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Enhancing Contact Lens Care: Harnessing The Power Of Hydrogen Peroxide For Dynamic Disinfection And Visibility Optimization

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Abstract

Background: Lens visibility, assessed in terms of transmittance, is crucial for contact lens wearers. Various contact lens solutions are employed to improve visibility by disinfecting the lenses.

Methods: In this study, a one-step disinfecting contact lens solution based on Hydrogen peroxide (H2O2) was formulated, similar to multipurpose solutions. The solution, compatible with all lens types, aids in the removal of lipids, protein, and trapped debris from contact lenses, thus enhancing their efficacy.

Results: We found that the pH of the solution was 6.9, making it nearly neutral and compatible with the tear film of the human eye. Hydrogen peroxide molecules degraded into free radicals, disrupting the cell walls of microorganisms and facilitating solution disinfection. Addition of stabilizers such as phosphate or catalase converted peroxide radicals into water and oxygen. Sterility tests confirmed the absence of bacterial growth.

Discussion: Antimicrobial activity assays conducted against five microbes revealed varying zones of inhibition after 48 hours. *Pseudomonas aeruginosa* displayed the maximum inhibition zones, while *Bacillus subtilis* exhibited the minimum.

Conclusion: The Hydrogen peroxide-based solution offers promising disinfection capabilities and compatibility with various contact lens types, suggesting its potential as a viable option for enhancing lens care and visibility.

Keywords: Hydrogen peroxide, Contact lens solution, Disinfection, Visibility, Lens care

1. Introduction

Contact lenses are artificial devices that replace the anterior surface of the cornea. Compared to spectacles, contact lenses typically offer improved peripheral vision and do not accumulate moisture from external sources like rain, snow, or perspiration **[12]**. Before handling contact lenses, thorough handwashing with soap and rinsing is essential. It's important to avoid soaps containing moisturizers or allergens, as they can cause eye irritation. Therefore, a contact lens solution is necessary to remove debris and moisture from the lenses **[5]**.

Contact solution is a commercially prepared chemical solution used for cleaning and disinfecting contact lenses. While there are various types and brands available, most contain preservatives, binding agents, buffers, and surfactants or wetting agents. These components effectively remove any buildup on the lenses without causing scratches and condition them to remain moist and wet on the eye surface. When not in use, lenses can be safely stored in a contact solution to maintain sterility and hydration. Contact lens solution is intended for rinsing, storing, and cleaning lenses. It serves to eliminate bacteria and ensure safety upon contact with the eyes. Although solutions come in different formulas tailored to specific needs, they all essentially perform a similar function **[16]**. Millions of people safely use contact lenses daily, but they require regular upkeep and care. Over time, oil, debris, makeup, and microorganisms can accumulate on lenses, potentially causing eye irritation or other issues.

A comprehensive cleansing regimen for contact lenses should incorporate contact solution and/or related products, encompassing cleaning, disinfecting, rinsing, and proper storage of the lenses. In the early days of their use, lens care was involved multiple steps, including the use of separate solutions for rinsing, cleaning, disinfecting, neutralizing, and protein removal. However, modern practices often utilize a single, multipurpose contact solution that integrates all these steps, eliminating the need for a saline solution rinse. This streamlined approach with multipurpose solutions is perceived to save both time and money, making them the simplest and most convenient method for cleaning, disinfecting, and storing soft contact lenses **[7]**. While traditional lens care solutions primarily targeted protein deposits, certain tear film proteins possess antimicrobial properties when maintained in their active state, potentially aiding in lens cleanliness. Variations in solution formulations among commercially available lens care products can influence patient comfort, lens disinfection, and the preservation of specific tear film proteins. Nevertheless, effective removal of denatured proteins remains crucial, as they can bind to lenses, impair visual acuity, and impact ocular health and comfort with contact lens use **[18]**.

Multipurpose contact lens solutions, hydrogen peroxide-based solutions, and saline solutions are the main types of contact lens solutions available. Multipurpose solutions efficiently clean, rinse, disinfect, and store contact lenses without the need for additional lens care products. With multipurpose solutions, lenses are moistened in the palm of the hand and do not require rubbing **[9,14]**. Hydrogen peroxide-based solutions are highly effective at disinfecting contact lenses but can cause stinging and burning if they come into contact with the eyes. These solutions are preservative-free and may be suitable for individuals allergic or sensitive to chemicals. However, they demand more time and attention for safe lens cleaning. Despite their hypoallergenic nature, hydrogen peroxide cleaners are typically more expensive than multipurpose solutions **[11, 15]**. A saline solution, composed of salt and water, is used to rinse contact lenses before insertion into the eyes. Its natural composition mimics tears and can help prevent reactions to chemicals found in other contact solutions. Typically containing 0.9 percent sodium chloride, saline solution is referred to as normal saline or physiological saline, reflecting its similarity to the sodium concentration in blood and tears. Saline solution serves various medical purposes, including wound cleaning, sinus clearing, and dehydration treatment. It is readily available at local pharmacies or can be prepared at home. Saline is utilized for rinsing contact lenses, nasal passages (nasal irrigation), and cleansing the bladder (bladder irrigation). However, it is crucial to use freshly prepared normal saline to prevent bacterial growth, which could lead to infections **[6,13]**.

The sterility test, a fundamental microbiological test in the pharmaceutical field, ensures the quality and safety of products. This test, introduced in the British Pharmacopoeia in 1932, remains unchanged in its essence. It operates as a presence-absence test, where turbidity in the culture media indicates microbial growth, verified through visual inspection. The absence of turbidity confirms the absence of microorganisms **[8]**.

Antimicrobial or antibacterial agents are substances that either kill or inhibit the growth of microbes. These chemicals are employed to combat bacterial growth specifically. It's important to note that antibacterial activity does not affect viral infections. Originally produced by microorganisms to suppress the growth of others, antibiotics are facing challenges due to the emergence of drug-resistant bacteria. Consequently, there's a growing need to develop less drug-resistant drugs that are highly effective against illnesses in plants, animals, and humans **[1,3]**.

2. Materials and methods

2.1. Chemicals

The laboratory experiment utilized analytical-grade chemicals including Boric acid, Sodium phosphate (dibasic anhydrous), Sodium phosphate (monobasic anhydrous), Hydrochloric acid, Sodium hydroxide, Sodium chloride, Hydrogen peroxide ($H2O2$) 3%, Sodium carbonate, Nutrient agar, Methanol, Ethanol and Amoxicilin trihydrate. These chemicals were used without additional purification. The entire experimental procedure was carried out within the Chemistry laboratory at the Lahore College for Women University, Lahore.

2.2. Preparation of Contact Lens Solution

The solution was prepared by accurately weighing the required amount of ingredients using a digital weighing balance and adding them to a glass beaker. Boric acid and buffer substances were dissolved in 80% of the water with slight heating. Subsequently, surfactant Hydrogen peroxide ($H2O2$) was incorporated into the solution. After cooling to room temperature, Sodium Chloride was added to the solution. To achieve a balanced solution, an additional 100ml of water was added. The resulting solution exhibited a pH of 8.6, indicating an alkaline/basic nature. To adjust the pH, a few drops of HCl were added.

2.3. Microbiological Assays and Antimicrobial Activity

The media preparation involved dissolving 4.3g of agar nutrients in 150ml of water, followed by autoclaving and pouring into Petri dishes. After the addition of samples, the dishes were incubated at 37 °C for a duration of 24-48 hours to facilitate microbial growth and observation. Antimicrobial activity involved the utilization of five bacterial strains, including *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Enterobacter aerogenes*, *Bacillus subtilis*, and *Salmonella typhi*. Wells were meticulously prepared in Petri dishes, and solutions containing the samples were added to these wells. Subsequently, the plates were incubated at 37 °C for a duration of 24 hours to facilitate bacterial growth, thereby allowing for the observation of inhibition zones.

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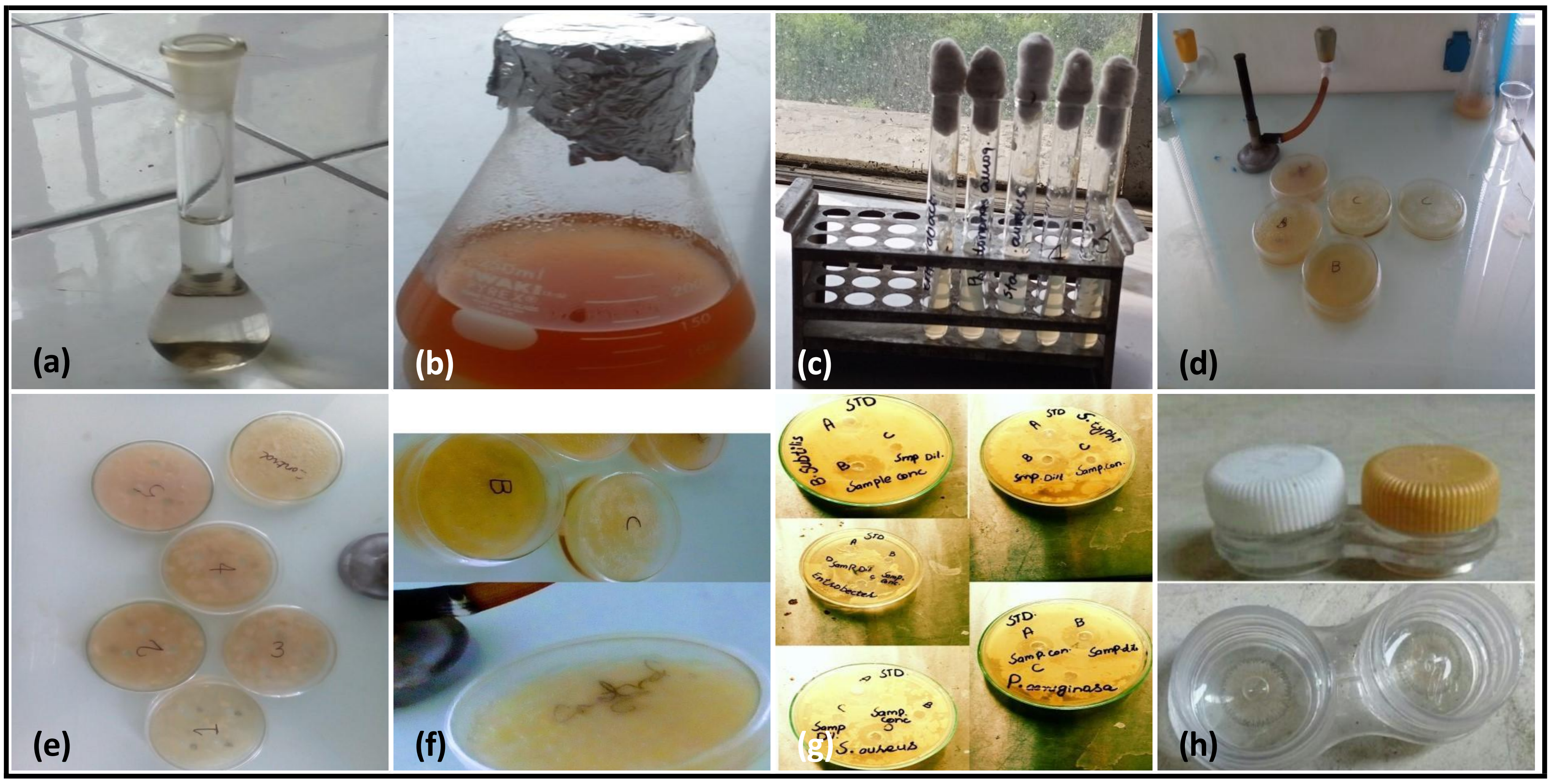

Figure 1: (a) Working solution, (b) Preparation of media, (c) Bacterial strains, (d) Petri plates after inoculation (e) Petri plates after incubation at 35 °C for 24 hours, (f) Petri plates after incubation with no turbidity, (g) Petri plates with zones of inhibition and (h) Contact lenses in solution for 24 hours.

3. Results

The one-step hydrogen peroxide-based system eliminates the necessity for additional neutralization steps after formulation. Featuring 3% hydrogen peroxide (H_2O_2) as the active ingredient, precise amounts of other ingredients, as outlined in accompanying **table 1**, are incorporated to regulate the solution's pH to 6.9 ensuring compatibility with the human eye.

Table 1: Composition of contact lens solution

Ingredients	W/W %
Boric acid	0.830
Sodium phosphate (dibasic anhydrous)	0.310
Hydrogen peroxide	3
Sodium phosphate (monobasic anhydrous)	0.155
Sodium chloride	0.375
Sodium Carbonate	0.100
Sodium hydroxide	As required for pH adjustment
Hydrochloric acid	As required for pH adjustment
Purified water	Balance to 100

3.1. Evaluation of Contact Lenses in Hydrogen Peroxide (H_2O_2) Based Formulation

Eye contact lenses were immersed in the hydrogen peroxide (H_2O_2) based formulation for 24 hours, then tested on human subjects. No adverse reactions such as burning, allergic responses, or excessive tearing were observed. Post-dipping, cleaning, and rinsing, the contact lenses retained their original physical appearance without any debris layer.

3.2. Sterility Assessment

The sterility test revealed no turbidity in Petri dishes containing the formulated solution, akin to standard Petri dishes with media and samples. This confirms the absence of bacterial growth, affirming the sterilization of the provided formulation.

3.3. Antimicrobial Activity

The contact lens solution underwent testing via the well diffusion method against five bacterial strains: *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Enterobacter aerogenes*, *Bacillus subtilis*, and *Salmonella typhi*. Notably, *Pseudomonas aeruginosa* exhibited the maximum zone of inhibition, followed by *Salmonella typhi*, *Enterobacter aerogenes*, and *Staphylococcus aureus*. Conversely, *Staphylococcus aureus* displayed the minimum zone of inhibition.

Table 2: Antimicrobial activity of contact lens solution

			Zone of inhibition in mm after 48 hours		
Sr#	**Microorganisms**	**Gram +/–**	**C.L.S(conc.)**	**C.L.S(dil.)**	**Standard drug**
1	*Staphylococcus aureus*	+	18±3	ND	20±3
2	*Pseudomonas aeruginosa*	_	21±2	ND	22±2
3	*Enterobacter aerogenes*	_	19±3	ND	22±3
4	*Bacillus subtilis*	+	15±2	ND	20±2
5	*Salmonella typhi*	_	20±2	ND	21±2

C.L.S= Contact lens solution, Conc. = Concentrated, Dil. = Dilute, ND= Not detected

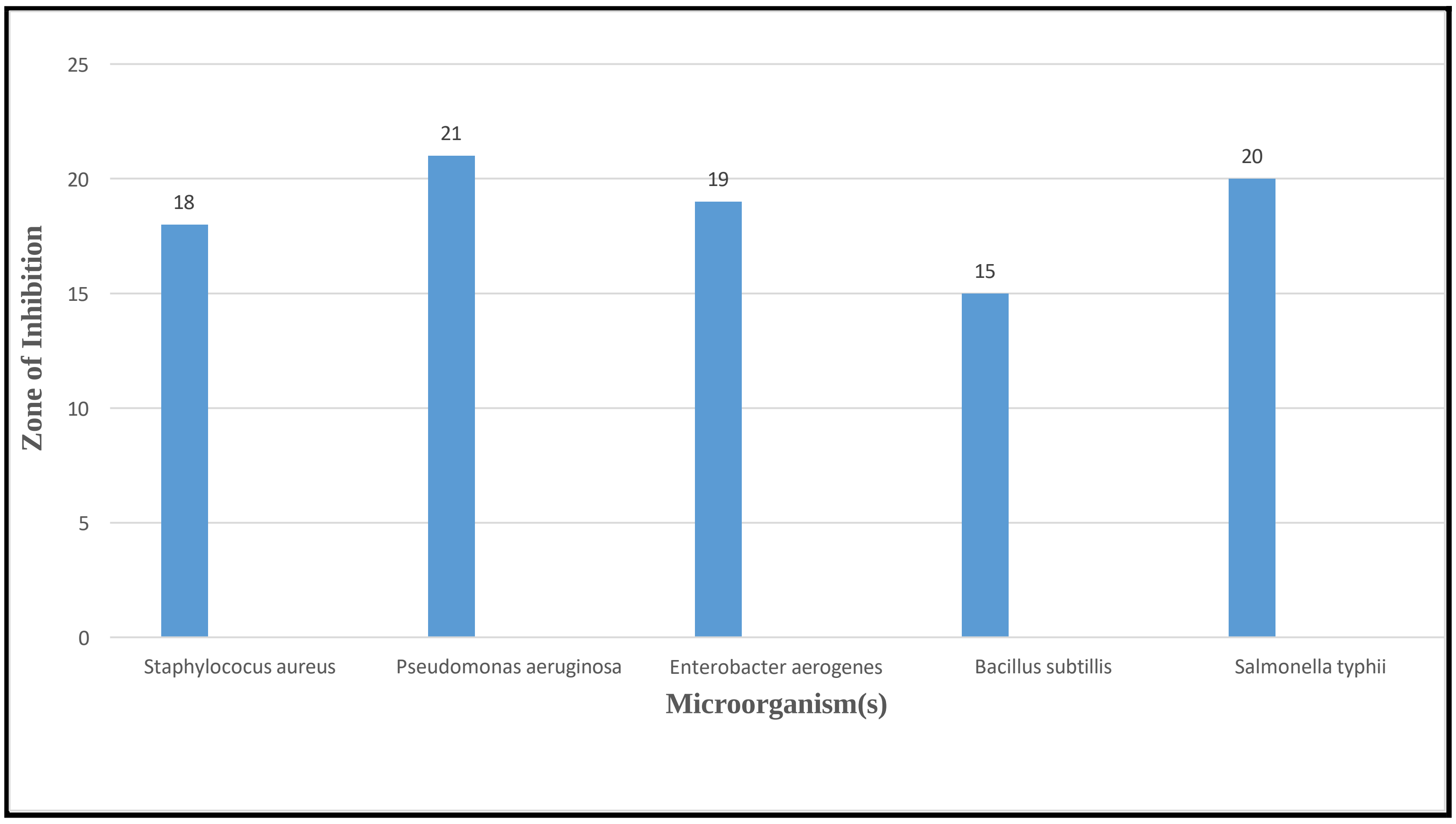

Figure 2*:* Antimicrobial activity of contact lens solution.

4. Discussion

Contact lens solutions play a crucial role in maintaining the hygiene and safety of contact lenses, encompassing rinsing, disinfection, and storage. Comprising preservatives, buffer systems, and other comfort-enhancing agents, these solutions are essential for achieving antimicrobial efficacy, ensuring safe contact lens usage **[4]**. Despite the eye's natural defense mechanisms, microbial keratitis (MK) poses a risk, primarily attributed to Acanthamoeba, a free-living amoeba found in water and soil, significantly impacting contact lens wearers **[2]**. Therefore, thorough removal of bacteria and debris from contact lenses before use is imperative.

The provided hydrogen peroxide-based solution offers a pH of 6.9, nearly neutral, ensuring compatibility and minimizing eye irritation. With 3% hydrogen peroxide as the active ingredient, this solution effectively eliminates germs, including most viruses and bacteria. The incorporation of surfactants aids in lipid removal from various contact lens materials, enhancing its cleaning properties. Moreover, the product undergoes sterilization, ensuring its quality and safety by eliminating bacterial growth.

Antimicrobial activity assessment, conducted against five bacterial strains using Amoxicillin trihydrate (standard) and methanol, further underscores the solution's efficacy. Notably, adherence to proper lens care practices is essential for maintaining eye health and preventing complications. Recommendations include timely lens removal, avoiding overnight wear, and adhering to recommended replacement schedules. Daily disposable lenses should be discarded daily, biweekly ones after 14 days, and monthly disposables after 30 days. Regular cleaning with contact lens solution is crucial for debris removal **[10, 17]**.

5. Conclusion

Hydrogen peroxide-based formulations play a vital role in ensuring the hygiene, comfort, and safety of contact lens wearers. Through effective disinfection and removal of bacteria and debris, these solutions mitigate the risk of microbial keratitis and other ocular infections. The antimicrobial efficacy, compatibility with various lens materials, and simplicity of use make them indispensable in everyday lens care routines. Adherence to proper lens care practices, including regular cleaning and timely replacement, is paramount for maintaining ocular health and preventing complications. Moving forward, continued research and development in contact lens solutions will further enhance their efficacy and contribute to the overall well-being of contact lens wearers.

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