were mixed various concentrations. Table 1 shows poloxamer concentrations, gelling temperature and pH of the prepared formulations. F11 was selected optimum composition which contains poloxamer 407 (20%) and poloxamer 188 (5%).

**Characterization of in situ gels**

Characterization of the new drug delivery systems are major issues to be considered in the formulation stage, especially those intended for ocular administration. The physicochemical characterization parameters of in situ gels are reported in Table 3.

The clarity of all the formulations was found to be satisfactory, as shown in Table 3. Gelation temperature was changed from 32.5°C to 34.3°C with incorporation of 0.1% w/w VCZ in the poloxamer solution, while the addition of the mucoadhesive polymers played a reverse role on gelation temperature. The results showed that incorporation of sodium alginate into in situ gel formulation significantly decreased the gelling temperature (p<0.05). When the concentration of

---

**Table 2. Compositions of the in situ gels (%)**

| Components (%) | S  | S1 | S2 | S3 | S4 |
|---------------|----|----|----|----|----|
| Poloxamer 407 | 20 | 20 | 20 | 20 | 20 |
| Poloxamer 188 | 5  | 5  | 5  | 5  | 5  |
| Sodium alginate | -  | -  | 0.1| 0.3| 0.5|
| Sodium chloride | 0.9| 0.9| 0.9| 0.9| 0.9|
| Voriconazole | -  | 0.1| 0.1| 0.1| 0.1|
| Benzalkonium chloride | 0.02| 0.02| 0.02| 0.02| 0.02|
| Distilled water qs to | 100| 100| 100| 100| 100|
sodium alginate was increased in the *in situ* gels, the gelling temperature was decreased (Table 3). Gelling temperature of the all formulations (S, S1-S4) were found between 32-35°C. This indicates that the formulations can be converting the gel when they installed the eye surface. At 32-34°C, the solutions are converted into gels with high viscosity. The gelling capacity data of prepared formulations presented in Table 3 represent that the formulations all formulations had immediate gelation and exist for an hour.

The pH of an ophthalmic formulation is important for patient compliance. The pH of the prepared formulations ranged between 7.07 and 7.13. The pH of the formulations was appropriate for ocular delivery since they were iso-hydric. This indicated the nonirritancy of the formulation in ocular mucosa. When a formulation is administered to the eye, it stimulates the flow of tears. Tear fluid is capable of quickly diluting and buffering small volumes of added substances, thus eye can tolerate a fairly wide pH range. Ophthalmic solutions may range from 6.5 to 8.5 (26,27).

The formulation should have an optimum viscosity, which will allow its instillation into the eye as a liquid, which will then undergo rapid sol-gel transition due to temperature change. When the *in situ* solutions were installed the 32-34°C surface, the solutions were converted to gel form after few seconds.

All the formulations reflected fairly uniform drug content ensuring adequacy in the method of preparation of the *in situ* gel. Drug content was found to be within the range of 82.68-92.58%. The drug content of the prepared formulations was within acceptable limits and ensured dose uniformity.

**In vitro drug release study**

The *in situ* gelling formulations of VCZ, S1-S4, were subjected to *in vitro* release studies, which were carried out using simulated tear fluid of pH 7.4 as release medium. Formulations showed sustained drug release for a period of 8 hours (Figure 1). At the end of the 8 h, *in vitro* VCZ release from S1, S2 and S3 formulations was found as 63%, 60% and 60%, respectively (p>0.05). S4 formulation was showed slower release than the other formulations. This could be the reason of higher concentration of sodium alginate among the developed formulations. Mandal et al. prepared moxifloxacin hydrochloride loaded *in situ* gel using sodium alginate and hydroxy propyl methyl cellulose as polymers. They were found that when sodium alginate and hydroxy propyl methyl cellulose concentration was increased, release rate was decreased (28).

### Stability

The stability studies were carried out at 5±1°C, 25±2°C and 40±2°C for 3 month using stability cabinets. The samples were analyzed periodically on every month, and found that there are no changes in visual appearance, clarity, and gelation time. After 3 month pH values of S1, S2 S3 and S4 formulations were found as 7.12±0.002, 7.18±0.001, 7.20±0.001 and 7.21±0.002, respectively. In addition 92-98% of initial drug content of formulations was kept its stability for in 3 month.

### Microbiological studies

The optimized *in situ* gels passed the test for sterility as there was no appearance of turbidity and hence no evidence of microbial growth when incubated for 14 days at 35°C in case of fluid thioglycolate medium and at 20-25°C in the case of soya-bean casein digest medium. Furthermore to control the used

![Figure 1. In vitro release of voriconazole from in situ gels at pH 7.4 simulated tear fluid buffer](image)

![Figure 2. Zone inhibition diameters of formulations against A. flavus, A. fumigatus, C. albicans and C. tropicalis](image)

| Formulations | S | S1 | S2 | S3 | S4 |
|--------------|---|----|----|----|----|
| **Clarity**  | +++| +++| +++| ++ | ++ |
| **Temperature (°C)** | 32.5±0.03 | 34.3±0.01 | 33.1±0.023 | 32.6±0.012 | 32.4±0.001 |
| **Gelling capacity** | +++| +++| +++| ++ | ++ |
| **pH**       | 7.07±0.002 | 7.08±0.001 | 7.1±0.002 | 7.11±0.001 | 7.13±0.001 |
| **Viscosity (cP)** | 358±31 | 362±6.21 | 400±11.32 | 424±2315 | 440a±917 |
| **Drug content (%)** | - | 8314±0.36 | 82.68±1.06 | 84.11±0.7 | 92.58±0.35 |
mediums for suitability of sterility test growth promotion test were performed and it was found that both microorganisms showed visible growth in all media.

The MIC endpoints were evaluated for the lowest drug concentration that showed a prominent reduction (90% and 50%) of the growth in the control well. MIC<sub>90</sub> values of VCZ against A. albicans, C. tropicalis, A. fumigatus and A. flavus were 2, 1, 0.5 and 0.5 µg/mL, respectively and MIC<sub>50</sub> values were against the formulations (32).

We can say that all of organisms are susceptible for all of VCZ for susceptible species is ≥17 mm and for resistant is ≤13 mm, sodium alginate is not effective on the absence of voriconazole (S) in the in situ gel (blank in situ gel) is not effective on C. albicans, A. fumigatus and A. flavus, because addition of sodium alginate into the in situ gel (S1) did not change the IZ diameter. While absence of voriconazole (S) in the in situ gel (blank in situ gel) is not effective on C. albicans, A. fumigatus and A. flavus, a minor inhibition zone was seen in C. tropicalis which may be caused by benzalkonium chloride (0.02%, w/w) or other components of the gel. Since the interpretive breakpoints of components of the gel. Since the interpretive breakpoints of the MIC ranges of A. flavus (≥4 µg/mL are accepted as resistant.

The efficacy of groups was investigated using the inhibition zone diameters in disc diffusion test. Disk diffusion testing was performed according to CLSI standard M44-A2 for yeasts and M51-A for filamentous fungi. C. albicans, C. tropicalis, A. fumigatus and A. flavus were used as they are the common organisms causing ocular fungal infections (22,23). Figure 2 shows inhibition zone (IZ) diameters of formulations. The developed VCZ loaded in situ gels were found to be more effective on more effective on moulds in comparison with yeasts (A. flavus than C. albicans) (Table 4). In addition to this, sodium alginate is not effective on the C. albicans, C. tropicalis, A. fumigatus and A. flavus, because addition of sodium alginate into the in situ gel (s1) did not change the IZ diameter. While absence of voriconazole (S) in the in situ gel (blank in situ gel) is not effective on C. albicans, A. fumigatus and A. flavus; a minor inhibition zone was seen in C. tropicalis which may be caused by benzalkonium chloride (0.02%, w/w) or other components of the gel. Since the interpretive breakpoints of VCZ for susceptible species is ≥17 mm and for resistant is ≤13 mm, we can say that all of organisms are susceptible for all of the formulations (32).

CONCLUSION

In the present study, the potential of VCZ loaded in situ gels as drug carriers for ocular delivery was investigated. The present study showed that in situ gels of VCZ can successfully be prepared with cold method. The clarity, pH, gellation time and drug content of all formulations was found to be satisfactory. In addition the formulations were found stable for 3 month. Further, all the formulations showed sustained drug release for a period of 8 h, which satisfied to treat ocular disease. The developed in situ gels showed anti fungal activity on C. albicans, C. tropicalis, A. fumigatus and A. flavus. In conclusion, this study showed that developed in situ gel formulations could be alternatively used as ocular delivery of voriconazole. The present study can open up a window for ophthalmic application of in situ gels loaded with VCZ, they would be a better alternative to conventional eye drops in the treatment of fungal keratitis of the eye.

Declaration of Interest

The authors declare no conflict of interest.

REFERENCES

1. Almeida H, Amaral MH, Lobão P, Lobo JM. In situ gelling systems: a strategy to improve the bioavailability of ophthalmic pharmaceutical formulations. Drug Discov Today 19, 400-412, 2014.
2. Üstündağ-Okur N, Homan-Gökçe E. Lipid nanoparticles for ocular drug delivery. Int J Ophthalmic Res 11(3), 77-82, 2015.
3. Mawana SB, Patel VA, Parmar SJ. Development and characterization of in-situ gel for ophthalmic formulation containing ciprofloxacin hydrochloride. Results Pharma Sci, doi:10.1016/j.rinphs.2015.06.001, 2015.
4. Üstündağ-Okur N, Gökçe EH, Boybıyık DI, Eğrilmez S, Ertan G, Özer Ö. Novel nanostructured lipid carrier based inserts for controlled ocular drug delivery: Evaluation of corneal bioavailability and treatment efficacy on bacterial keratitis. Expert Opin Drug Deliv 12(11), 1-17, 2015.
5. Üstündağ-Okur N, Gökçe EH, Eğrilmez S, Özer Ö, Ertan G. Novel ofloxacin-loaded microemulsion formulations for ocular delivery. J Ocul Pharmacol Ther 30(4), 319-332, 2014.
6. Swapnil D, Sonawane, Lahoti S. Design and evaluation of ion induced in situ gel formulation for levofoxacin hemihydrateocular delivery. Int J Pharm Sci Invent 3, 38-43, 2014.
7. Darwehekar G, Jain P, Jain DK, Agrawal G. Development and optimization of dorzolamide hydrochloride and timolol maleate in situ gel for glaucoma treatment. Asian J Pharm 1, 93-97, 2011.
8. Jung JH, Abou-Jaoude M, Carbia BE, Plummer C, Chauhan A. Glaucoma therapy by extended release of timolol from nanoparticle loaded silicone hydrogel contact lenses. J Control Release 165, 82–89, 2013.
9. Gallarate M, Chirio D, Bussano R, Peira E, Battaglia L, Baratta F, Trotta M. Development of O/W nanoemulsions for ophthalmic administration of timolol. Int J Pharm 440, 126-134, 2013.
10. Mandal S, Thimmasetty MKMJ, Geetha MS. Formulation and evaluation of an in situ gel-forming ophthalmic formulation of moxifloxacin hydrochloride. Int J Pharm Investig 2(2), 78-82, 2012.
11. Hosny KM. Preparation and evaluation of thermosensitive liposomal hydrogel for enhanced transcorneal permeation of ofloxacin. AAPS PharmSciTech 10, 1336-1342, 2009.
12. Hosny KM, Hassan AH. Intranasal in situ gel loaded with saquinavir mesylate nanosized microemulsion: Preparation, characterization, and in vivo evaluation. Int J Pharm 475(1-2), 191-197, 2014.

13. Varshosaz J, Tabbakhian M, Salmani Z. Designing of a thermosensitive chitosan/poloxamer in situ gel for ocular delivery of ciprofloxacin. TODDJ 2, 61-67, 2008.

14. Garala K, Joshi P, Patel J. Formulation and evaluation of periodontal in situ gel. Int J Pharm Investig 3, 29-41, 2013.

15. Moemen D, Bedir T, Awad EA, Elayeh A. Fungal keratitis: Rapid diagnosis using methylene blue stain. EJBAS doi:10.1016/j.ejbas.2015.08.001, 2015.

16. Kumar R, Sinha VR. Preparation and optimization of voriconazole microemulsion for ocular delivery. Colloids Surf B Biointerface 117, 82-88, 2014.

17. Qian Y, Wang F, Li R, Zhang Q, Xu Q. Preparation and evaluation of in situ gelling ophthalmic drug delivery system for methazolamide. Drug Dev Ind Pharm 36(11), 1340-1347, 2010.

18. Qian Y, Wang F, Li R, Zhang Q, Xu Q. Preparation and evaluation of in situ gelling ophthalmic drug delivery system for methazolamide. Drug Dev Ind Pharm 36(11), 1340-1347, 2010.

19. Efron N, Young G, Brennan NA. Ocular surface temperature. Curr Eye Res 8, 901-906, 1989.

20. Clinical and Laboratory Standards Institute. Reference method for broth dilution antifungal susceptibility testing of filamentous fungi; approved standard CLSI document M38-A2. Clinical and Laboratory Standards Institute, Wayne, PA, 2008.

21. Clinical and Laboratory Standards Institute. Reference method for broth dilution antifungal susceptibility testing of yeasts. Approved Standard M27-A3. Clinical Laboratory Standards Institute Wayne, PA, 2009.

22. Clinical and Laboratory Standards Institute. Reference method for broth dilution antifungal susceptibility testing of filamentous fungi; approved standard CLSI document M38-A2. Clinical and Laboratory Standards Institute, Wayne, PA, 2008.

23. Clinical and Laboratory Standards Institute. Reference method for broth dilution antifungal susceptibility testing of yeasts. Approved Standard M27-A3. Clinical Laboratory Standards Institute Wayne, PA, 2009.

24. Borole PM, Chaudhari YS, Dharashivkar SS, Kumavat SD, Shenghani K, Shah PR. Preparation and evaluation of in situ gel of levofloxacin hemifluoride for treatment of periodontal disease. IJPRBS 2(3), 185-196, 2013.

25. Dumontier G, Grossiord JL, Agnely F, Chaumel JC. Review of Poloxamer 407 Pharmaceutical and Pharmacological Characteristics. Pharm Res 23, 2709-2728, 2006.

26. Gonnering R, Edelhauser HF, Van Horn DL, Durant W. The pH tolerance of rabbit and human corneal endothelium. Invest Ophthalmol 18, 37-390, 1979.

27. Üstündağ-Okur N, Gökçe EH, Boybıyık DI, Eğrilmez S, Özer Ö, Ertan G. Preparation and in vitro-in vivo evaluation of ofloxacin loaded ophthalmic nano structured lipid carriers modified with chitosan oligosaccharide lactate for the treatment of bacterial keratitis, Eur J Pharm Sci 2014; 63: 204-215.

28. Mandal S, Thimmasetty MKMJ, Prabhushankar GL, Geetha MS. Formulation and evaluation of an in situ gel-forming ophthalmic formulation of moxifloxacin hydrochloride. Int J Pharm Invest 2(2), 78-82, 2012.

29. Espinel-Ingroff A, Johnson E, Hockey H, Troke P. Activities of voriconazole, itraconazole and amphotericin B in vitro against 590 moulds from 323 patients in the voriconazole Phase III clinical studies. J Antimicrob Chemother 61, 616-620, 2008.

30. Araujo R, Pina-Vaz C, Rodrigues AG. Susceptibility of environmental versus clinical strains of pathogenic Aspergillus. Int J Antimicrob Agents 29, 108-111, 2007.

31. Arikan S, Sancak B, Alp S, Hascelik G, Mcnicholas P. Comparative in vitro activities of posaconazole, voriconazole, itraconazole, and amphotericin B against Aspergillus and Rhizopus, and synergy testing for Rhizopus. Med Mycol 46, 567-573, 2008.

32. Pfaller MA, Diekema DJ, Rinaldi MG, Barnes R, Hu B, Veselov AV, Tiraboschi N, Nagy E, Gibbs DL. Results from the ARTEMIS DISK global antifungal surveillance study: a 6.5-year analysis of susceptibilities of candida and other yeast species to fluconazole and voriconazole by standardized disk diffusion testing. J Clin Microbiol 43(12), 5848-5859, 2005.