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Redesigning a Bilateral Grip Strength Device for Assessing Forelimb Function in Rodents

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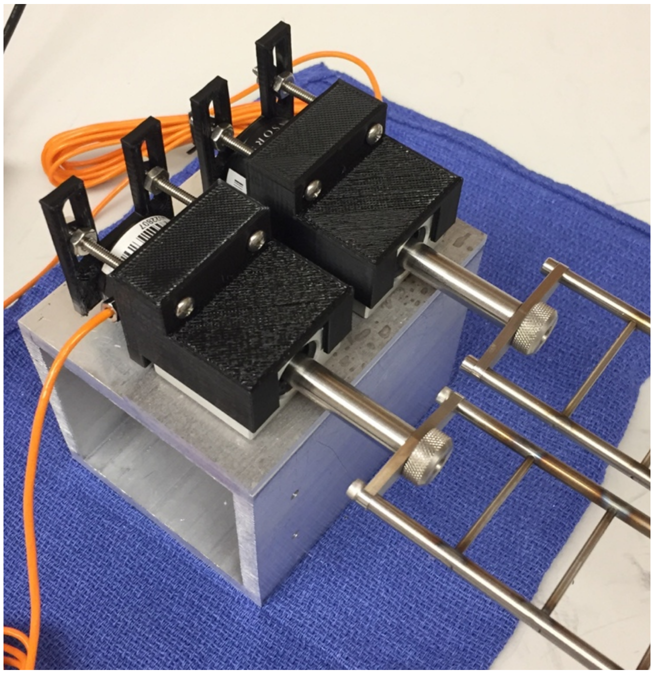
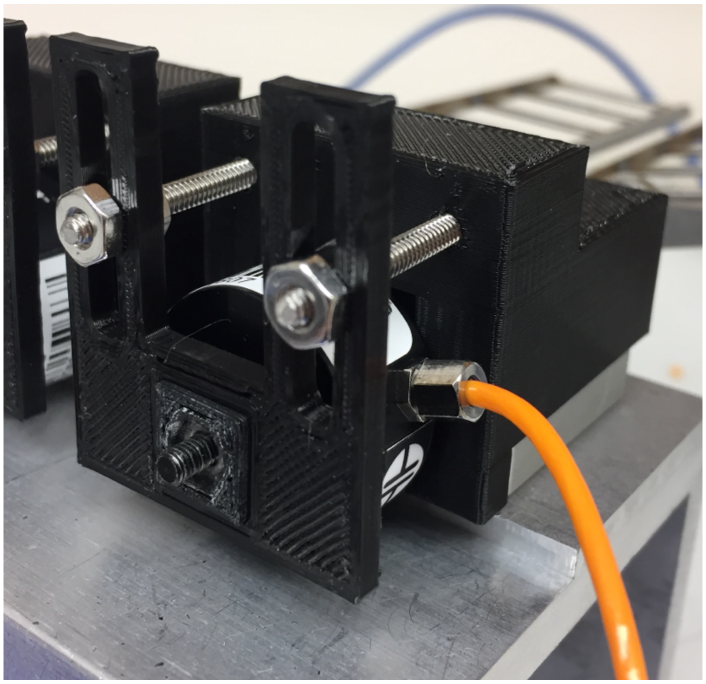
Griffin Kivitz Progress Report Fall 2017





Kivitz, Griffin

Musculoskeletal Soft Tissue Laboratory

Summary:

My primary complete accomplishment of the Fall 2017 semester in the Musculoskeletal Soft Tissue Laboratory is the addition of 3 3D printed parts to the grip strength device to improve the precision of the device. To reach the end result of these 3 parts, I 3D-modelled the parts, 3D printed the prototypes, and integrated the parts into the device for testing. Near the end of the semester I had seen this process through, and the grip strength device is now fully functional and the most accurate and precise it has been.

Aside from my primary project of the grip strength device, Alex Reiter and I reconstructed AGATHA with thicker acrylic.

Introduction:

I have been working in this lab since May of 2017. During the summer, Alex and I performed a preliminary study to determine any issues we would face and if any modifications need to be made to the methods we use.

My primary project in the lab is analyzing and performing grip strength tests on our rat elbow model. We use the grip strength device to measure individual limb strength of the rats during the 6 weeks after free mobilization. An in depth description of the grip strength device can be found in Appendix A.

Upon returning to the lab from my summer work, Alex informed me of a drop in force readings of the left load cell in our setup.

This report with cover the methods we used to determine the issue and the process we went through to fix the issue. In addition, I will briefly discuss the smaller contribution of reconstructing AGATHA.

Methods:

The journey to the current product in the lab consisted of 3 distinct steps. First, we simply replaced the load cells with new load cells with a higher maximum load capacity of 2kg. Next, we removed the linear slides from their housing and reconstructed the entire device with extremely small tolerances. Finally, we came to the realization that designing the device in a way that the load cells align themselves is the only way to get consistent and logical measurements. The parts for the final design were 3D modelled and 3D printed in PLA.

Replacing the Load Cells:

To determine the calibration error in our setup, I oriented the grip strength device so the ladders are pointed straight down, as shown in fig. 1. When hanging 500g and 200g masses from the rungs, the load cell did not give a correct reading according to the weight of the calibration mass.

After recalibrating each load cell several times, we were unable to obtain any sort of accurate and precise reading. It was known that the left load cell was slightly bent, so we blamed that for our difficulties. We upgraded load cell from the LoadStar REB7 1kg mini-load cell to the 2kg version of the same model.

When replacing the load cells didn't solve our problems, we tried to reconstruct the set up to more properly align the load cells with the rungs through the linear slide.

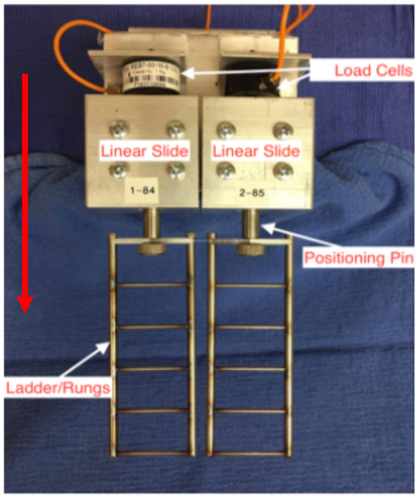


Fig 1. The old (summer) version of the grip strength device is shown, and the red arrow indicates the direction of gravity. This is the orientation of the device used for calibration.

Reconstructing the Device:

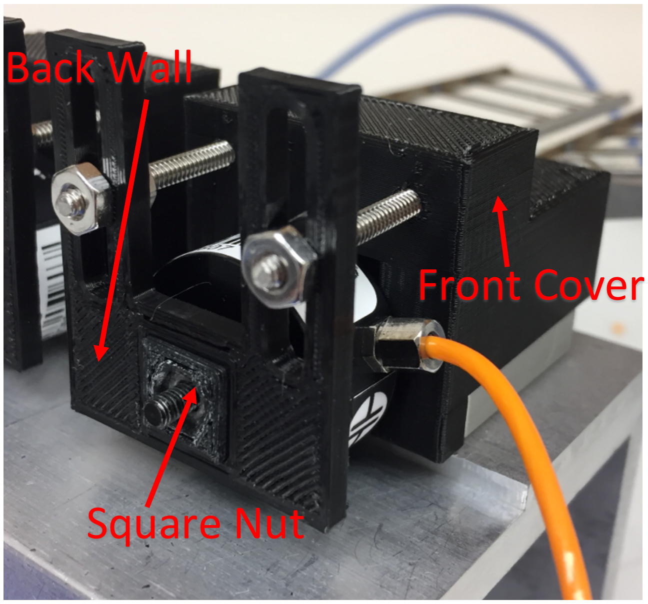
The most notable change we made was removing the linear slide from its housing to have it attached directly to the base plate, as opposed to attached to a housing which is attached to a base plate. In addition, the holes were drilled with very low tolerances to ensure proper alignment of the device.

This did not fix the problem of getting repeatable and representative readings. The linear slide was not fully eliminating 2 and 3 dimensional motion, and the metal rungs slightly deflect as well when under load.

We had the idea, instead of making the parts of the device tight to ensure alignment, we should give the load cell the freedom for its position to move depending on the direction of the force on the rungs.

3D Modelling and Printing:

After a few dimensioning and tolerance errors, we arrived at the final 3-part assembly. The SolidWorks drawings for each part can be found in Appendix B. Images of the final and tested device can be seen below in fig. 2.



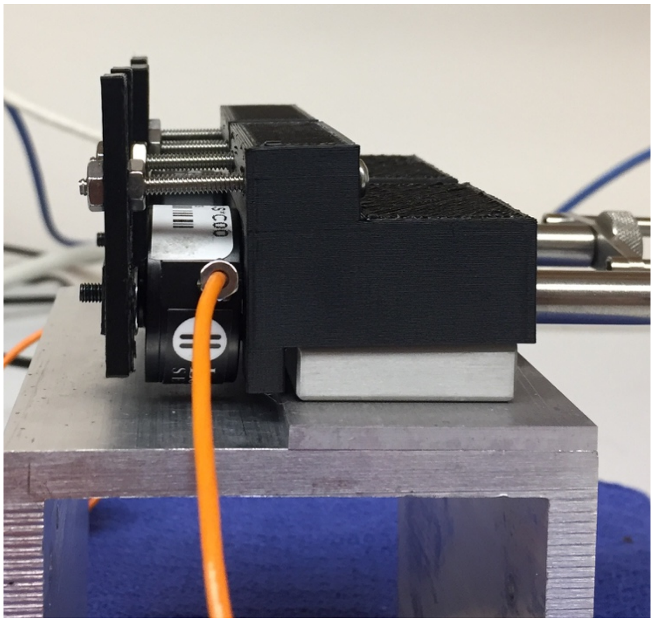
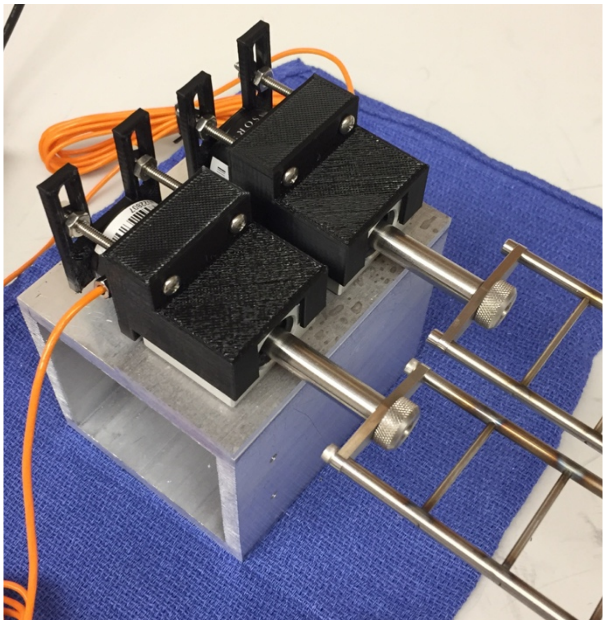


Fig 2: The Square Nut, Back Wall, and Front Cover 3D-printed pieces are labelled, and the device is shown at three different angles.



This assembly works because the load cell is not tightened to a fixed part, but it is still restricted in movement by its surroundings. The Square Nut is a square piece with a hexagonal hole in the center. We superglued an M3 nut into the hole, and essentially created a square nut.

The Front Cover piece simply sits on the top of the linear slide. It is dimensioned to fit over it perfectly and not slide forward or backward.

Two bolts run through the front cover toward the back of the device to secure the Back Wall in place. The Back Wall prevents the load cell from being pushed backward. Also, the Back Wall has a square hole in it that the Square Nut fits through. This Square Nut in the Square Hole restricts rotation of the load cell because the corners of the square nut will hit the walls of the square hole.

After assembling the device, we performed a calibration test and found that the newly improved setup gave accurate and repeatable readings. We then conducted a test with rats to ensure that the device would work in practice, and everything proceeded as expected.

The grip strength device is ready to be used.

Reconstructing AGATHA:

A difficult problem we faced with the AGATHA arena was the lack of precision with which the acrylic was cut. The back wall of the arena did not sit flush with the bottom, so shadows formed and the lighting was not ideal.

After testing potential solutions, including the use of a rubber gasket on the bottom of the back wall, and lining the bottom of the back wall with foam, we realized that we need to just buy new acrylic.

We bought all new acrylic pieces for the arena and had them cut thicker to ensure a smooth edge. On my last day, we constructed the new arena from these pieces, and although they were not cut quite as precise as we would have liked, we will be able to trouble shoot the slight imprecisions.

Conclusion and Future Work:

The primary accomplishment of my time in the lab this semester was the redesigning and prototyping of the grip strength device. This entire semester was in a way a trouble shooting semester to fix the problems we encountered from the summer. Next semester and over winter break, Alex and I will be collecting data with the newly improved grip strength device to assess the effectiveness of treatment therapies for recovery of strength after injury.

Appendix A – Abstract submitted to BMES discussing the grip strength device

Design and Use of a Bilateral Grip Strength Device for Assessing Forelimb Function in Rodents

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Washington University in St. Louis, St. Louis, MO

Introduction: Post traumatic joint contracture (PTJC) is a debilitating condition that effects up to 50% of patients after suffering an elbow dislocation or fracture [1]. PTJC can result in permanent joint stiffness and a loss of range of motion long after the injury [1]. Our lab has recently established the first animal model of PTJC in the elbow replicating this debilitating condition in Long-Evans rats [2-4]. We sought to make limb-specific longitudinal strength measurements to assess how PTJC affects elbow joint function, however commercially available devices compute an average value across both limbs [5]. A custom grip strength device was developed to track individual limb function during rehabilitation in our unilateral elbow injury model. In this study, we describe the novel grip strength device and demonstrate its use by showing functional differences between injured limbs and control/contralateral limbs in our rat model of PTJC.

Materials and Methods: Long-term PTJC was induced in Long-Evans rats as done previously [2-4]. Briefly, animals received a lateral collateral ligament transection and capsulotomy of the left elbow, followed by unilateral immobilization of the injured limb. After 6 weeks, bandages were removed and grip strength measurements were obtained one day later using a custom grip strength test device. The device consists of two sets of metal rungs, or ladders, each held in place by a linear slide and connected to separate load cells (Fig. 1). This setup allows for the measurement of individual limb strength, important for tracking progression/recovery of a unilateral injury, and for variability in the pronation-supination positioning of the rungs. Specifically, each ladder can be rotated inward or outward to measure strength in a pronated, supinated, or neutral position. The paws of the rat were placed on the same rung of each ladder and the rat was pulled by the base of its tail along the direction of the linear slides. Six trials were collected on injured (n=8) and age-matched control rats (n=8). For each trial, the right, left, and total forces exerted on the load cells were recorded. For each animal, force values were averaged across the six trials; these average values were then used to compare groups (i.e., injured vs. control). Side-to-side limb differences were compared within each group using paired *t*-tests, and unpaired *t*-tests were used to compare groups.

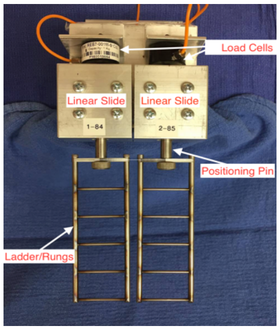

Fig. 1: Grip strength testing device has two ladders, each connected to separate load cells through a linear slide.

Results and Discussion: The grip strength device is similar in concept to the setup of a grid or T-bar connected to a load cell, which is a common apparatus in grip strength studies [6]. However, this device presents a novel advance because it allows for the data collection of individual limbs as well as the ability to test grip strength in the pronated or supinated position. The grip strength of injured/immobilized limbs was significantly less than contralateral uninjured limbs and the grip strength of control animals (Fig 2a). Furthermore, contralateral limb grip strength was not significantly different from control (Fig 2a). Likewise, the ratio of the left to right grip strength of the injured rats (L/R ratio) was significantly less than the ratio for control rats (Fig 2b). As expected, L/R ratio for controls was ~1. During testing, three injured rats would not grip the ladder with their left paw; these rats were excluded from the data (thus, n=5 for injured data) but further demonstrate limb weakness in this animal model. Results show that the PTJC protocol induces significant functional consequences (i.e., decreased strength) in the injured limbs of animals, similar to deficits common to clinical patients with PTJC.

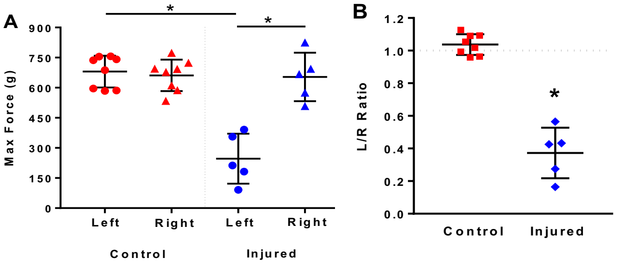

Fig. 2: (A) Significant decrease in injured left arm strength compared to contralateral limb and control limbs. (B) Significant decrease in the injured rats' left to right grip strength ratio compared with control ratio validating the method for grip strength testing. (* p<.05)

Conclusions: This study described a custom bilateral grip strength device/method and demonstrated its ability to measure functional changes in our rat elbow model of PTJC. Moving forward, these tests will be performed to track recovery of limb strength post-immobilization. We will also make longitudinal measurements to evaluate the effectiveness of therapy strategies looking to reduce or prevent PTJC in our rat elbow model of PTJC.

References: [1] Anakwe RE JBJS, 2011;93(13): 1220-6. [2] Lake SP JOR, 2016;34(2):354-64. [3] Dunham CL JSES, 2017;26(4):611-618. [4] Dunham CL JBME, 2017;139(7). [5] Bonetto A BoneKey Rep, 2015;4(732) [6] Maurissen JPJ Neuro Tera, 2003;25(5):543-553.

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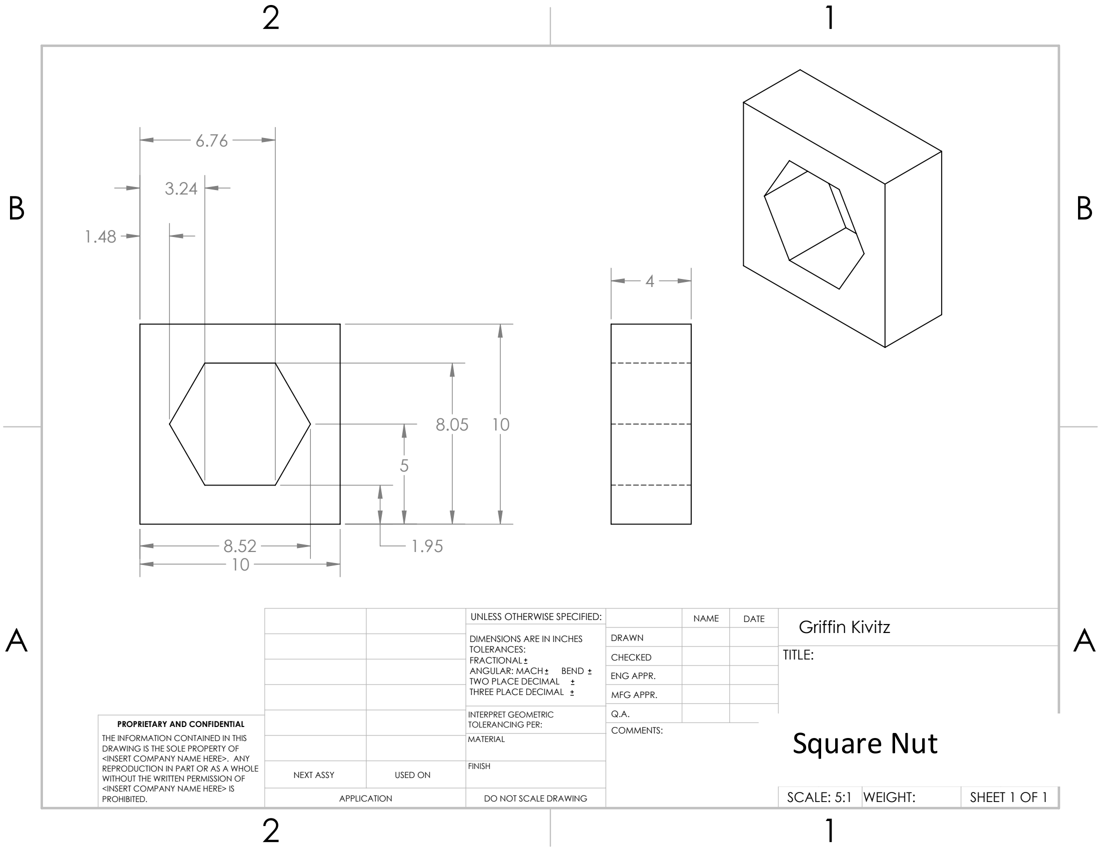
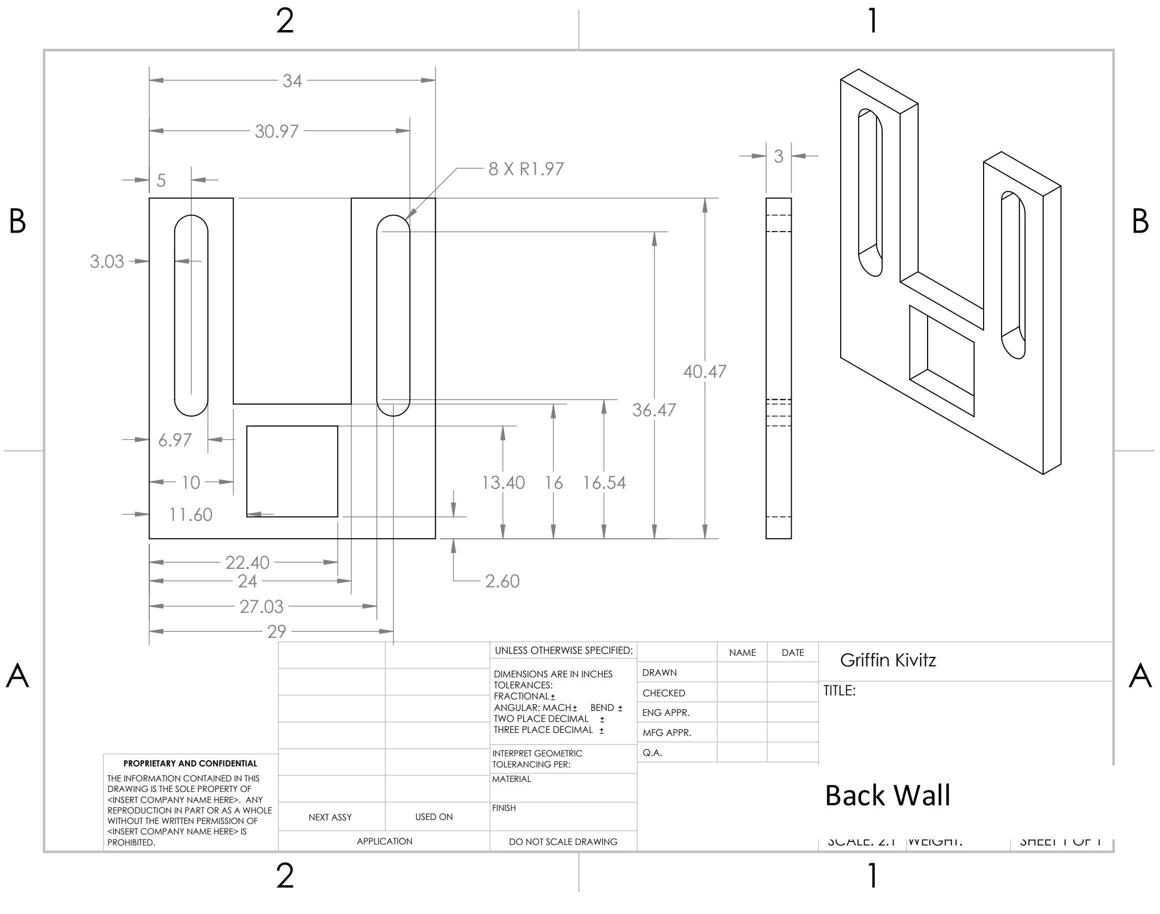
Appendix B – SolidWorks drawings of the 3 3D-printed parts – All dimensions are in mm.





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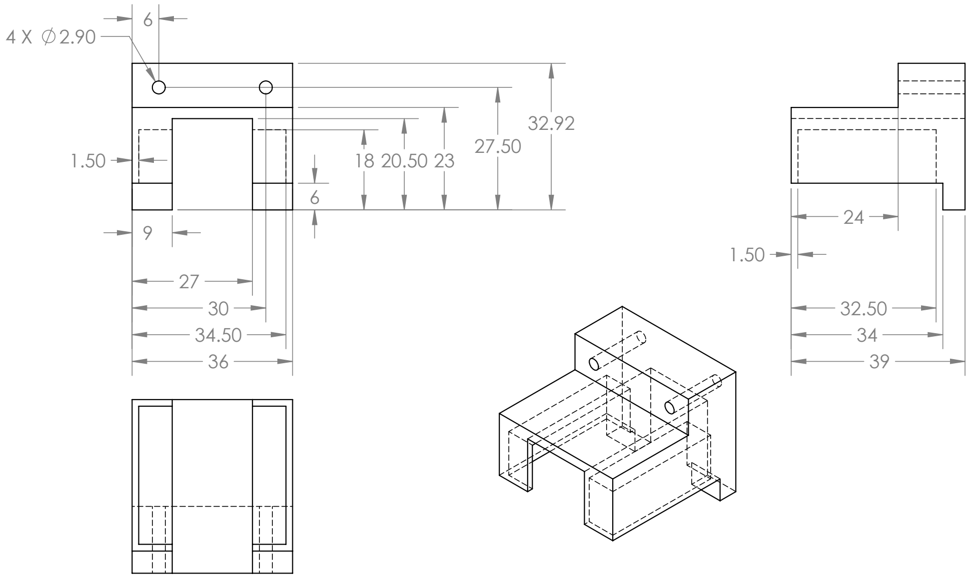

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Griffin Kivitz

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