

OBJECTIVE

- Complete development of an arthroscopic tool capable of reshaping bone and cartilage
- Approximate a random orbital sanding motion

BACKGROUND

- Osteoarthritis (OA) causes breakdown of joint tissues, causing chronic frictional pain
- ~750k annual knee arthroscopies occur in US for OA pain mitigation
- Commonly used arthroscopic shaver heads often leave grooves or rough edges
- This can further irritate joint tissues and leads to a longer rehabilitation periods

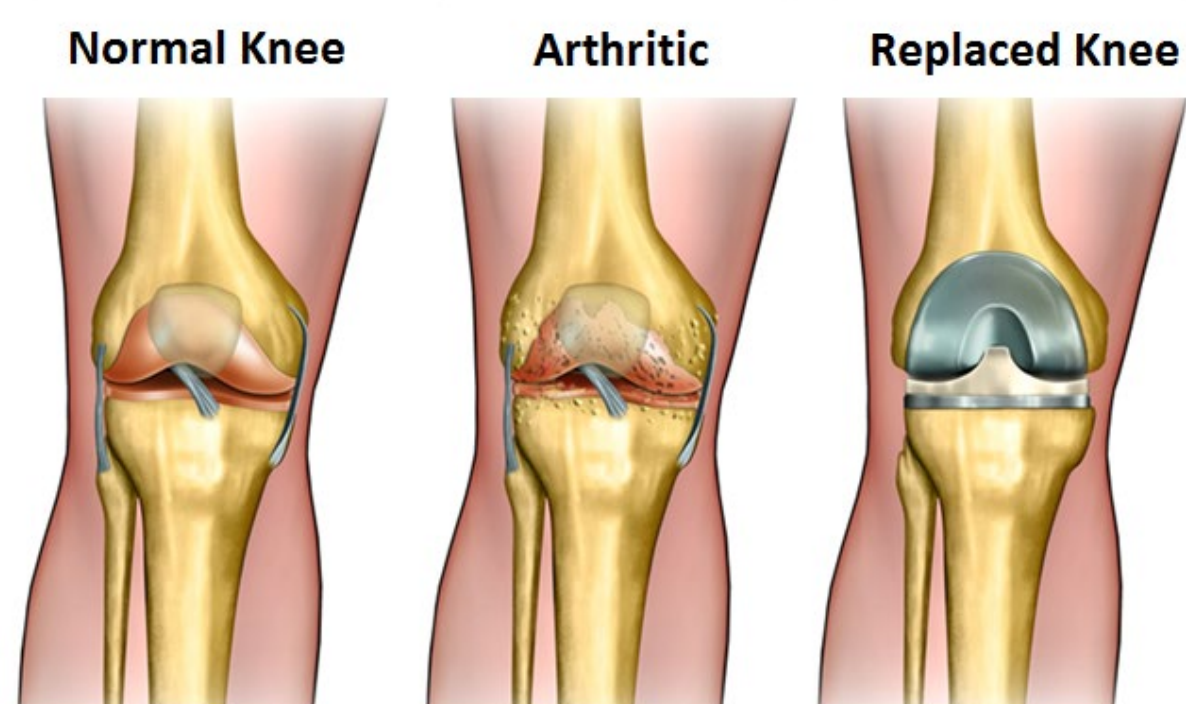


Figure 1.
Longitudinal
degradation of an
OA knee joint

VALUE PROPOSITION

- No current technology exists to re-shape damaged joint surfaces
- This device aims to create a modular smooth-sanding platform for OA arthroscopic surgeries
- Allow reshaping of bone and cartilage to treat OA pain via random orbital sanding
- Incorporate inexpensive tooltips to reduce patient costs
- Why? Faster patient rehabilitation, reduced post-operative pain**

KEY REQUIREMENTS

- Variable output speed from 900-6000 RPM
- Random orbital sanding
- Hypoallergenic, replaceable tooltips
- Output shaft- 5mm diameter
- Modular tooltips, different grits
- Reliable 1-hour intermittent battery life with modular power supply
- Reusable device with reusable tooltips capable of sterilization

CONCEPT DEVELOPMENT

- Two initial designs: Sawzall DC motor and linear actuator, fixed DC motor with linear solenoids
- Reliability concerns directed decision towards second option
- Preliminary testing with first prototype yielded approved results
- Several prototypes were developed for the project

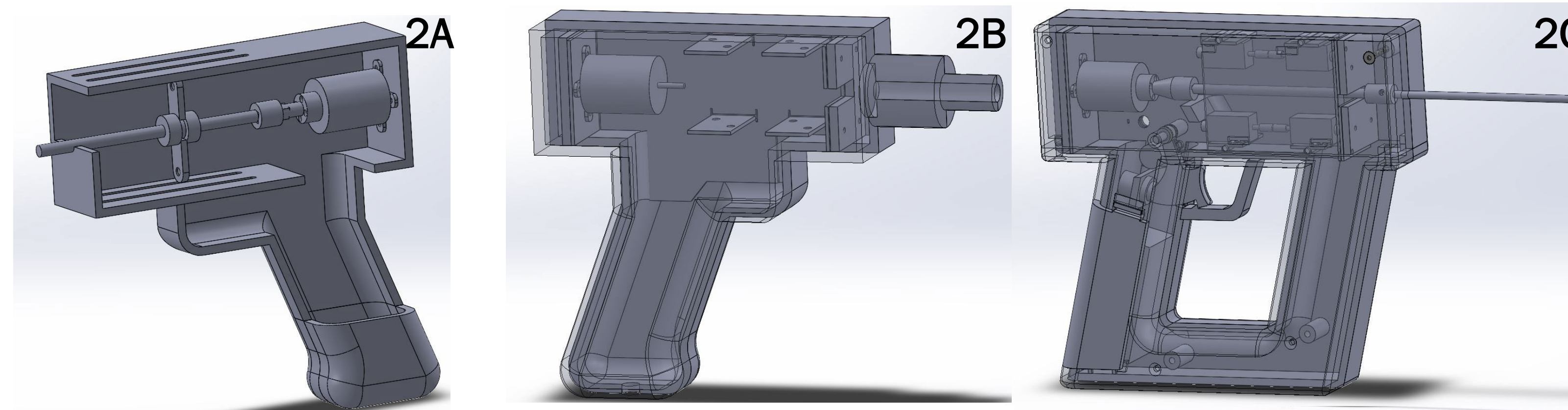


Figure 2. Development of an
internal mechanism and housing
for this device
A) Proof of Concept
B) First CAD housing model
C) Final CAD housing model

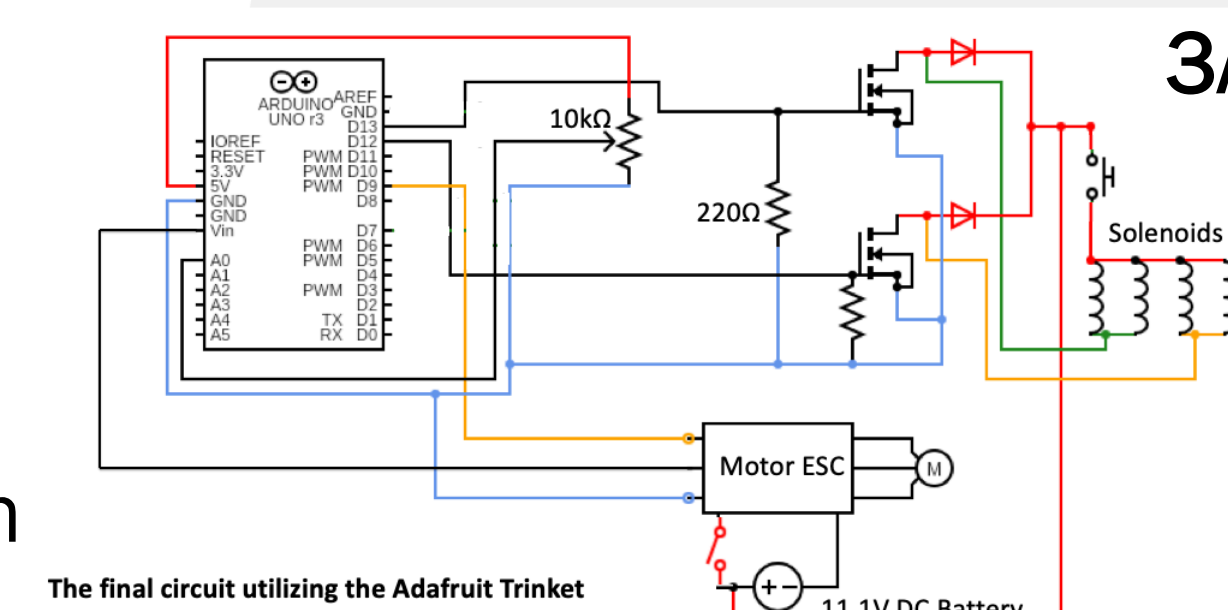
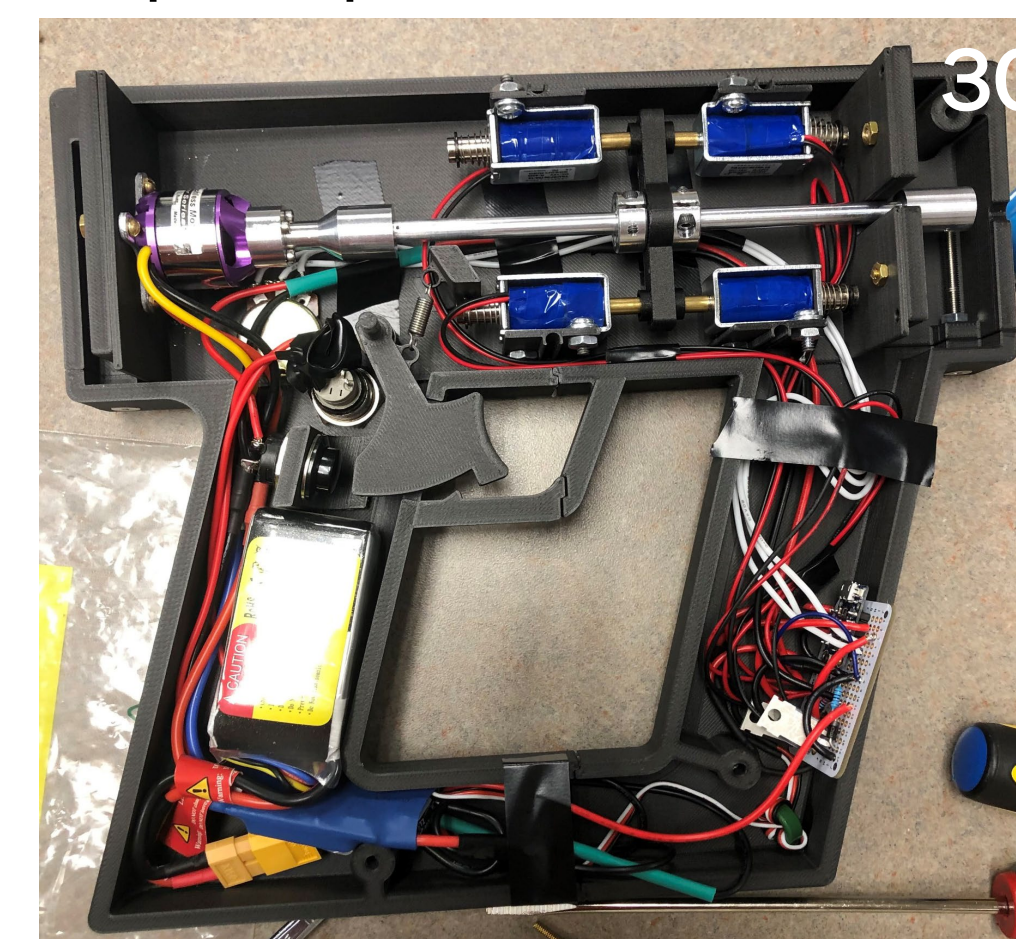
FINAL DESIGN

Design functions with DC motor mounted linearly to the rotating shaft, conjunctive to 4 micro solenoids working in tandem to create linear actuation

- Achieves linear and rotational motion, creating random orbital shaving
- Potentiometer controls revolutions, toggle to activate solenoids, button to turn on device
- 4 swappable cylindrical rounded steel shaving heads, varying grits from 1200-2400
- Speed varies from 900-30000 RPM
- All material made from hypoallergenic stainless steel and high-grade hypoallergenic plastics
- Device head is less than 5mm, around 4.8mm diameter after gritted
- Battery lasts for 6 hours used intermittently for 45 minutes on varying power, modular powerpack that can be easily replaced
- Device is reusable with tooltips capable of autoclave sterilization

Figure 3. Device circuitry and
programming

- A) Final circuitry design
- B) Adafruit Trinket programming
- C) Final model with electronics installed



```
#include <Adafruit_SoftServo.h> // SoftwareServo (works on non PWM pins)
#define SERVO1PIN 3 // Servo control line (orange) on Trinket Pin #0
#define POTPIN 1 // Potentiometer sweep (center) on Trinket Pin #2 (Analog 1)
#define BUTTON_PIN 4

Adafruit_SoftServo myServo1, myServo2; //create TWO servo objects

int motorState = LOW; // the current state of motor
int solenoidState = LOW; // the current state of the solenoids
int lastButtonState; // the previous state of button
int currentButtonState; // the current state of button

void setup() {
  // Set up the interrupt that will refresh the servo
  OCR0A = 0xAF; // any number is OK
  TIMSK1 |= _BV(OCIE0A); // Turn on the compare interrupt (below!)

  myServo1.attach(SERVO1PIN); // Attach the motor to pin 0 on Trinket
  myServo1.write(90); // Tell servo to go to position per quirk
  delay(15); // Wait 15ms for the motor to reach the speed
}

pinMode(BUTTON_PIN, INPUT_PULLUP); // set arduino pin to input pull-up mode
pinMode(SERVO1PIN, OUTPUT); // set arduino pin to output mode
pinMode(0, OUTPUT);
pinMode(1, OUTPUT);

currentButtonState = digitalRead(BUTTON_PIN);
}

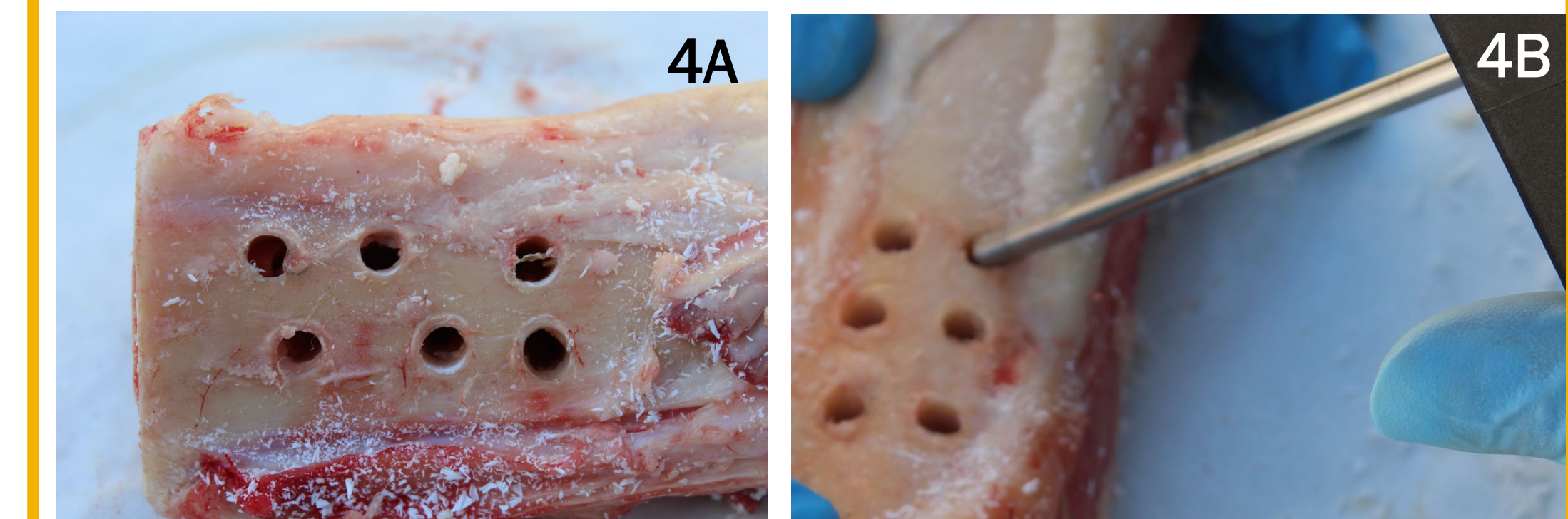
void loop() {
  int potValue; // variable to read potentiometer
  int servoPos; // variable to convert voltage on pot to motor speed
  lastButtonState = currentButtonState; // save the last state
  currentButtonState = digitalRead(BUTTON_PIN); // read new state

  if (lastButtonState == HIGH && currentButtonState == LOW) {
    motorState = !motorState;
    digitalWrite(SERVO1PIN, motorState);

    potValue = analogRead(POTPIN);
    servoPos = map(potValue, 0, 1023, 0, 179); // scale it to use it with the servo
    myServo1.write(servoPos); // tell servo to go to position

    delay(15); // waits 15ms for the servo to reach the
    {
      while (potValue < 70)
      {
        digitalWrite(0, HIGH); // turn the Solenoid on (HIGH is the voltage level)
        digitalWrite(1, LOW);
        delay(750);
        digitalWrite(0, LOW); // turn the Solenoid off by making the voltage LOW
        digitalWrite(1, HIGH);
        delay(750);
        break;
      }
      while (potValue > 70 && potValue <= 100)
    }
  }
}
```

VALIDATION



- Matlab simulation results indicated that best results can be achieved when linear actuation to rotation ratio is not constant
- Tested 3 shaving tips at low, medium, and high rotational speeds with linear actuation scaling at set increments to smooth out sharp edges on cattle bone
- Found best results using medium speed with medium rate of linear actuation

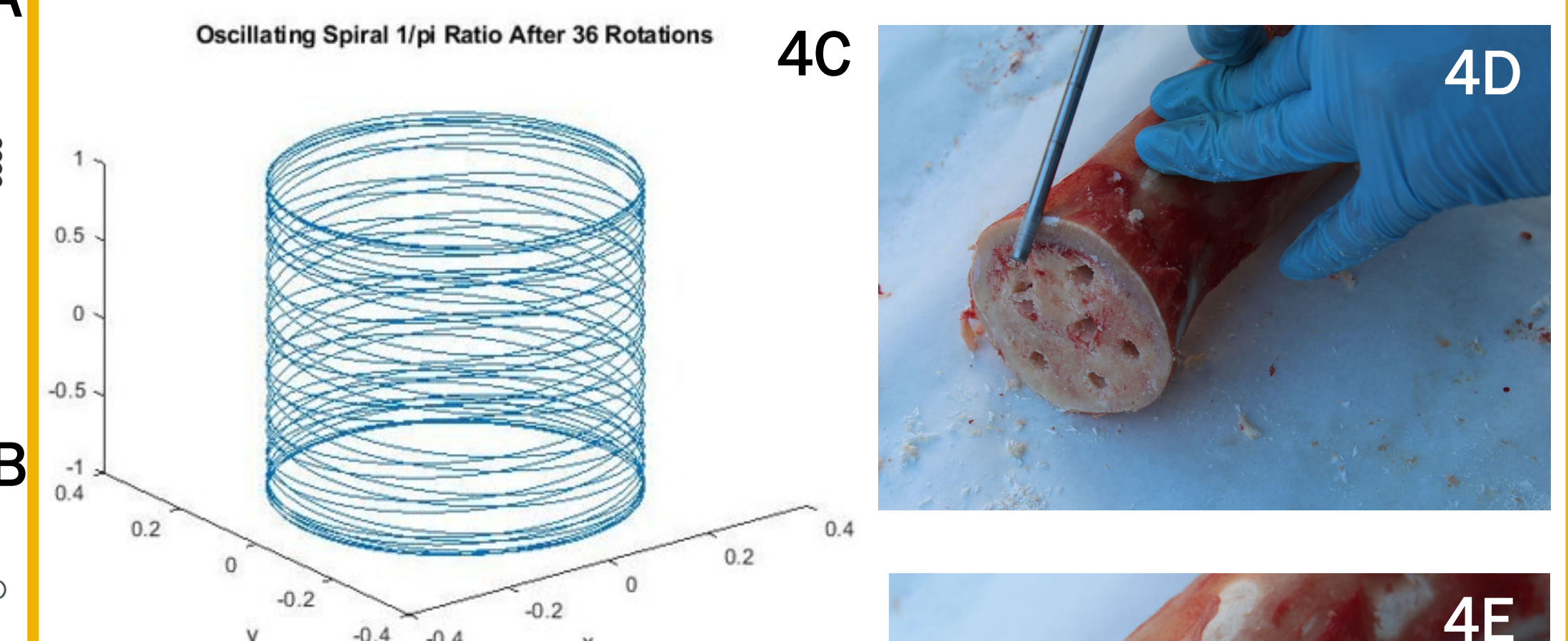
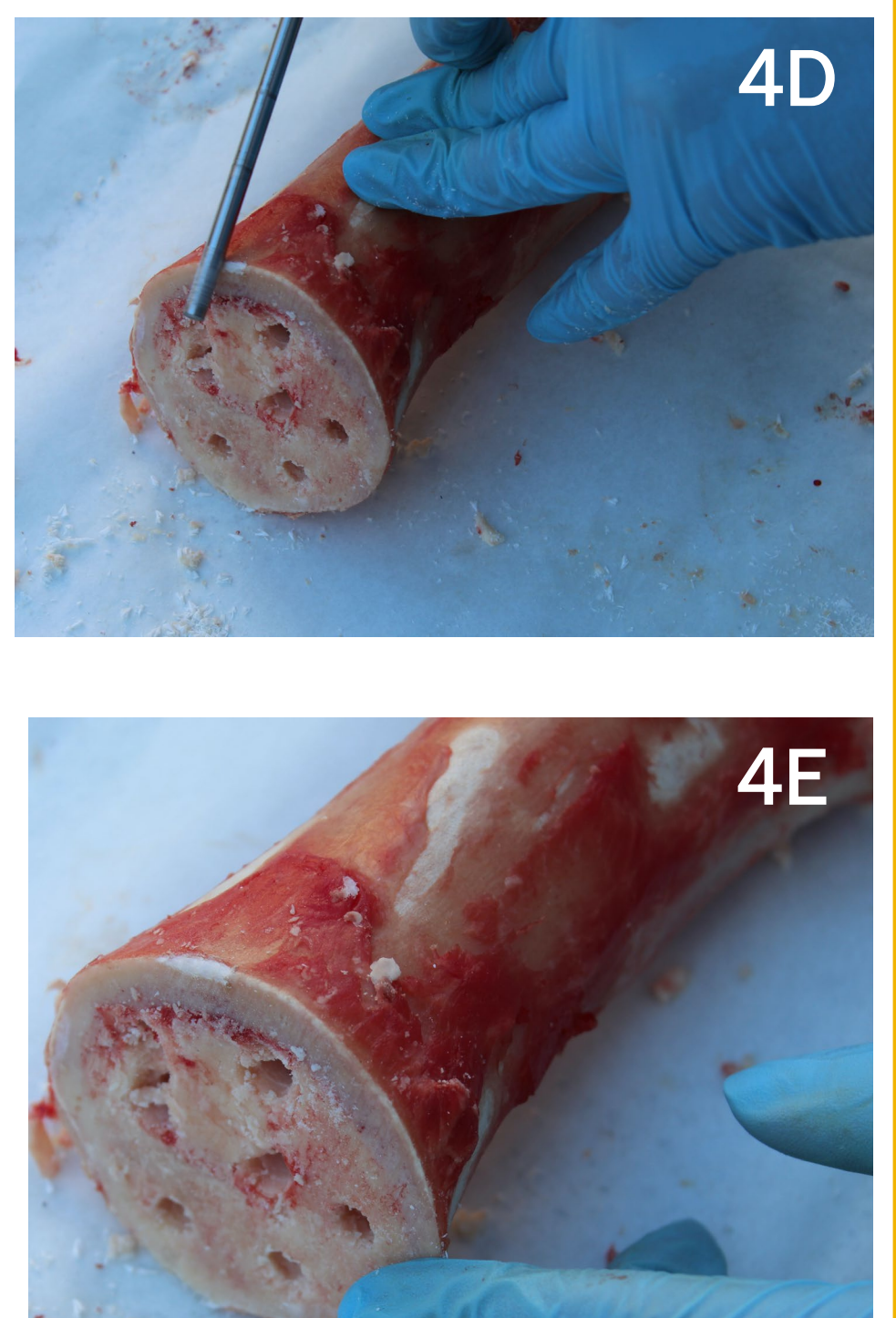


Figure 4. Validation of design and
prototype

- A) Bone used for testing shaver
- B) Testing the shaver
- C) Matlab simulation results
- D) Testing shaver on sharp edge
- E) Result of shaving bone edge



FUTURE RECOMMENDATIONS

- Slim down the device handle for user comfort
- Use smaller solenoids to slim down top of device
- Speed up linear actuation via Adafruit code
- Add door on the device for faster tip replacement
- Test device on damaged cartilage

ACKNOWLEDGEMENTS

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