

# Device for Administration of Intra-ocular Injections

**Department of Biomedical Engineering –  
University of Wisconsin-Madison  
BME 301**

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05/10/02*

## **Abstract**

This paper explores a number of different design possibilities for modifications to an existing 1cc syringe to allow for the user to depress the plunger with the fingertips near the tip of the syringe. Both single use and reusable solutions are presented. The two main mechanisms for applying the needed force to depress the plunger are air pressure and the use of a spring. A locking mechanism will be used to allow the doctor to stop an injection at any time during the procedure. After considering all of the possible ideas, a reusable device was chosen as the best solution due to the fact that it would be the most user friendly and cost effective.

**Problem Statement:**

Our goal is to design an attachment to an existing syringe to allow for a doctor to control the plunger from the tip of the syringe, allowing one person to administer injections into the vitreous body of the eye.

**Background information:**

Doctors are currently treating many eye conditions that affect the posterior surface of the eye, such as the retina, including age-related macular degeneration, ocular inflammatory disease, branch and retinal vein occlusion, and diabetic macular edema.

In the past, medications were either given in pill form or as drops onto the surface of the eye. However, these approaches often proved to be ineffective in delivering the correct amount of medication to the back of the eye and exposed the body to possible side effects corresponding to the particular medication. In order to target the back of the eye more effectively, doctors began administering medications directly into the vitreous body of the eye with a 1cc syringe. The patient is given a topical anesthetic and sterilizing eye drop before the syringe is depressed into the eye 4 mm from the outside of the iris. The doctor uses one hand to stabilize the eye and the other to hold the syringe similar to a pencil. An assistant is then required to depress the plunger at the back of the syringe to inject the medication in the eye. Typically between 0.1 and 0.3 cc of medication are injected into the eye. These injections allow the doctor to place the medication directly at the problem site and minimize the amount of side effects on the body due to the medication. (Dr. Blodi; 02/05/02)

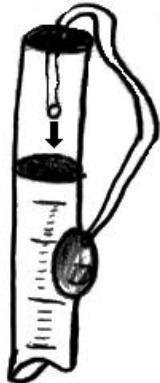
**Description of product function:**

The problem with the existing procedure in administering intra-ocular injections is that it requires the assistance of another person to inject the medication. This practice brings about the possibility of miscommunication between the two people, which could result in damage to the eye of the patient. The client is looking for a device that will allow a single doctor to administer the injections with one hand, allowing their other hand to be free to stabilize the eye for safe and effective medication injection.

The product will inject medication into the vitreous body of the eye through minimal movement of the hand supporting the syringe and without the previously required help of an assistant. This product will use the existing 1cc syringe, as specified by the client, with the typical injection volume of 0.1cc to 0.3cc. The modification to the syringe should be easily operable with a single hand and will be easily reusable without contamination. The device should inject the medication at a slow and steady rate, roughly 0.1cc per second, allowing the doctor to stop the injection at any time during the procedure. The medications being injected often differ in viscosity, with the most viscous being similar to whole milk, so the device should be able to apply a large enough force to push a number of different medications at an even rate. A complete list of the product design specifications (PDS) is attached at the end of this report.

**Alternative solutions:***Hydraulic Pressure Pump:*

Placed on the existing syringe is a small finger tip sized air bladder with a small hose coming out of the air sac and going into an air tight chamber in the shaft of the syringe. A sketch of this is seen below in Figure #1. This airtight chamber will fill up with pressure by pumping the bladder with a stationary index finger and create a force on the sliding portion that moves the medicine down the syringe. The faster one pumps with his/her finger, the faster the injection will take place, allowing the doctor to vary the rate of the injection during the procedure. This helps to deliver the shot at a variable speed. This attachment would have to make an airtight seal on the top each of the syringes and could not be reusable. This design was not seen as very feasible due to the amount of modifications that would need to be done to the existing syringe as well as the fact that it would not be a reusable solution.



**Figure #1 – Hydraulic pressure pump**

*Spring Operated Administration:*

This system incorporates a spring driven syringe plunger and a pivot displacement mechanism. A spring would be attached to the bottom portion of the top of the plunger and at the end of the syringe opposite to the needle (as seen in Figure #2). This spring would have a high spring constant ( $k$ ) so it could deliver a large force to the plunger for the administration of the medicine. This plunger would be stopped by a strong cylindrical material located on the outside of the syringe with an arrangement of several teeth-like structures protruding perpendicular to it; catching the plunger at each click. This clicking mechanism is created by the pivot point operated by the fingertips on the outside surface of the syringe. By pressing the button by the index finger, it allows the cylindrical part to lose its hold on the plunger and cause the spring to pull in plunger down. When the index finger takes the force off the cylindrical part goes back to its normal position and catches the top of the plunger, which can vary the speed of the injection. This design is not reusable because of the attaching of the spring to the existing syringe and the placement of the pivot on the side on the syringe would need to be applied to each individual syringe. This design could be modified to place the spring and locking mechanism in a number of different positions to better suit the application as needed.

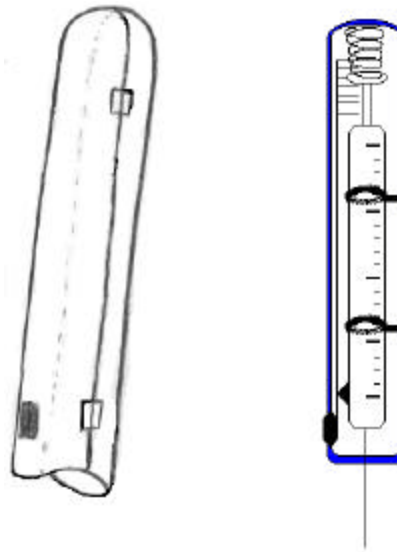


**Figure #2 – Spring operate administration**

*Reusable Case Mechanism:*

A larger syringe or plastic tube is the starting point to this design alternative. The tube would need to be cut down the longitudinal side of the shaft, creating two different halves. A hinge would then be used to attach the two halves together and allow for the tube to be opened and shut and a locking mechanism on the opposite side would allow the tube to remain closed. This larger capsule will be large enough to encase the existing syringe and this is shown below in Figure #3. The device will have a spring in the back that will be used to apply a force to the plunger, administering the medication. A button will be located at the tip of the device that will be controlled by the fingertips of the hand holding the syringe. A locking mechanism will hold the spring in place and will be disengaged when the fingertip depresses the button, allowing the medication to be administered into the patient. If the doctor releases the button at any time, the locking mechanism will re-engage, stopping the plunger and thus stopping the injection.

In order to use this device, the spring will first have to be “cocked” by locking the spring plate (plate below the spring which transfers the force of the spring to the plunger) in position. The loaded syringe will be placed in the larger tube. The larger tube will then be shut and locked into place. The device is now able to administer the injection. Once the injection is through, the doctor will simply open the larger tube and remove the used syringe and dispose of it.



**Figure #3 – Reusable case mechanism**

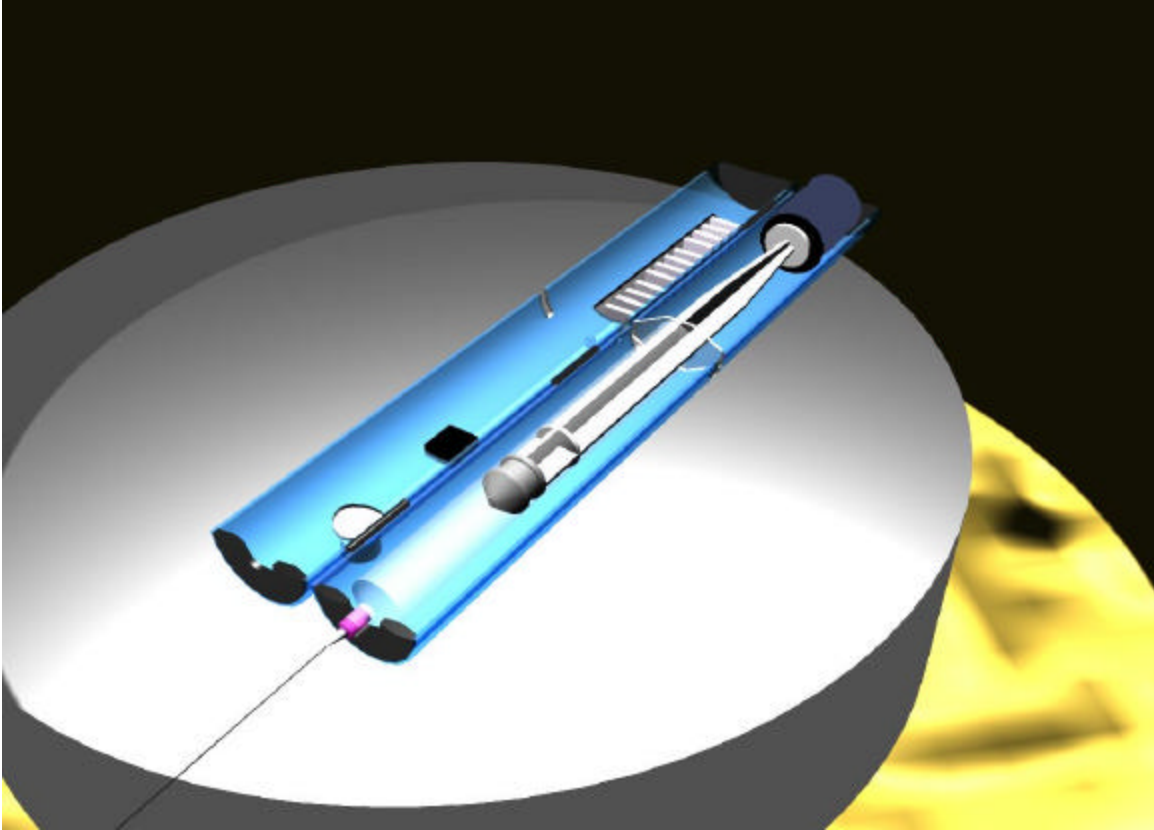
**Final Design Solution:**

The solution that was chosen was the reusable case mechanism. The main criterion for this choice was the fact that this design is reusable. This will allow the client to use the same device multiple times without making alterations to each existing syringe. The two other solutions would have required a fair amount of alterations to be made to each individual syringe. This would have been a large inconvenience as well as much more expensive in the long run. Making alterations to each individual syringe would

have also required sterilization of the device since syringes used for injections must be sterile, adding to the overall cost. This solution allows the doctor to load and dispose of the existing syringe as they normally do, allowing the device to be easily incorporated into the process of delivering intra-ocular injections.

Below is a picture of our proposed design solution, including a compressed spring behind the syringe's plunger, a locking mechanism to hold the spring in a compressed position, and a push-button trigger to release the locking mechanism. The specifications pertaining to the final design are the same as the reusable case mechanism that is outlined in the previous section of the paper.

The actual case and locking mechanism will be constructed from a clear plastic, allowing the user to actually see how much has been injected. We plan to use a plastic similar, or identical, to the plastic that is used in the construction of current syringes since we know that it is compatible with current medications and safe for user and patient contact. We are thinking of either using larger syringes to build the outer case or having a plastic tube constructed to our required dimensions.



**Figure #4 – Proposed solution**

**Prototype:**

Due to the complexity of the design, our group decided to postpone work on the locking mechanism until an adequate spring was found to provide the needed force for injection. Wood blocks were used to house the syringe and springs in holes drilled down the center of the blocks (unable to be seen in the picture). A dowel with a slit down the middle is used to push the springs into compression. A pin is then inserted into one of the small holes that have been drilled in the face of the blocks, holding the springs in compression. The two blocks, the front one holding the loaded syringe and the back one holding the compressed springs, are then held together either with a clamp or simply by

hand. When the pin is removed, the spring exerts force on the end of the syringe's plunger, forcing the liquid to be expelled from the needle.

The bulk of our semester was spent building a device to hold the syringe and springs in position so that the action of the spring on the syringe could be observed. At first, we attempted to determine the amount of force that would be needed to inject the different volumes of liquid as well as determine the spring constant ( $k$ ) values. However, we did not have equipment that was precise enough to find accurate values. Therefore, we chose to qualitatively determine which springs were needed and worked best for the 26 and 30 gauge needles. We tested the springs by seeing how long and at what rate the injections occurred with each different spring and chose the most even injection time and rate. We found that to inject using the 26-gauge needle, the two springs on the left side of the wood block on the left are used. (See figure 5) They are compressed to the 0.3 mark on the device and the injection takes roughly 3 seconds to expel all the contents of the syringe. To inject using the 30-gauge needle, you can either use the large spring, which is shown on the right of figure 5, or by compressing all three springs shown on the wood block on the left. Due to the smaller diameter of the 30-gauge needle, more force is needed to inject the contents of the syringe. The combination of springs on the left side of figure 5 will most likely be used in the final construction since they have the potential for injecting with both needle sizes. The user would just have to add the smaller spring to the device if they wanted to inject using the 30-gauge needle. Also, these springs take up less space, making the device more compact and easier to control.



**Figure #5 – Prototype for testing of springs**

### **Potential Problems:**

One potential problem with a reusable device is making sure that the device does not become contaminated or transmit disease, bacteria, and/or viruses between patients. The device may need to be sterilized so the materials should be able to withstand such a treatment. However, the only part of the syringe that actually comes into contact with the patient is the needle, which is a one-time use, sterile needle. Therefore, after speaking with the client, we did not consider contamination to be a risk.

Another concern is the ability for the injection to be stopped during the process of an injection. If a problem arises during the injection, the doctor needs to be able to stop the injection. To guarantee this, we will need to design a fail-safe locking mechanism that is 100% successful. This may include a back up lock or some other sort of safety measure. This issue will be looked at more carefully next semester.

One other aspect of our design that we need to keep an eye on is the action of the spring while it is exerting force on the plunger of the spring. We need to make sure that there is absolutely nothing that the spring could be caught on while it is in motion, such as plastic debris or any other debris that could alter the motion of the spring. If the spring does get caught on something, it could potentially jump forward if moved and dislodged. This movement could cause damage to the patient's eye so it must be very carefully considered to ensure that no damage is done to the patient's eye. One way to ensure this would be to enclose the springs so that they will not be exposed to any debris. This aspect of the design will be one of the focuses of the project next semester.

**Ethical Concerns:**

Whenever you are designing medical equipment, you have to take a look at the ethics involved with the project. Typically, ethics tend to play a large role in medical practices that have the potential to create or destroy life. Our project does not really pertain to ethics in that manner though, since it is not used in an application that even deals with life threatening medical conditions. However, we do need to consider situations that could possibly harm the patient if our device were to malfunction in any way. We have addressed a number of these concerns in the previous section and plan to continually evaluate our ideas and consider any situation that could arise that could cause harm to the patient. Through testing, we hope to produce a device that is both user friendly and one hundred percent safe to use.

Another aspect of designing medical devices that calls for the evaluation of ethical concerns is the use of invasive procedures to treat certain medical conditions. The

line between an appropriate treatment and going too far is often quite hazy, especially when a new technique offers a lot of promise. However, this aspect does not directly pertain to our project since we are not actually creating or allowing for a new medical treatment. Intra-ocular injections are already being performed and been having excellent results. Our device will only aide in the efficiency and accuracy of these injections, making the procedure safer and more comfortable for the patient and doctor.

**Future Work:**

Our group plans to continue working on this design during the next semester, while taking BME 400. We will use the data that we collected during this semester pertaining to the springs needed for each needle size to continue working on the project. During the next semester, we will focus on the construction of a locking mechanism to give the user the ability to start and stop the injection as needed. Also, we will work to design a trigger that will be easily accessible to the user, easy to use, and provides a reliable interface between the user and the locking mechanism. This is very important because the trigger will serve as a safety mechanism to prevent the injection from proceeding too quickly or from injecting too much fluid into the eye. Lastly, we will design a functioning outer case that incorporates the springs, locking mechanism, and the trigger, giving the device a professional look.

Appendix 1 -

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05/10/02

## Product Design Specifications

**Title:** Device for administration of intra-ocular injections

**Function:** Develop a syringe that allows for a safe and efficient means of injecting medication into the vitreous cavity of the eye.

**Client requirements:**

- Allow for thumb and forefingers to be close contact to the tip of syringe
- Inject medication at a slow and steady rate
- Roughly the same size as the existing syringe
- External and detachable from the existing syringe (multiple uses)

**Design requirements**

**1. Physical and Operational Characteristics**

a. *Performance requirements:* Enclose a 1cc-unmodified syringe and deliver medication at a slow and steady rate, roughly 0.1cc per second. Device must be operable with one hand while the needle is being held in the eye.

b. *Safety:* Must not affect the doctor's ability to hold the syringe steady while injecting medicine. Eliminate need for additional assistance while injecting. Does not need to be sterile.

c. *Accuracy and Reliability:* Inject medicine at a slow, steady rate. Should allow for injections up to 0.8cc, in increments of 0.1cc.

d. *Life in Service:* Multiple uses, not specified by client.

e. *Shelf Life:* N/A

f. *Operating Environment:* Normal medical clinic and hospital conditions.

g. *Ergonomics:* Device should be easy to use and require the use of only one hand.

- h. *Size*: Attach to existing syringe, fitting easily in the palm of average hand.
- i. *Weight*: Very light (less than one pound)
- j. *Materials*: Materials should be non-hazardous, similar to existing syringes
- k. *Aesthetics, Appearance, and Finish*: Should be professional looking

## **2. Production Characteristics**

- a. *Quantity*: One (prototype)
- b. *Target Product Cost*: \$200 – 300 for a reusable device

## **3. Miscellaneous**

- a. *Standards and Specifications*: Needs to be certified as safe to use in clinical settings
- b. *Customer*: Ophthalmologists who give intra-ocular injections. Could also be used for other applications that would be aided by the ability to inject accurately with the use of only one hand
- c. *Patient-related concerns*: Must allow doctor to use easily with one hand
- d. *Competition*: None known of at this time