# DEVELOPING A REVERSIBLE CONTRACEPTIVE DEVICE


**Team: Emily Junger, Jolene Enge, Ngoc Phung, Zach Katsulis, Yifan Li**

**Client: Dr. John Webster, PhD**

**Advisor: Dr. Wan-Ju Li, PhD**

**University of Wisconsin-Madison Department of Biomedical Engineering**


## Abstract


Current pharmaceutical methods of contraception utilize hormones or cause unwanted side effects. Most methods have a susceptibility to user error. Surgical contraceptive methods are invasive and generally cause permanent infertility.

This drives the need for a device that can be implanted within a woman's reproductive system and allow her to control her fertility via an external controller. We have designed a sliding valve mechanism powered by a solenoid to meet these needs.


## Introduction

**Client:** Dr. John Webster, PhD, University of Wisconsin-Madison, Department of Biomedical Engineering
•Expertise in biomedical instrumentation, implantable intracranial pressure monitors, and bioelectrodes
•Area of interests include safety of less-lethal electromuscular incapacitation device (EMD) biopotential amplifiers and interference

**Motivation:**
•Global need: UN Millennium Development Goals to improve maternal health and achieve universal access to reproductive health
•Current methods of contraception have many deficiencies

**Background:**
•Oviduct could be cut and reconnected to either side of the valve housing
•Valve would be placed in isthmus section of oviduct
•Oviduct cross section is irregular with a 1 - 2 mm inner diameter diameter in the isthmus

**Design Criteria:**
•Provide reversible, non-permanent contraception
•Be biocompatible
•Be compatible with both MRI and CT scan
•Turn a woman's fertility on and off on demand via an external controller
•Can not cause long term harm to the women's reproductive system

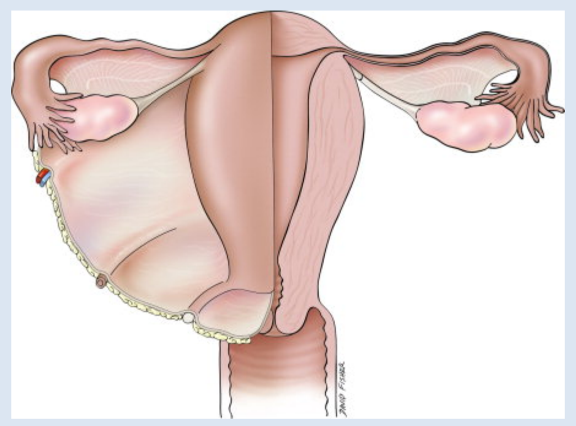


Figure 1: Female reproductive anatomy

## Final Design

**Final Design:**
•Sliding plate design
•Alignment of holes controls state of fertility
•Grab-latch mechanism changes alignment of holes
•Solenoid system provides uni-directional magnetic force

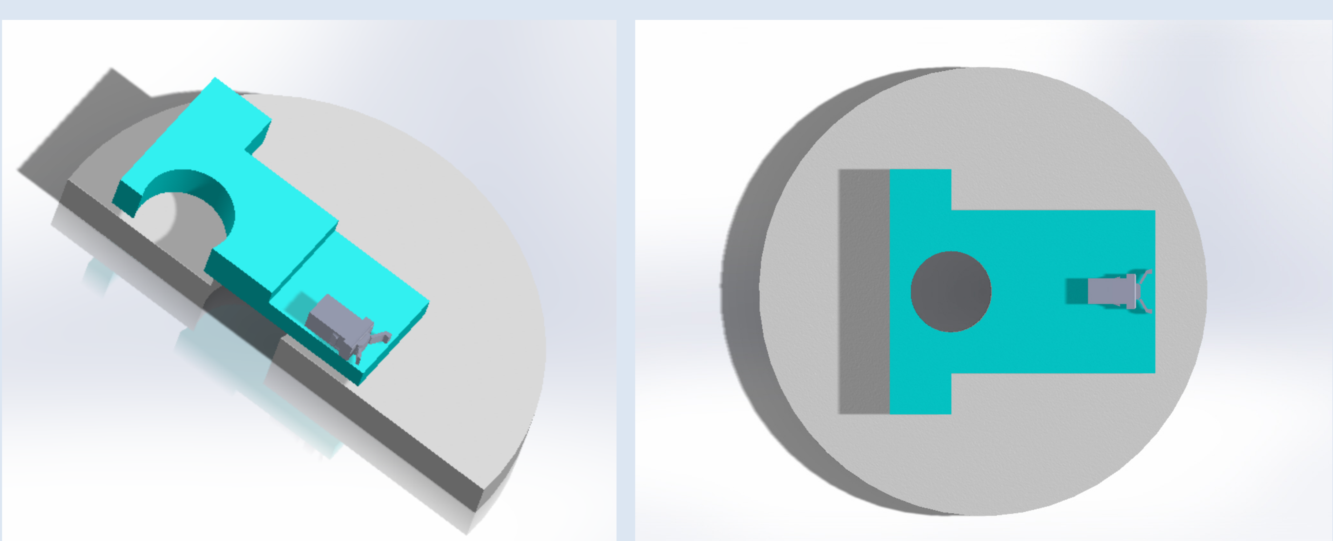


Figure 2: Final design bottom disc and sliding plate with push-push mechanism. Left: Closed position (infertile). Right: Open position (fertile).

## Materials and Methods

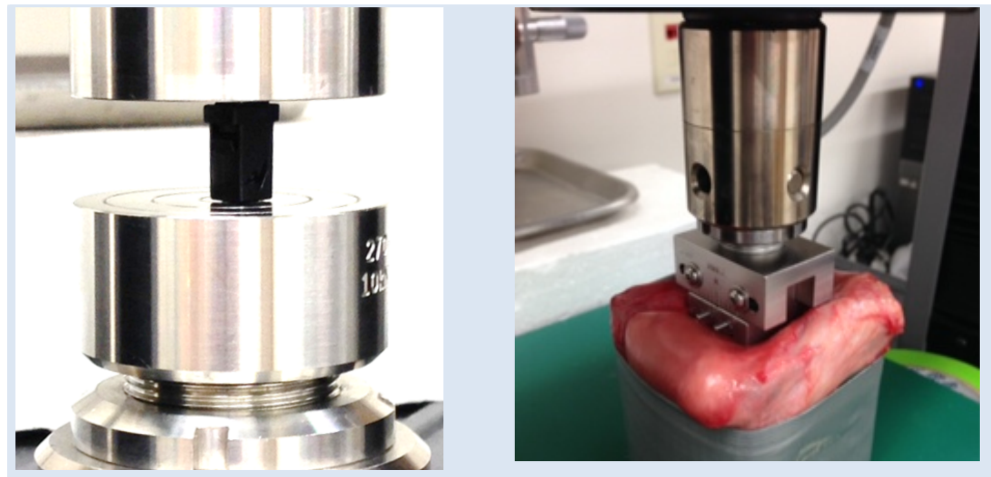


Figure 2: Mechanical testing of push-push mechanism (left) and oviduct (right)

**Oviduct:**
•Obtained bovine reproductive system from Black Earth Meats
•Cut oviduct longitudinally
•Stretched single wall of tissue over square frame
•Constant displacement and manual testing
•Applied pressure using MTS Criterion over area of 7.60 $cm^2$

**Sliding Plate Valve**
•Fabricated from acrylic
•Utilizes push-push mechansim (Sagatsune Prpk – 4)
•Performed activation force testing with the MTS Criterion
•Performed SolidWorks force simulation

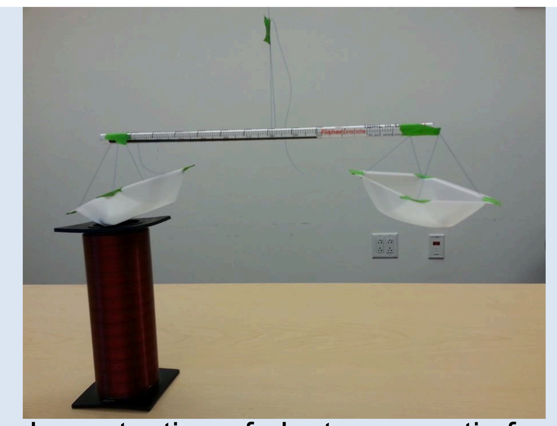
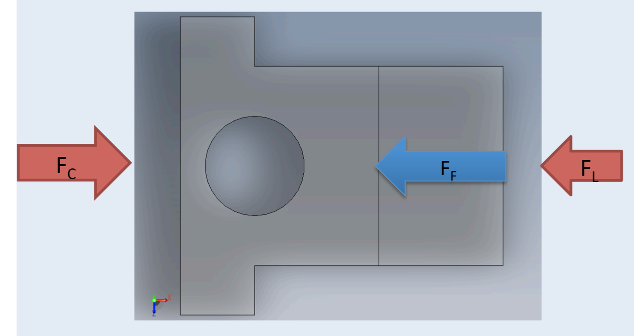


Figure 3: Force balance testing of electromagnetic force strength

**Solenoid System:**
- Primary coil: 15 cm length, 4 cm diameter, 540 turns of 16 gauge copper wire
- Varied applied voltage
- Used balance with ferrous materials on both sides
- Coil positioned vertically below one side
- Turned on primary coil to create magnetic force on one side
- Measured force generated by solenoid on ferrous material
- Initially attempted to move a short-circuited coil, results will be discussed in the next section
- Shorted coil hung from string and we attempted to repel it using primary coil




Friction Force ($F_F$), Coil Force ($F_C$), Latch Force ($F_L$)

Figure 4: Force diagram of sliding plate

$F_F = \mu_s mg$
$F_F = (0.8) * (0.09043\ kg) * (9.81\ m/s^2)$
$F_F = 0.71\ N$
$FC \geq 2 F_F + F_L$

Coil force must exceed 6.42 N

- Limit on amperage we could apply due to power transformer
- Compared force generated to theoretical using following equation
  $F=(\mu_0^2 N^2 I^2 A)/2L^2$
- Force loss due to heat dissipation due to coil not being able to handle current.

## Results

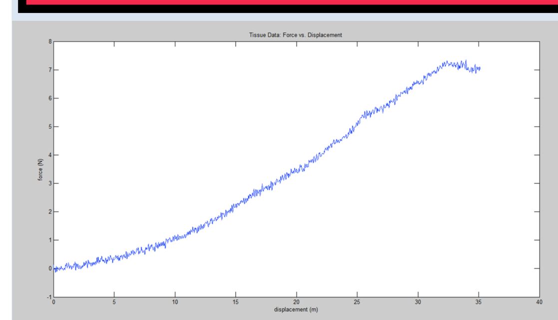


Figure 5: Mechanical testing of tissue

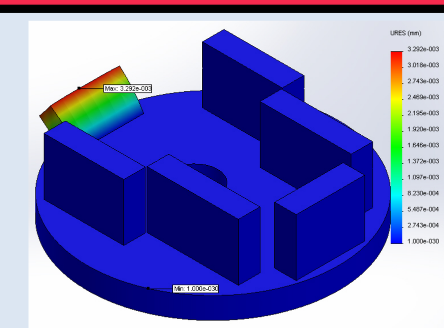
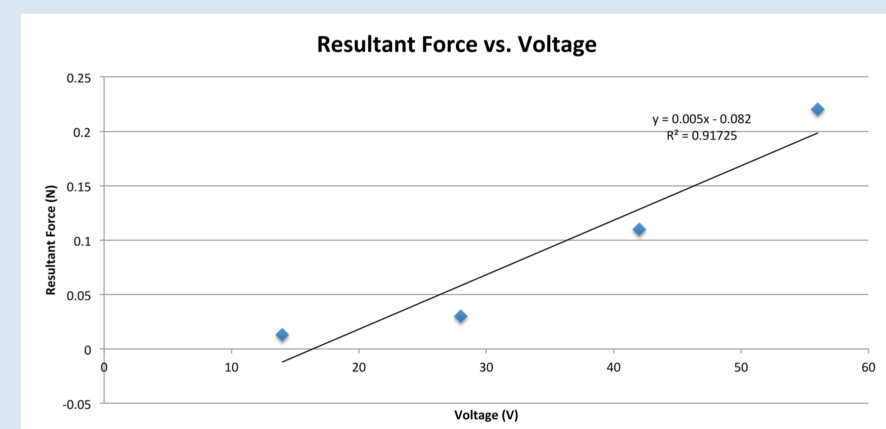


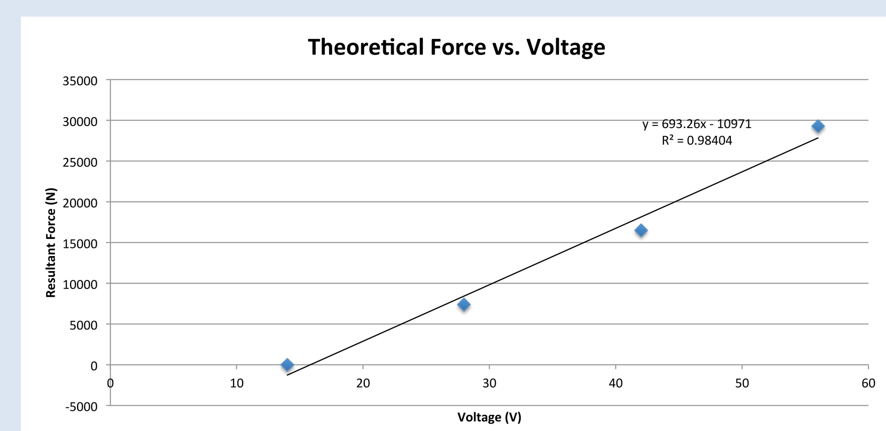
Figure 6: SolidWorks force analysis of valve

**Force Testing:**
Oviduct:
- Low force testing:
  - Max force recorded was 7.431 N
  - Max displacement was 30.13 mm
  - Max applied stress was 96.23 Pa
- Max force testing:
  - Maximum force recorded was > 28N
  - Max applied stress was 368.42 Pa
- Push-Push Mechanism:
  - Force required to engage mechanism: approximately 5 N
  - Force required to disengage: approximately 2 N

- Solidworks Modeling:
- Force required to engage mechanism: approximately 5 N
- Force required to disengage: approximately 2 N

**Solenoid System:**
- Little to no movement of short-circuited coil
- Shorted coil would twist in place
- Movement of ferrous material




## Discussion

**Oviduct:**
- Not able to obtain failure stress
- Oviduct wall strength was greater than expected
- **Sliding Plate:**
- Actuation force was calculated not observed

**Solenoid System:**
- Coil able to generate magnetic field on ferrous materials
- Force decreases further away from coil
- Heat dissipation due to primary coil
- Small primary coil causes low force generated
- Difficulties of winding own coil and cost of purchasing coil limited options

## Conclusions

- The oviduct can withstand the forces that would be applied to the device during operation
- The device itself can withstand the forces applied by electromagnetic repulsion
- In theory, the push-push mechanism should be operable by forces generated by electromagnetic flux
- Differences in observed force values in relation to calculated force values could be due to energy loss, specifically in the form of heat
- The coil was able to move the sliding plate alone when a ferrous material was attached, thus we are optimistic that better coil wrapping techniques and further study could lead to successful results with a short circuited coil

## Future Work

**Valve Design:**
- Scale reduction
- Choice of material (PTFE, etc.)
- Coating to ensure water-tight performance
- Coating to ensure smooth passage through device and to prevent adhesion

**External Controller and Operating Mechanism:**
- Create a non-ferrous system
- Reduce the actuation voltage
- Improve force generation efficiency

**Other Considerations:**
- Analysis of oviduct fluid viscosity and shear forces
- Develop mathematical model to study kinetics of egg and sperm movement in oviduct
- Further research is needed to investigate side-effects of induced electromagnetic fields inside the body

## Ackowledgements


**Dr. John Webster, PhD, Dr. Wan-Ju Li, PhD, Dr. John Puccinelli, Dr. Amit Nimunkar, PhD, Lucas Hurtley, Mr. Eric Gettrust, Dr. Gary Shiu, PhD, Dustin Weiss, Black Earth Meats**


## References


Foreman, K.H. Albertine (Eds), *The Big Picture: Gross Anatomy*. Retrieved October 4, 2013 from http://www.accessmedicine.com.ezproxy.library.wisc.edu/content.aspx?aID=8666862.

Harris-Glocker, M., & McLaren, J. (2013). Role of female pelvic anatomy in infertility. *Clinical Anatomy*, *26*, 89–96.

Kurman, R. J. (2011). *Blaustein's pathology of the female genital tract* (6 ed.). New York: Springer.

Morton D.A., Foreman K.B., Albertine K.H. (2011). Chapter 14. Female Reproductive System. In D.A. Morton, K.B.

Mwalwanda, C. S. (2013). "Immediate post-partum initiation of intrauterine contraception and implants: A review of the safety and guidelines for use." *Australian & New Zealand Journal of Obstetrics & Gynaecology*, *53*(4), 331-337. Retrieved October 2, 2013, from http://onlinelibrary.wiley.com.ezproxy.library.wisc.edu/store/10.1111/ajo.12095/asset/ajo 12095.pdf?v=1&t=hmb5g00r&s=62a39177a95fd707ea

"United Nations Millennium Development Goals." *Welcome to the United Nations: It's Your World*. Retrieved October 2, 2013, from http://www.un.org/millenniumgoals/ maternal.shtml

YASMIN Highlights of Prescribing Information. (2001). *Bayer HealthCare Pharmaceuticals, Inc.* Retrieved September 16, 2013, from labeling.bayerhealthcare.com/html/products/ pi/fhc/Yasmin_PI.pdf?WT.mc_id=www.berlex.com