DEAD BLOW HAMMER IN ORTHOPEDICS

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ABSTRACT

Total joint replacements surgeries can be physically difficult on both the patient and the surgeon because of the large amounts of force exerted. Our client, Dr. John Wollaeger, came to the group because this causes wear and tear on the surgeon's shoulder and elbow joints Also, the amount of force needed to be generated by the surgeon limits the field of surgeons that are physically capable to perform such surgeries. To solve this problem, our group has designed an orthopedic mallet that limits recoil and limits the force needed to be generated by the surgeon by use of a dead-blow style hammer, which are typically used in construction settings. A prototype has been created and tested to confirm the ideal force curve that is expected when in use compared to current orthopedic mallets. The next step in this project is to manufacture a heavier duty prototype to calculate max force generation, and eventually a prototype manufactured with medical grade stainless steel.

PROBLEM STATEMENT

Design Motivation:

- Current orthopedic mallets have significant recoil upon striking a chisel during surgery
- Large amounts of force must be generated by the surgeon swinging the mallet

Objective:

Create a mallet to be used in orthopedic surgeries that lowers the force exertion needed by the surgeon and limits the recoil caused from striking the chisel during surgeries.

BACKGROUND

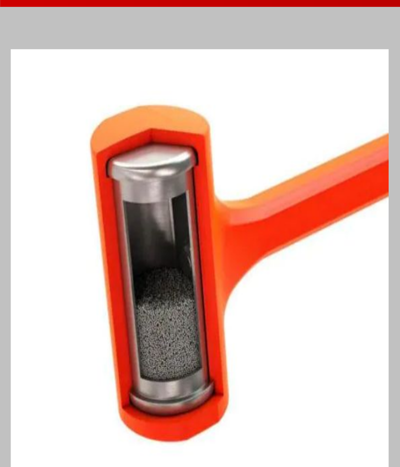

Figure 1: Dead-blow hammer for construction and manufacturing [1]

Figure 2: Coronal (left) and sagittal (right) views of a knee replacement [2]

Dead Blow Hammers

- Primarily used in the construction industry [1]
  - Minimize damage to the struck surface
  - Allow one to help control their striking force
  - Produce minimal recoil comparatively
- Steel beads within these hammers contribute to much of their characteristics

Orthopedic Surgery Application

- This device has not been utilized effectively in the medical industry yet
  - Several patents currently exist
  - Our device would exist as a Class 2 Medical Device [5].
- Orthopedic surgeries currently use a "surgical hammer" or "orthopedic mallet" for large joint replacements (i.e. knee, hip, etc.) [2,3]
- Surgeons often have to use excessive manual force to perform total joint replacement [2,4].

DESIGN CRITERIA

- Able to exert 40 kN onto the body which it is striking
- Limit recoil upon impact when compared to currently used mallet
- Lightweight enough to limit physical stress for surgeon (0.45-1.35 kg)
- Able to be sterilized with current autoclave protocol
- Material must not interfere with patient's biological systems

FINAL DESIGN

Components:

- Mallet Outer Shell and Handle
  - Medical grade stainless steel
- Caps
  - Polymer - absorb recoil
  - Threads to screw onto head
- Inner casing
  - Flexible polymer
  - Contain the metal beads
- Metal beads
  - Steel (lower grade than stainless)

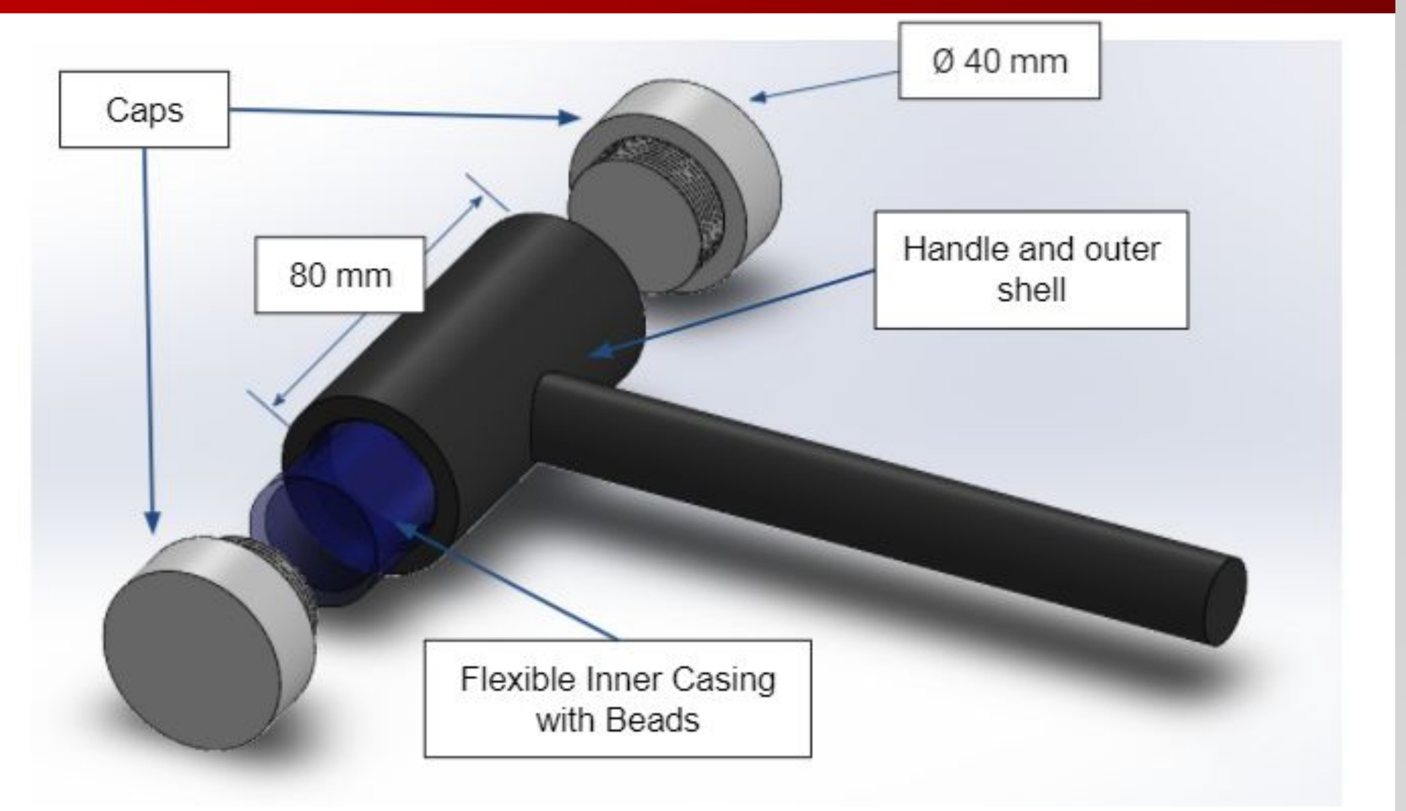

Figure 3: Replaceable Cap Design

TESTING AND RESULTS

- **Testing Procedure:** A force plate was struck by a PLA dead-blow mallet and control mallet to determine the force-time characteristics. Each one was struck 3 consecutive times, which was then repeated 5 times for a total of 15 strikes each.

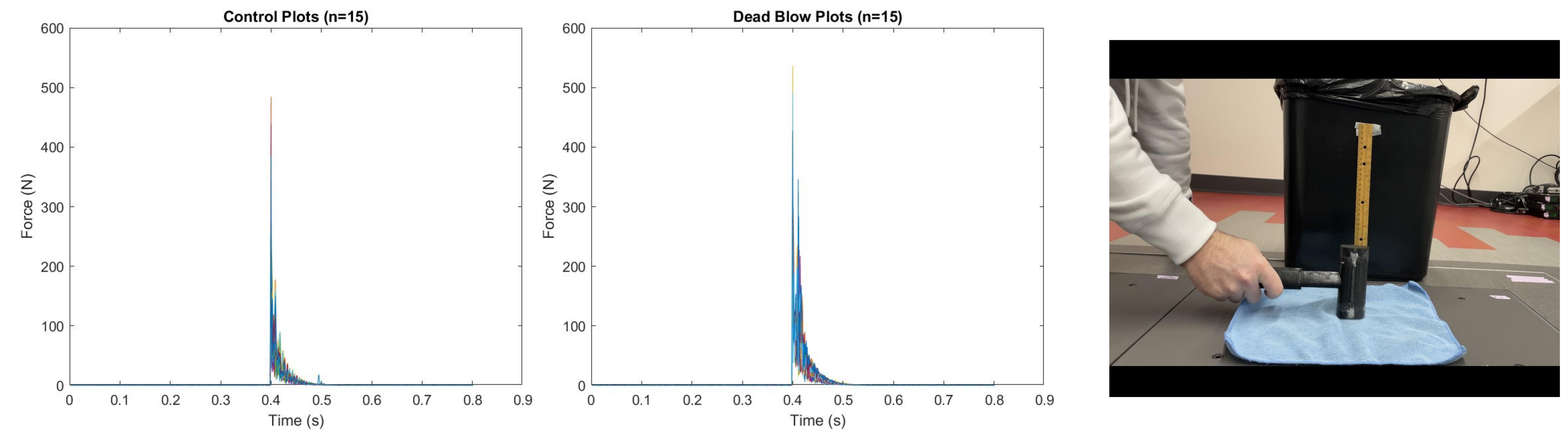

Figure 4: Force-time plot for the control mallet (left) and dead blow mallet (middle) and a force plate strike with dead blow mallet (right). Each test was overlaid so that the maximum impact force occurred at a time of 0.4 seconds.

- **Results:**
  - *Impact Time:* The impact time was found by determining the amount of time that each strike was over 5 N of force. The mean (+/- the standard deviation) for the control mallet was 0.061 +/- 0.007 seconds and for the dead blow 0.077 +/- 0.009 seconds.
    - Running a two-tailed t-test it was found that there was a significant difference with a p-value < 0.001

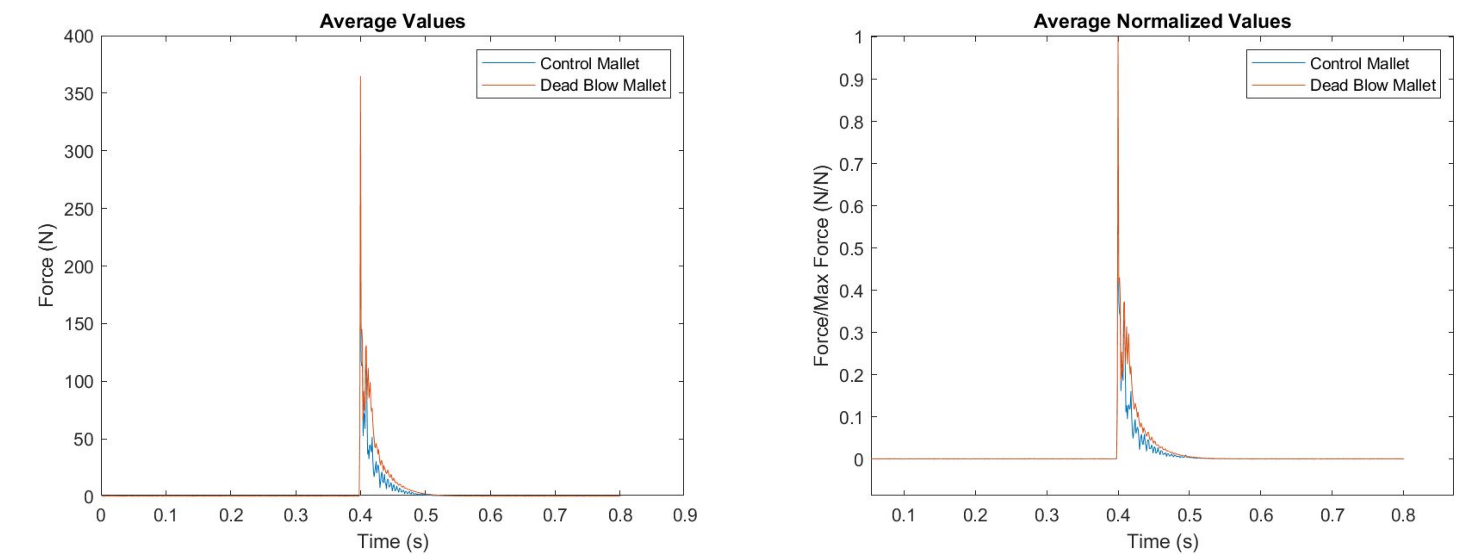

Figure 5: Force-time plot of averages for all 15 tests of each mallet. The left plot is for the average force values, while the right plot normalizes the data to the maximum force of each test.

DISCUSSION

- PLA prototype gives a rough estimate of what will be possible with future fabrications.
- Prototype is durable and can be used for continuous testing if needed.
- Higher fidelity prototype will be manufactured to continue testing to record more relevant data.
- Results are strictly preliminary and will needed to be expanded in order to provide accurate conclusions.
- After first inspection, data supports idea that dead blow distributes force over a longer period of time.
- Limitations in percent recoil due to first prototype and video quality.

FUTURE WORK

Improvements:

- Editing Solidworks model to bring down manufacturing cost.
  - Larger threads
  - Standardize hole dimensions
- Adding grip to the handle to promote ease of use.
- Metal prototype

Testing:

- Force plate testing with metal prototype.
- Force plate testing to determine percentage of beads that best limit recoil.
- Sterilization testing to ensure device withstands temperature.
- Add lever arm to limit human error in force plate striking.

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