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(54) Title: AUTOMATED EYE DROP INSTILLATION

Figure 1

(57) Abstract: A device for the delivery of fluids to one or both eyes of a patient includes a frame for placement over the patient's eyes, a fluid reservoir or a connector to a fluid reservoir, a video camera to monitor the opening and closing of the eyes, a fluid delivery means that has valves and/or pumps to deliver fluid through an outlet, and a processor or a connector to a remote processor with software to receive input from the camera and deliver output to the delivery means to start and stop fluid flow through an outlet to the eye. The controlled device allows for the delivery of fluid when the eye is open and stops the delivery of the fluid when the programmed processor has determined that it must stop to avoid a blink and allows the processor to control one or more periods of fluid delivery until a prescribed dosage is delivered.
BACKGROUND OF INVENTION

The delivery of medications to the eye can be advantageous in many ways; however, the administration is plagued with challenges. The application of fluids as eye drops has been problematic for many, and is the norm with children who tend to blink or jerk during delivery. Elderly patients often lack the dexterity to correctly position the eye dropper or squeeze bottle for consistent delivery to the eye. The medication is worthless if it lands on the eyelid, nose, forehead, or cheek. Consistent and assured dosage can be extremely difficult to achieve. This method of administrating medicines is inaccurate and wasteful as presently carried out.

Eye droppers and, particularly, eye dropper bottles often poke the patient in the eye, which, in the worst case, can damage the eye and permits the delivery tip to become contaminated with bacteria, viruses, or fungi, which, can proliferate in the ophthalmological solution. This can promote subsequent infection in the patient or a second patient that happens to use the solution. Common eye drop technology does not satisfactorily control the amount of medication that is dispensed or ensure delivery.

Accordingly, there remains the need for an ophthalmic delivery device where a consistent volume of fluid is delivered into the eye. A device is needed that avoids under-dosing because the fluid misses the target eye or over-dosing because the patient attempted to compensate for the partial administration by delivering an addition unknowable portion of a dose.
BRIEF SUMMARY

The delivery of eye drops to eyes is carried out using a device where a frame is configured for placement over a patient's eyes, contains or connects to one or more fluid reservoirs and means to observe and/or induce synchronized blinking, and a means to deliver drops or droplets to an eye at the time the eye is in a stage of the rhythm that the eye is open and/or determined to be open.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a drawing of an eye fluid delivery device where drop control and camera control is of a single unit mounted to the frame, according to an embodiment of the invention.

Figure 2 shows a drawing of an eye fluid delivery device where drop control is separate from camera control and reside as three units that are mounted to the frame, according to an embodiment of the invention.

DETAILED DISCLOSURE

Embodiments of the invention are directed to a device and method for the delivery of an ophthalmic solution to the eye in a controlled and consistent manner. Additionally, in this manner the contamination of the ophthalmic solution, or subsequently the eye can be assured. The device employs a frame, similar to that for eye glasses, where the medicating fluid reservoir is positioned to provide fluid consistently when delivered to the eye, and a device by which the delivery can be made when the eye is open and while there is a high probability that the state of being open will remain so during the administration of the fluid. The fluid may be provided in a controlled manner to the eye as a drop or as a spray such that a prescribed quantity, for example a single drop, is reliably delivered. Typically, but not necessarily, the fluid outlet of the device will be positioned within about 2.5 cm from the eye to which the fluid is delivered. The frame may include a reservoir into which the ophthalmic solution is placed or the frame may have a means of attaching an exchangeable reservoir of the ophthalmic solution. The attached reservoir can contain an outlet that directly delivers drops, a stream, or an aerosol to the eye, or an exchangeable reservoir outlet that connects to a conduit inlet from which the fluid is administered to the eye from a conduit outlet distal to the reservoir. The reservoir outlet or conduit outlet is effectively controlled by a processor.
that receives a signal from a video imager that has monitored the eye over a period of time such that the processor can determine a mode of administration of the fluid to the eye with high assurance that the eye is open when the processor outputs a signal or series of signals that controls the outlet of fluid. In an embodiment of the invention, fluid can be delivered simultaneously to both eyes of a patient. In embodiments of the invention, the fluid is delivered to only one eye or to both eyes, sequentially.

The frames can have a fluid reservoir within, upon, or under one or both temple portions. The frames can have a reservoir within or upon the bridge or a top bar of the frames. The frames can have a reservoir within one or both rims of a frame or in one or both areas that are occupied by the lens of a typical pair of glasses, or goggles. The frames can have a connector to position and fix an external fluid reservoir to the frames. The frames can be connected to the external reservoir by a conduit, for example, a tube. The reservoir can be detachable from the frame and the frame can have a means of connecting to the reservoir. For example, the frames can have a portion that is threaded to receive a threaded reservoir that can be attached to the frames by screwing the reservoir onto the frame. The connection on the frame can be a fitting, such as a hose barb or a quick release fitting, where a conduit from a remote reservoir can be connected to the fitting.

In an embodiment of the invention, the reservoir can be under a desired pressure greater than ambient. The reservoir may have a means to apply a pressure, for example, a plunger in a cylindrical receiver or a clamp that can be placed on the outside of a compressible receiver where the clamp can apply a desired pressure. The plunger can be threaded or have other means for applying and retaining a position and pressure. A clamp can be actuated by a screw or other mechanism that can be variably applied and retained when sufficient pressure is achieved, for example, controlled by a solenoid or a motor. A maximum pressure can be controlled, for example, by a release valve situated such that air and not fluid will exit the reservoir when the means applies a pressure higher than optimal and where an indicator can be activated that lets a user know that the release valve has actuated. Power can be applied as required from a battery or a transformer that can be plugged into a common house outlet. If provided by a battery, the battery can be connected to the device by a cord or is of a size and weight as to permit the attachment or incorporation into the device without undue discomfort to the patient or present difficulty in maintain an alignment of the device while in use.
In an embodiment of the invention, the reservoir can be under ambient pressure and the fluid delivered by gravity, or by the use of a micropump, for example, a diaphragm pump or peristaltic pump that is controlled by the processor. The fluid delivery can be controlled by a valve, for example, an isolation diaphragm valve or a pinch valve. The pump can deliver the fluid to an outlet that can be one that forms a single drop that falls from a tip or a plurality of tips constructed to have orifices that cause dropping of a particular sized drop once formed. The surfaces of the tip can be one with a low surface energy material, such as a Teflon or silicone to discourage adherence of the fluid drop, particularly an aqueous fluid drop, to the tip. The tip can have a partitioned superhydrophobic surface such that drop size is minimal before falling from the outlet tip. The outlet can be a nozzle that forms an aerosol. In an embodiment of the invention, the nozzle can be one or more inkjet-type jet dispensers, for example, a thermal droplet jet or a piezoelectric droplet jet dispenser. In this manner the aerosol formed by a plurality of nozzles can be, for example, 3 to 500 picoliter per droplet per nozzle at a jet speed of, for example, 6 m/s dispensed at a rate of, for example, 4,000 droplets/s where the dispenser can have, for example, 12 to about 300 nozzles per dispenser. In an embodiment of the invention, the outlet or a conduit to the outlet or valve can provide a signal to the processor that the outlet is in a state of prime and is ready for delivery of a fluid. Alternatively, the processor, valve, pump, or nozzle can be placed in a manual control mode such that fluid can be delivered to a cloth, other absorbent receiver, or a receiver for retention of the fluid; where assurance that the outlet is in a state of being primed can be made before delivery of the fluid is initiated by the processor.

In an embodiment of the invention, the reservoir can be made of a flexible polymer than can deform in response to an external pressure. The drop creation can then be initiated by applying the pressure, for example, by use of a linear actuator or a cam. In an embodiment of the invention, the drug reservoir can be made of a responsive polymer that can change shape in response to stimulus such as electricity or magnetic fields, with the shape change proving the driving force for creation of the drop. In another embodiment of the invention, the reservoir could be surrounded by another reservoir full of fluid with the pressure in the outer reservoir triggering the shape change in the inner reservoir. This has the benefit of eliminating contamination of the inner reservoir by contact with any other device. In another embodiment the reservoir is a commercially available eye drop bottle that can be integrated into the drop producing mechanism.
In an embodiment of the invention, sensor is included that allows the determination of motion and/or the state of the eye to which the fluid is to be delivered. The sensor can be a motion sensor, or a light, visible or infrared, which can provide a signal when the eyelid is open and the eye is exposed. In an embodiment of the invention, the sensor can rely on video input that is provided by one or more cameras that receive images through one or more lenses that are positioned for continuous observation of one or both eyes. The video camera can be a CCD device, a CMOS device or any other type of device. The image need not be of high resolution and 0.3 megapixels or less is adequate, although higher resolution is acceptable as long as the processor used for assessing the blinking and actuation of the valve controlling the fluid is sufficiently rapid to effectively perform the necessary calculation in effectively "real time" where the time lag between receiving the images and providing the outlet is sufficiently short, for example, fractions of a second. The frame rate can be 20 or more frames per second (fps), for example, the common 30 to 60 fps of typical video display rates. The common frame rate can permit the actuation of the control valve in as little as, for example, 0.1 seconds. The received images permit the processor to employ software that determines if the eye is or should be in an open state to permit access of a fluid or if the eye is in a closed state that inhibits access to a fluid. The video feed can be received for a period of time that permits calculation of a periodic or quasi periodic sequence of blinks, such that expected periods of fluid access to and restriction from the eye can be predicted and used during the control of the outlet for fluid delivery during a confident access period. The video feed can be used to determine the most rapid rate at which the patient blinks and detect the moment of opening of the eye after a blink. In this manner, the fluid delivery can commence as soon as the eye is accessible to the fluid and is delivered at a rate such that delivery will be halted before the subsequent blink is anticipated, or determined to commence. During this "access window" the aligned fluid outlet assures delivery into the eye and not the eye lid or eye lashes. The continuous video feed can be employed to detect the closing of the eye in real time where the processed signal can evoke an output signal to the control valve of the controlled outlet to halt delivery. The control system can permit the delivery of portions of the dosage over a plurality of access windows until the entire prescribed dose is delivered and then place the controlled outlet in a closed state. If desired, the video imaging can be used to detect physiological changes to the eye, such as dilation or other responses of the eye to the
delivered dose, for assurance that the dose is delivered rather than the device attempted
delivery from an empty reservoir or an unprimed outlet.

Control of the device can be carried out with a computer. In an embodiment of the
invention, the computer can be linked via a cable to the device or, in another embodiment of
the invention, a small single board computer, for example, a BeagleBone by Beagleboard can
be included into the device. Positional and rotational information can be controlled with the
aid of a Gray code. The processor can be a microprocessor that is included as a portion of the
frame or can be connected to the camera(s) mounted on the frame. The processor employs
imaging software to determine the end and/or commencing of a blink and the blink rate. The
processor can be a personal computer, for example, a portable laptop computer, or other
microprocessor driven portable device, for example, a tablet computer or a smartphone. The
signal between the camera mounted on the frame and the processor can be wired or wireless.
The processor has a user interface for input of dosage variables. Dosage variables that can be
input include: fluid identity; solute concentration; solution viscosity; prescribed dosage; or
any other needed input.

Among the many configurations that the drop delivery and camera features can be
combined on the frame of an eye fluid delivery device, two possibilities are illustrated in
Figures 1 and 2. In Figure 1, the cameras are mounted to a common portion of the frame
with the drop delivery features. The mounting feature can house or support any
microprocessor, transmitter, reservoirs, and/or controllers desired. In Figure 2, the mounting
of the camera is separate from a first drop delivery feature and a second drop delivery feature.
In this manner, the supporting and controlling portions of the device can be separated on the
frame. In alternate embodiments of the invention, configuration of the camera or the eye
observation system does not require attachment to the dispensing device, but permit remote
communication. For example, a camera phone or a camera attached to a computer could be
used for the imaging and communicating the information to the dispensing device mounted
on the glasses, through, Wi-Fi, Bluetooth, or other radio communication. A positioning stage
may be employed with these configurations to facilitate positioning of the head for camera
imaging. In another embodiment of the invention, the camera and the dispensing device are
mounted on a stage with a specific location and assembly for placement of the chin. Many
other configurations can be employed, as would be appreciated by one of ordinary skill in the
art.
In another embodiment of the invention, additionally, the video feed can be used to precisely locate the region within the eye where the medication should be delivered and to orient the drop or aerosol producing device to ensure delivery to the desired region of the eye.

In another embodiment of the invention, the processor can be replaced by a sequence of audio cues, for example, beeps or similar sounds, where the subject is instructed to close eyes at every cue. After a few cues, the drop creating device can use the cue sequence to synchronize the drop delivery with the timing to assure a fully opened eye. In another embodiment of the invention, the camera and the beeps can be used to enhance the synchronization between drop delivery and eye opening.

The fluid can be delivered to the eye of a patient with the position of the eye looking directly ahead in the eyeglasses-like frame or looking at any desired angle relative to the eyeglasses lens equivalent area of the frames. The fluid can be delivered when the patient's head is facing out, up, or any orientation that is consistent with the means of providing the drop or droplets of fluid. For example, for a device where the drop is relatively large and delivered by gravity or pump with a relatively low discharge pressure, the patient may face upward, for example, when lying down, or otherwise positioning the face upward. Where a droplet jet dispenser provides the means of administering the fluid, the patient may face outward as when standing or sitting in a normal fashion.

It should be understood that the examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be suggested to persons skilled in the art and are to be included within the spirit and purview of this application.
We claim:

1. An eye fluid delivery device, comprising:
   - a frame, wherein said frame is configured for placement over a patient's eyes and at least one fluid reservoir or at least one means to connect at least one fluid reservoir;
   - a means of delivering said fluid to said eye, comprising at least one fluid outlet, at least one controlled valve and/or a means of forcing flow through said fluid outlet;
   - optionally, a means for observing at least one of said eyes to determine a state of being open and a state of being closed, said means comprising at least one video camera, lens, or lens and image sensor electronically or electromagnetically connected to a processor wherein said processor is within or attached to said frame or is remote to said frame and/or
   - optionally, a means of providing a series of audio cues, wherein a rhythm is provided to for synchronization of blinking with said audio cues, and wherein said processor has software for providing an output signal for delivering said fluid to said means of delivering when said processor has received a signal from said video camera and has computed that said eye is in said state of being open or at a time predetermined to coincide with a specific number of said audio cues.

2. The eye fluid delivery device of claim 1, wherein said frame comprises a pair of temples, a bridge, nose pads and a holder for positioning said fluid outlet to address said eyes.

3. The eye fluid delivery device of claim 1, wherein said means of connecting a fluid reservoir comprises a threaded receiver or a tube fitting attached to said frame.

4. The eye fluid delivery device of claim 1, wherein said video camera is mounted on said frame.

5. The eye fluid delivery device of claim 1, wherein said lens or lens and video image sensor is mounted on said frame and connected to a processor.
6. The eye fluid delivery device of claim 1, wherein said means for delivering said fluid comprises a means for applying a pressure within said reservoir, wherein said means is a plunger or a clamp.

7. The eye fluid delivery device of claim 1, wherein said means of delivering comprises a pump.

8. The eye fluid delivery device of claim 1, wherein said means of delivering comprises an outlet comprising a thermal droplet jet or a piezoelectric droplet jet dispenser.

9. The eye fluid delivery device of claim 1, wherein said processor includes a user interface.

10. A method of delivering an ophthalmic fluid to an eye, comprising
    providing an eye fluid delivery device according to claim 1;
    providing an ophthalmic fluid to said reservoir of said fluid delivery device;
    inputting dosage information to said processor of said fluid delivery device;
    positioning said frame of said fluid delivery device on a patient in need of said ophthalmic fluid;
    placing said patient in a desired orientation;
    monitoring one or both eye of said patient with at least one of said video camera of said fluid delivery device;
    optionally, observing the onset and end of a plurality of blinks and calculating the average period of the open eye between consecutive blinks with said processor and/or synchronizing a plurality of blinks with a plurality of audio cues; and
    detecting the opening of the eye after a blink or establishing a blinking rhythm and providing a signal to said means of delivering to initiate delivery of said ophthalmic fluid to said eye;
    delivering said ophthalmic fluid to for a period less than the average period between blinks; and
    repeating said steps of observing, detecting and/or synchronizing, and delivering until a prescribed volume of said ophthalmic fluid is delivered to said eye.
11. The method of claim 10, wherein said ophthalmic fluid comprises a drug, vitamin, or lubricant.

12. The method of claim 10, wherein observing is carried out while said patient is intentionally blinking as rapidly as possible.
Figure 1

Figure 2
**INTERNATIONAL SEARCH REPORT**

**International application No.**
PCT/US2015/016109

**A. CLASSIFICATION OF SUBJECT MATTER**

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<th>IPC</th>
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According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

A61F 9/00; A61M 31/00; A61M 35/00; A61M 31/00; A61M 35/00; A61M 31/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: eye fluid delivery, frame, fluid reservoir, fluid outlet, video camera, processor, audio cues

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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<td>X</td>
<td>US 8128606 B2 (ANDERSON et a l...) 6 March 2012 See column 5, line 65-column 6, line 46; column 7, line 2-column 8, line 44; column 9, line 44-co lumin 10, line 53; column 11, lines 4-19; and figures 1-4.</td>
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<td>A</td>
<td>US 5368582 A (BERTERA, JAMES H.) 29 November 1994 See column 4, line 56-column 7, line 66; and figures 1-6.</td>
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<td>US 2003-0135169 A (COHEN et a l...) 17 July 2003 See abstract ; paragraphs [0032]-[0035] , [0048] ; and figures 1, 2, 12, 13.</td>
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<td>A</td>
<td>US 3976072 A (WALKER, ELIJAH C.) 24 August 1976 See column 3, lines 28-54; column 4, lines 12-57; and figures 1-3, 6.</td>
<td>1-9</td>
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* Further documents are listed in the continuation of Box C. **See patent family annex.**

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**Date of the actual completion of the international search**
18 May 2015 (18.05.2015)

**Date of mailing of the international search report**
19 May 2015 (19.05.2015)

**Name and mailing address of the ISA/KR**

| International Application Division |
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Form PCT/ISA/210 (second sheet) (January 2015)
INTERNATIONAL SEARCH REPORT

Box No. II  Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 10-12
   because they relate to subject matter not required to be searched by this Authority, namely:
   Claims 10-12 pertain to methods for treatment of the human body by therapy and thus relate to a subject-matter which this International Searching Authority is not required, under PCT Article 17(2)(a)(i) and PCT Rule 39.1(iv), to search.

2. ☐ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III  Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.

3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest  ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
☒ No protest accompanied the payment of additional search fees.
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<td>US 8128606 B2</td>
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Form PCT/ISA/2 10 (patent family annex) (January 2015)