0PRECISION LIQUID MEDICATION DELIVERY SYSTEM IN OPHTHALMOLOGY

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ABSTRACT

Medication delivery to sensitive tissues—such as mucosal surfaces, surgical sites, or inflamed areas—often suffers from imprecise targeting, inconsistent dosing, and substantial loss of active ingredients. These inefficiencies not only compromise therapeutic outcomes but can also cause discomfort and unintended systemic exposure.

This proposal outlines a novel platform for precision medication delivery using the **Piezo-Generated Aerosol Wand (PAW)**: an applicator designed for controlled, gentle, and waste-free administration of liquid medications. The system enables metered dosing and spatially confined targeting, avoiding the limitations of conventional droppers and sprays. This document presents the core concept, technical approach, and proposed development plan **for application in ophthalmology**.

*Note that the PAW platform will be broadly applicable to multiple other therapeutic areas, including **ENT** for nasal, pharyngeal, and ear canal applications; **Dermatology for** burns, wounds, and sensitive skin treatment; **Dental care for** localized oral delivery; **Surgical and post-surgical for** precise application of anesthetics, antimicrobials, or hemostatic agents; and **Pediatrics and geriatrics for** safe, comfortable dosing for those with physical or cognitive limitations.*

1. THE PROBLEM: IMPRECISE DELIVERY, SYSTEMIC EXPOSURE, PATIENT DISCOMFORT

Across many medical domains—dermatology, ENT, ophthalmology, wound care, dental medicine, and surgery—medication delivery methods are hampered by:

- **Excess medication loss** due to imprecise aiming or overflow.
- **Uncontrolled systemic absorption** from drainage or spread beyond the intended site.
- **Patient discomfort or pain**, especially on inflamed, sensitive, or post-operative tissues.
- **Manual administration issues**, such as dosage inconsistency and user error in children, elderly, or non-compliant patients.
- **Cross-contamination risk** in contact-based devices.

Conventional sprays and droppers often oversaturate or undersupply the target tissue and fail to provide adequate control over both **dose** and **delivery geometry**.

2. THE SOLUTION: A CONTROLLED LIQUID MEDICATION DELIVERY PLATFORM

We propose the development of a **non-contact, precision medication applicator platform**—the **Piezo-Generated Aerosol Wand (PAW)**—capable of:

- Delivering a **precisely metered dose** of liquid medication,
- Shaping the dose into a **focused aerosol micro-cloud/jet**,
- **Targeting tissue with geometric precision** while avoiding adjacent areas,
- Operating **without physical contact**, thus reducing risk of contamination and mechanical irritation.

3. OPHTHALMIC DELIVERY OF LIQUID MEDICATIONS

In this proposal we are focusing on **Ophthalmology by** addressing liquid medication delivery for post-operative or chronic ocular conditions.

The inefficiencies of standard **eye drop administration** are well-documented:

- **Over 90% of eye drop volume is lost** via spillage or drainage into the nasolacrimal duct.
- **Drainage into the nasal cavity** may trigger sneezing or rhinorrhea, risking post-operative complications such as displacement of intraocular lenses.
- **Instillation challenges**—especially for elderly or post-op patients—reduce adherence and effectiveness.
- **Tear duct overload** may cause long-term dysfunction due to prolonged exposure.

The PAW applicator adapted for ophthalmology:

- **Delivers an exact dose directly into the conjunctival sac**, avoiding overflow,
- **Avoids contact with periorbital skin**, reducing contamination and irritation,
- **Minimizes systemic exposure**, especially corticosteroids or antibiotics,
- **Simplifies use**, eliminating the need for coordinated squeezing, tilting, or manual occlusion of tear ducts.

This application will not only demonstrate PAW's utility but will also showcase its comfort, safety, and precision in a highly sensitive use case.

4. TECHNOLOGY. COMPOSITE SPHERICAL PIEZO-LENS IN PAW DESIGN: A FOCUSING SYSTEM FOR PRECISION MEDICATION DELIVERY

The centerpiece of the proposed platform is the Piezo-Generated Aerosol Wand (PAW)—a hand-held, contact-free system for the precision application of liquid medications. In its baseline form, PAW uses a micro piezoelectric actuator to generate a soft, confined aerosol cloud/jet.

This gentle mist can be directed with precision onto the eye sensitive surface, minimizing waste, physical discomfort, and systemic absorption. PAW is particularly suited for applications involving the eye, where handheld control provides essential adaptability.

To extend the PAW platform's capability, we propose an integrated or modular enhancement: the Composite Spherical Piezo-Lens (CSPL). system This system allows a hand-held user-controlled device to focus converging streams of micro-droplets toward a tunable focal point—much like a lens focuses light. The CSPL enables highly controlled and localized medication delivery or broader coverage, depending on therapeutic need and proximity to the target surface.

4.1. How It Works

- Piezoelectric micro-nozzles are arranged on a spherical or parabolic dome housed in the hand-held unit.
- Each nozzle emits micro-droplets on demand, forming streams that converge spatially at a focal region in free air.
- The focal zone is controlled by adjusting droplet velocity, timing, or by moving the wand closer or farther from the treatment surface of the eye.
- The operator can easily guide the device to follow anatomical contours, enabling both spot treatment and wide-area coverage.

4.2. Benefits

- High precision and portability: The hand-held PAW + CSPL system allows flexible, user-directed application.
- Contact-free targeting: The lens design eliminates the possibility of physical contact, preserving sterility and avoiding discomfort.
- Versatile use: Designed for clinicians, caregivers, and patients alike, the portable format makes it suitable for both in-clinic and at-home use.

4.3. Optional Enhancements

- Aerodynamic assist: A coaxial low-velocity airflow may be added to guide droplets in varied room conditions.
- Electrostatic or acoustic steering: Advanced versions may allow dynamic adjustment of convergence via internal field control.
- Smart targeting: Future models may integrate miniaturized sensors to help the operator maintain optimal distance and aim.

This combined architecture—PAW's gentle cloud jet generation with CSPL's precision-focused delivery—forms a compact, intelligent, and adaptable medication applicator, advancing the state of non-invasive therapeutic delivery for ophthalmology.

5. DEVELOPMENT APPROACH

To realize the hand-held PAW + CSPL platform, we propose a structured, four-phase development plan that balances innovation, usability, and clinical validation.

Phase 1: Feasibility and Simulation

- Model piezo-droplet dynamics and convergence behavior in CSPL dome geometry under mobile hand-held use conditions.
- Simulate fluid dispersion, focal tuning, and interaction with irregular body surfaces.
- Explore acoustic and aerodynamic approaches to stabilize droplet trajectories in open air.

Phase 2: Prototype Fabrication

- Construct hand-held PAW prototypes with integrated piezo elements.
- Develop the CSPL curved nozzle array and fit it within a lightweight ergonomic housing.
- Integrate user interface components for manual focal adjustment and spray modulation.

Phase 3: Application Testing and Adaptation

- Validate performance across various therapeutic use cases using test surfaces and tissue analogs.
- Evaluate the handheld device's precision, coverage, and ease of use in comparison with traditional methods.
- Adapt device form factor, grip, and feedback mechanisms based on use-case feedback.

Phase 4: Clinical Integration and Regulatory Review

- Conduct small-scale trials in partnership with clinical centers.
- Initiate regulatory pathway based on intended use and classification (likely as a Class II device).
- Finalize designs for scalable production, considering both consumer and clinical market entry points.

6. CONCLUSION

The **hand-held PAW system**, enhanced with the **Composite Spherical Piezo-Lens**, represents a breakthrough in medication delivery for sensitive eye surfaces. By combining precision, comfort, and non-contact control in a compact and user-friendly form, the device addresses longstanding inefficiencies of drops and conventional sprays.

Whether used in an operating room, clinic, or home setting, the **portable PAW + CSPL unit** empowers users with controlled, focused, and gentle application of liquid medications. Its adaptive targeting capabilities enable both high-precision micro-delivery and uniform surface coverage—critical features in ophthalmology.

This proposal outlines a realistic and flexible development path, grounded in proven piezoelectric and microfluidic technologies. The PAW + CSPL platform promises to deliver measurable improvements in therapeutic outcomes, patient safety, and delivery efficiency.