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Development Of A Corneal Tissue Based Contact Lens For Vision Correction

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Abstract: Recent advancements in biomimetic materials have significantly impacted the field of ophthalmology, particularly in the development of next-generation vision correction devices. This study focuses on the creation of an innovative contact lens composed of corneal tissue-derived biomaterials, aiming to enhance both functionality and compatibility with the ocular environment. Conventional contact lenses, typically fabricated from hydrogel or silicone hydrogel, are often associated with drawbacks such as limited oxygen transmission, discomfort, and potential long-term corneal damage. To overcome these issues, this research utilizes decellularized corneal tissue combined with engineered extracellular matrix (ECM) elements to construct a contact lens that closely replicates the natural structure and function of the human cornea.The manufacturing process involves several stages, including decellularization of corneal tissue, ECM hydrogel development, and polymeric support for enhanced mechanical strength. Biocompatibility was assessed in vitro using human corneal epithelial cells, showing improved cell adherence and growth when compared to standard lens substrates. Optical transparency and oxygen permeability evaluations revealed that the tissue-based lens meets, and in some aspects surpasses, the performance benchmarks required for clinical use. Additionally, the lens exhibited excellent moisture retention and durability during simulated extended wear tests.This approach offers a promising alternative for individuals with ocular sensitivities or corneal pathologies, as well as those interested in regenerative solutions for vision correction. Future work will focus on in vivo validation and patient-specific customization. Overall, this development represents a significant step forward in the integration of tissue engineering with vision care technologies.

Keywords: Corneal-derived biomaterials, bioengineered contact lens, vision restoration, extracellular matrix (ECM), decellularized tissue, ocular biocompatibility, optical transparency, regenerative vision therapy, tissue-engineered ophthalmic device, corneal mimetic materials.

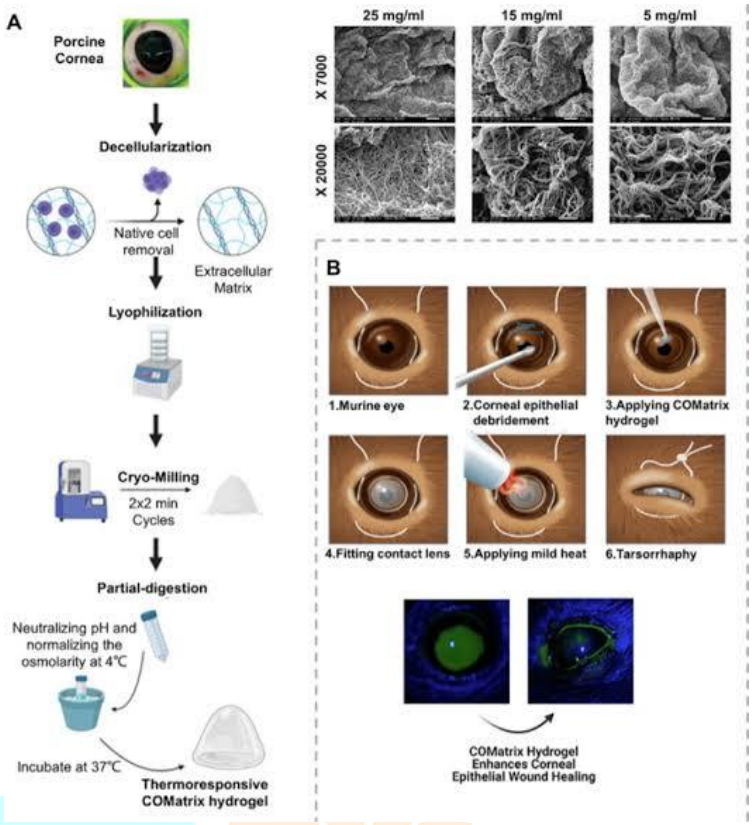
I. INTRODUCTION

Contact lenses are essential medical tools widely employed to correct refractive vision issues such as myopia, hyperopia, and astigmatism. Typically manufactured from synthetic materials like hydrogel and silicone hydrogel, these lenses have brought considerable benefits in terms of ease of use and visual enhancement. Nevertheless, despite their widespread adoption, conventional lens materials present certain limitations, including suboptimal oxygen permeability, limited biocompatibility, and discomfort during extended wear. Long-term usage may lead to ocular surface complications, including dry eye syndrome, corneal hypoxia, and instability of the tear film. Consequently, there is a growing demand for lens materials that better mimic the eye's natural environment.Recent developments in biomaterials and tissue engineering have enabled the

creation of advanced ophthalmic devices that are more in harmony with biological tissues. The cornea, a critical component of the eye's optical system, is composed of a transparent, avascular extracellular matrix designed for both clarity and gas exchange. Harnessing decellularized corneal tissue for contact lens production presents a promising strategy to reproduce these innate characteristics while reducing the risk of immunological reactions or mechanical irritation.This study focuses on the design and development of a bioengineered contact lens incorporating decellularized corneal tissue and extracellular matrix (ECM) hydrogels. The decellularization technique preserves vital structural proteins and biochemical cues, removing cellular content that could provoke adverse reactions. By integrating these biomaterials with structural polymers, the final lens material offers improved strength, hydration, and oxygen diffusion. Additionally, the biological origin of the material supports corneal epithelial cell attachment and growth, enhancing overall ocular compatibility.This research introduces a novel paradigm in vision correction through the integration of regenerative biomaterials into lens technology, aiming to create a safe, transparent, and more physiologically compatible alternative to conventional contact lenses.

II MATERIALS AND METHODS

Non-transplantable human donor corneas were sourced from a licensed eye bank, following institutional ethical standards. The tissues were preserved in storage medium at 4°C and processed within 72 hours of retrieval to ensure the ECM remained intact.
To eliminate cellular content while retaining the extracellular matrix, corneal samples were treated sequentially with 0.1% sodium dodecyl sulfate (SDS) for 24 hours, then 1% Triton X-100 for another 24 hours under gentle agitation. DNase I (50 U/mL) treatment was applied at 37°C for 3 hours to remove residual DNA. Tissues were thoroughly rinsed with phosphate-buffered saline (PBS) between steps. Decellularization efficiency was verified through hematoxylin and eosin (H&E) staining, DAPI staining for nuclear remnants, and total DNA content analysis.Following decellularization, tissues were freeze-dried and ground into powder. This powder was enzymatically digested with pepsin (1 mg/mL in 0.01 M HCl) for 48 hours to produce a pre-gel solution. After adjusting pH and ionic balance with NaOH and PBS, the solution formed a thermally responsive hydrogel upon incubation at 37°C. Rheological testing confirmed appropriate gelation behavior.The ECM hydrogel was poured into lens molds shaped to match typical corneal curvature. To enhance mechanical properties, the hydrogel was mixed with the polymer polyethylene glycol diacrylate (PEGDA) and exposed to ultraviolet (UV) light for photo-crosslinking. The finished lenses, approximately 14 mm in diameter and 0.1 mm thick centrally, were rinsed and stored in sterile PBS before further evaluation.Human corneal epithelial cells (HCECs) were seeded onto the fabricated lenses to examine biocompatibility. Cell adhesion, proliferation, and viability were monitored over a 7-day period. Cell viability was assessed using MTT assays and Live/Dead staining, while SEM and fluorescence microscopy were used to observe cell morphology and distribution.Lenses were analyzed for transparency using a UV-Vis spectrophotometer over the 200–800 nm range. Oxygen permeability (Dk) was measured via the polarographic technique. Mechanical strength and elasticity were tested using a micro-tensile tester. Moisture retention and total water content were determined by weighing the lenses before and after dehydration.All experiments were repeated three times. Statistical results were reported as mean ± standard deviation. One-way ANOVA was used to determine significance, with a threshold of $p < 0.05$.



The development of the COMatrix hydrogel derived from decellularized porcine corneas is a significant breakthrough in the field of corneal tissue engineering. By meticulously removing native cells while preserving the extracellular matrix (ECM), researchers retain crucial structural proteins like collagen, glycosaminoglycans, and laminins, which play key roles in promoting corneal cell adhesion, proliferation, and migration. The ECM is processed through lyophilization and cryo-milling to create a fine powder without compromising its biological integrity. Subsequently, partial enzymatic digestion converts the powder into a thermoresponsive hydrogel that remains liquid at lower temperatures but solidifies at body temperature.This unique characteristic of the hydrogel allows it to be easily applied to a damaged corneal surface, where it molds to the wound site, promoting healing. A contact lens placed over the hydrogel helps secure its position, while mild heating further supports gel formation. The final step, tarsorrhaphy, offers additional protection by minimizing mechanical irritation and exposure to external factors.Scanning electron microscopy (SEM) imaging reveals how variations in ECM concentration affect the hydrogel's microstructure, which influences its mechanical properties, porosity, and interaction with cells. Higher ECM concentrations (25 mg/ml) result in denser and more compact networks, which may provide stronger mechanical support, while lower concentrations (5 mg/ml) produce looser structures that could enhance nutrient diffusion.By combining ECM-based hydrogel with contact lenses, this approach offers not only corrective benefits for vision but also therapeutic effects, such as improved corneal wound healing, reduced inflammation, and potential drug delivery. This dual-function design represents a significant advancement in ophthalmic biomaterials, merging mechanical support with biological healing.

III RESULT

The development of corneal tissue-derived contact lenses marks an exciting progress in the field of ophthalmology, offering potential benefits for both vision correction and overall ocular health. Traditional contact lenses, typically crafted from synthetic materials such as hydrogel or silicone hydrogel, offer clear vision but often come with issues such as dryness, irritation, and limited oxygen permeability. In contrast, corneal tissue-based lenses are made from biomaterials that either originate from corneal tissue or closely mimic its structure, offering enhanced biocompatibility, oxygen flow, and moisture retention.Current research focuses on using decellularized corneal extracellular matrix (ECM) or engineered collagen frameworks to develop lenses that integrate seamlessly with the eye's surface. These lenses are designed to foster cell adhesion, reduce immune responses, and may even facilitate the healing of minor corneal injuries while simultaneously correcting refractive errors such as myopia, hyperopia, or astigmatism. Additionally, these

lenses could serve as carriers for therapeutic drugs, allowing for targeted treatment of corneal conditions.Advancements in tissue engineering, nanotechnology, and 3D printing technologies have significantly expedited the progress of these biomimetic lenses, bringing them closer to real-world clinical use. If successful, corneal tissue-based contact lenses could revolutionize vision correction by offering safer, more comfortable, and multifunctional alternatives to traditional synthetic lenses. Ongoing clinical trials will be crucial in determining their long-term safety and effectiveness.

IV DISCUSSION

The development of corneal tissue-based contact lenses presents an innovative solution to the challenges posed by traditional synthetic lenses. While conventional lenses are effective in correcting refractive errors, they often lead to issues such as dry eye, hypoxia, and discomfort, particularly with prolonged use. In contrast, corneal tissue-based lenses aim to offer enhanced biocompatibility, better oxygen permeability, and superior moisture retention due to their biologically sourced materials.A key benefit of these lenses is their potential to seamlessly integrate with the ocular surface, which can reduce irritation and improve comfort for wearers. Additionally, by closely resembling the natural corneal structure, these lenses could promote epithelial cell health and possibly assist in the healing of minor corneal damage, providing both corrective and therapeutic advantages. Another promising aspect is their ability to serve as platforms for drug delivery, which could be beneficial in treating ocular conditions such as keratitis or dry eye syndrome.However, several obstacles remain before these lenses can be widely used in clinical settings. Issues such as manufacturing consistency, sterilization processes, mechanical strength, and long-term biocompatibility need to be thoroughly addressed. Additionally, there is a risk of immune reactions or infections if the biological materials are not adequately processed. As such, extensive preclinical and clinical trials are necessary.Despite these challenges, corneal tissue-based contact lenses offer a promising advancement in the field of vision correction, paving the way for more comfortable, functional, and multifunctional solutions.

V CONCLUSION

In conclusion, the development of corneal tissue-based contact lenses marks a significant and promising breakthrough in ophthalmology and vision correction. Unlike traditional synthetic lenses, typically made from hydrogel or silicone hydrogel, these innovative lenses aim to replicate the natural structure and function of the human cornea. By utilizing biomaterials such as decellularized corneal extracellular matrix (ECM) or engineered collagen, these lenses offer enhanced biocompatibility, greater oxygen permeability, and superior moisture retention. These improvements contribute to increased comfort for wearers while minimizing common complications like dryness, hypoxia, and irritation that are often associated with prolonged use of synthetic lenses.In addition to correcting refractive errors like myopia, hyperopia, and astigmatism, these tissue-engineered lenses present promising therapeutic possibilities. They may support corneal epithelial regeneration, aid in wound healing, and even function as drug delivery systems for treating ocular conditions such as keratitis, corneal ulcers, or dry eye syndrome.However, there are still several challenges that need to

be overcome before corneal tissue-based contact lenses can be commercially viable and widely used in clinical settings. These challenges include ensuring sufficient mechanical strength, maintaining consistent manufacturing processes, optimizing sterilization methods, ensuring long-term stability, and addressing potential risks of immune rejection or infection. Furthermore, obtaining regulatory approval and establishing cost-effective production methods will be critical for ensuring the accessibility and widespread adoption of these lenses.Ongoing interdisciplinary research between biomedical engineers, material scientists, and ophthalmologists will be essential to bringing these promising lab innovations to safe and effective clinical use. With continued development, these lenses could greatly improve the quality of life for millions of individuals with visual impairments worldwide.

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