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RatFlex: A ROM Device Used to Measure Post-Traumatic Joint Contracture in Rat Elbows

Ethan Riak
Washington University in St. Louis

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Abstract:

During the fall 2023 semester, I worked in Dr. Lake's musculoskeletal soft tissue lab. My main task was working on a device designed by previous students that is used to measure elbow range of motion in rats. The end goal of the device is to be able to detect differences in the range of motion between injured and uninjured rat elbows. The current protocol for comparing the range of motion of injured vs uninjured elbows requires that the rats be sacrificed and their elbows dissected for testing on a Biax machine. This device would allow for range of motion tests to be conducted while the rat is still alive, however, allowing for measurements to be taken throughout recovery.

Introduction:

Post-traumatic joint contracture is a condition that can occur after a joint has suffered injury and can lead to pain, contracture, and also the loss of range of motion. PTJC is very common in patients after experiencing an injury to the elbow. It's important to study the effects of PTJC so that we can come up with better recovery methods, which can lead to increasing the quality of life of those experiencing the condition. In the Lake Lab, the current method of measuring the amount of joint contracture in rat elbows involves the use of a Biax machine. The elbow of a rat is first surgically injured, and then immobilized for a certain period of time. Once the immobilization time is over, the rat is sacrificed and the elbow is dissected. The dissected elbow is then placed in the Biax machine and the range of motion is measured and compared to the uninjured limb [1]. One of the limitations of this method is that the range of motion measurements can only be made once the rat is sacrificed. The RatFlex device would allow for measurements to be taken while the rat is still alive, and thus many measurements could be taken throughout the recovery process. In order for the RatFlex device to work properly, it had to take consistent and accurate measurements. There were a few issues with the device that were creating problems within both of these categories.

Methods:

RatFlex is an arduino based device. It utilizes a motor that is attached to a rack and pinion gear. The rat’s arm is attached to a wheel that spun when the gear rotated. A load cell is also used to measure the amount of force being produced at different ranges of motion. A picture of the device is shown below [2].

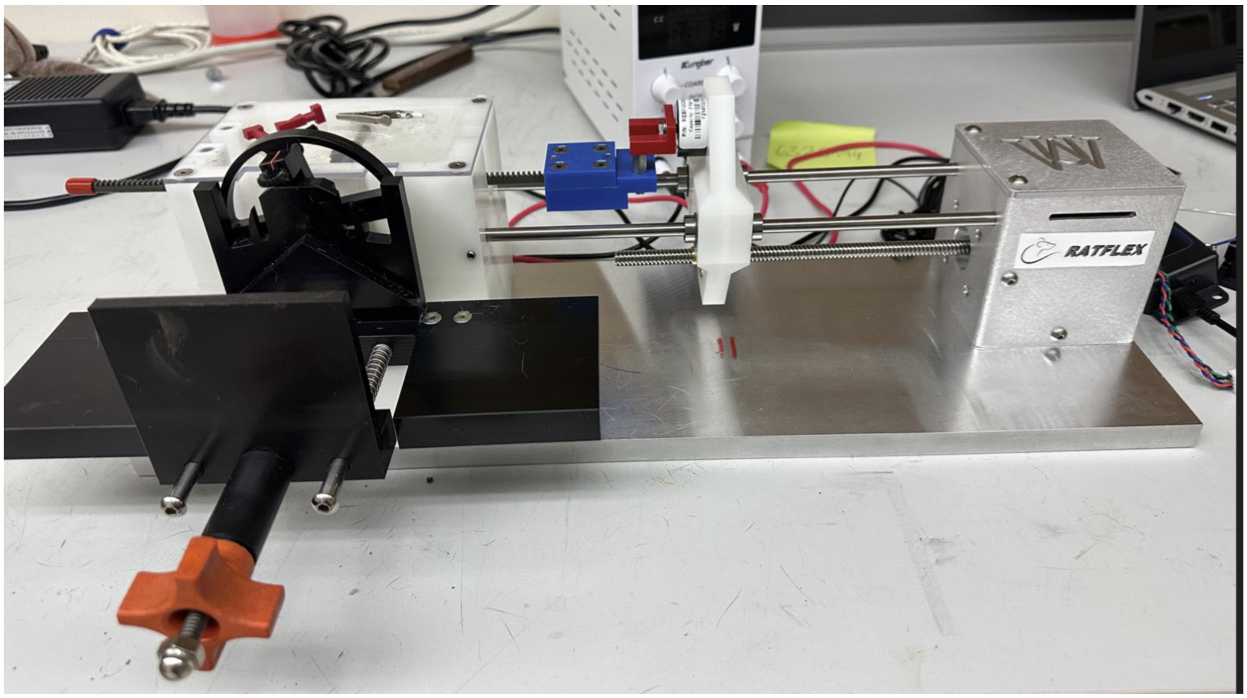

Figure 1: RatFlex device [2]

The current protocol for using the device involves placing the rat in the device and lining up its elbow on the ramp. The rat’s wrist is then placed through the loop on the wheel and secured. The device then starts rotating which flexes and extends the elbow. The arduino would then show the force experienced at different ranges of motion, and this data could be put into a graph to be analyzed.

Results + Discussion:

The issue with the method described above is that it isn’t super consistent and heavily relies on placing the rat perfectly every time the device is used. Another thing I noticed was that the elbow consistently slipped off of the ramp, causing the force values to be quite different between trials. Graphs of some of the preliminary trials are shown below.

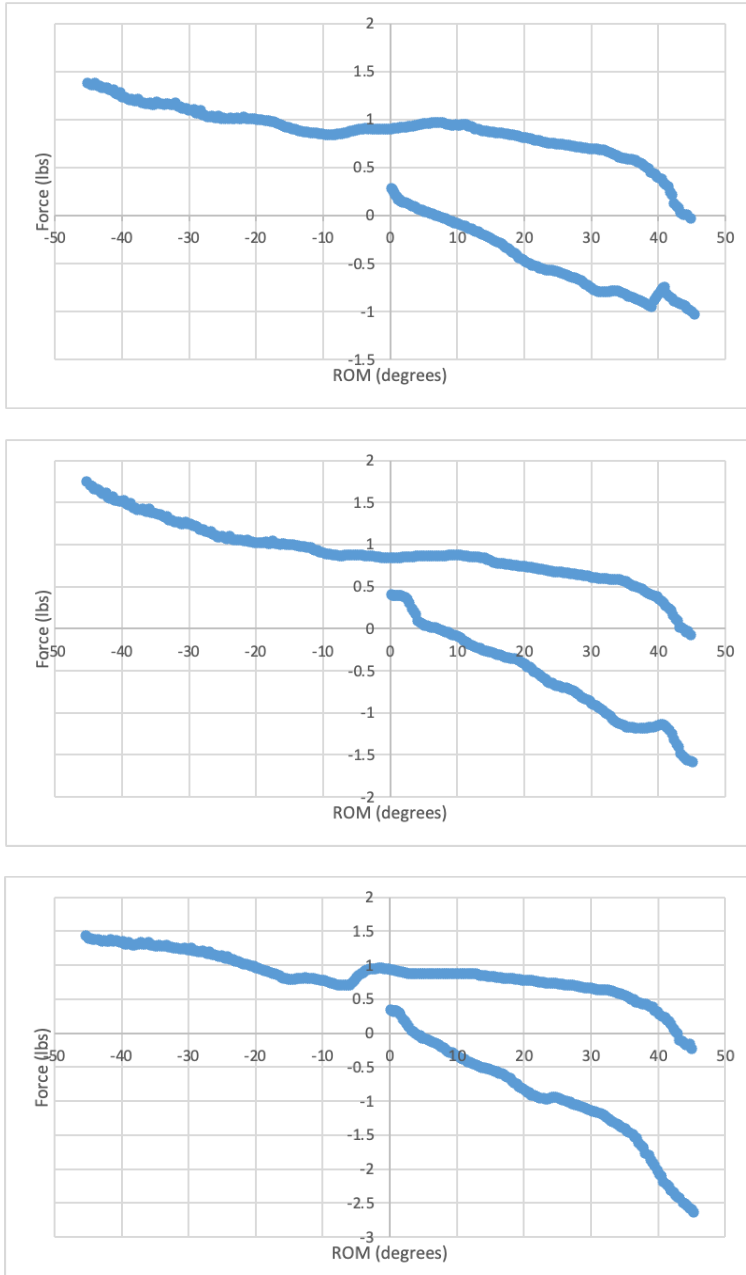

Figure 2: Graphs showing force vs ROM. The bottom line represents flexion and the top line represents extension.

The differences in the force values in the graphs clearly show that there are some inconsistencies within the device. One of the issues with the device was that the rat couldn't be raised up or down to match the height of the ramp. This meant that different sized rats would yield different results since their arms wouldn't be placed in the exact same spot every time. Another issue was the elbow slipping off of the ramp. To combat these issues, different sized flat slabs that acted as risers were 3D printed. Depending on the size of the rat, these risers could be placed under the rat to raise it up. A second ramp was also 3D printed that ultimately doubled the width of the ramp. With a wider ramp, the rat’s elbow had a greater chance of not slipping off.

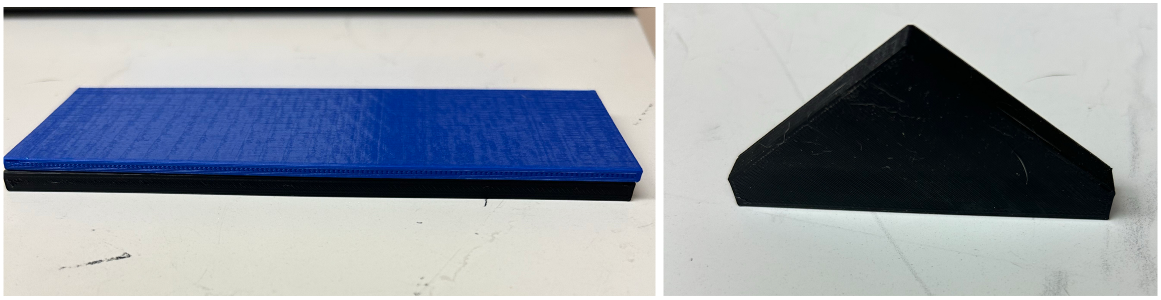

Figure 3: Images showing 3D printed risers (left) and ramp (right)

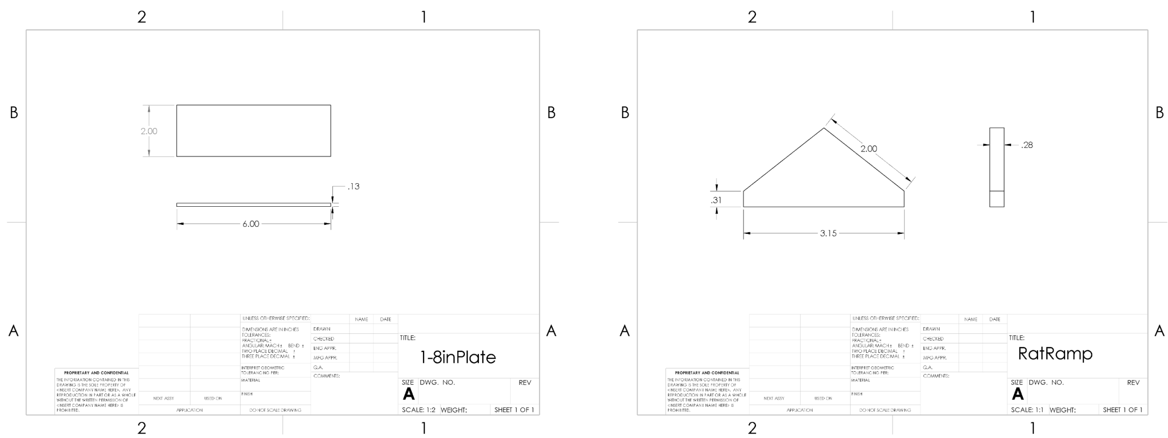

Figure 4: Drawings of 3D printed riser (left) and ramp (right)

The risers were placed under the rat and the ramp was offset so that the arm could comfortably sit on the ramp.

Figure 5: Rat in RatFlex device with riser in place. Ramp is offset with the original ramp.

These changes did yield more consistent results. Shown below are some of the graphs after the changes were made to the device.

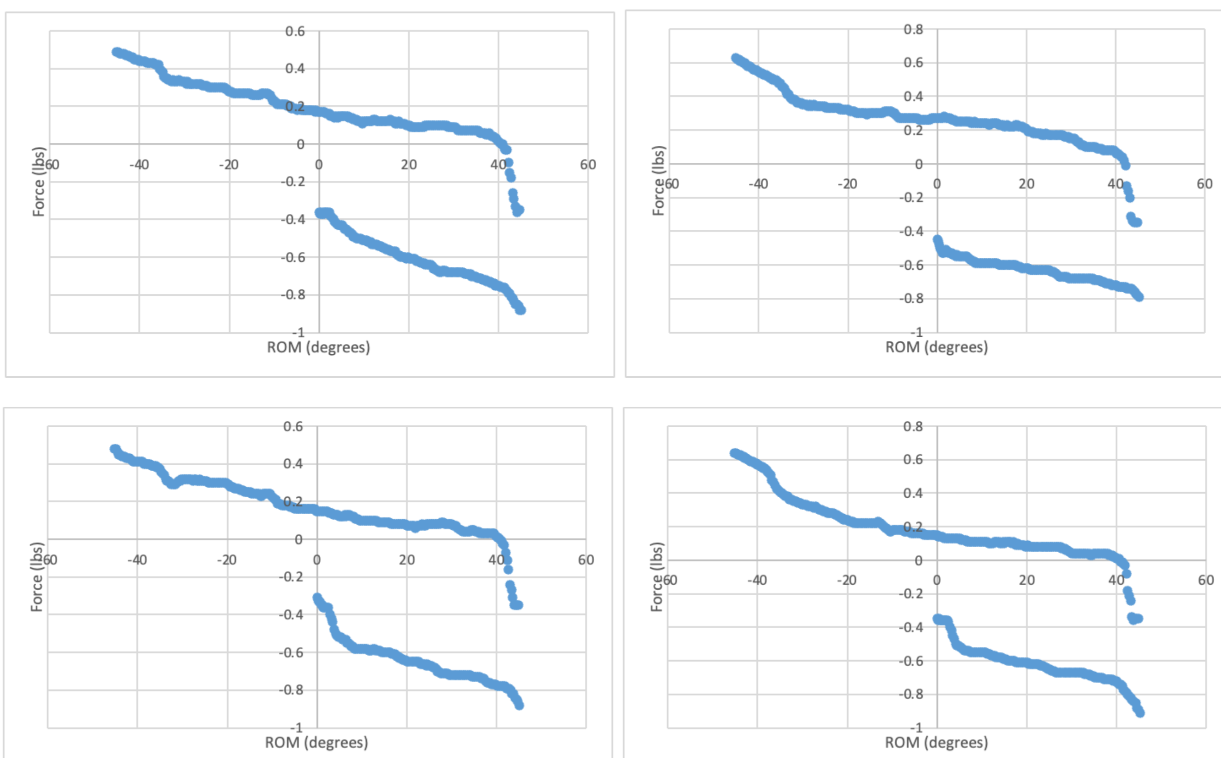

Figure 6: Graphs showing force vs ROM after changes were made. The bottom line represents flexion and the top line represents extension.

These graphs show that the max force the arm experienced during flexion and extension was around 0.85 lbs and 0.6 lbs respectively. While the addition of the riser under the rat seemed to help a bit with lining up the arm on the ramp, it wasn't clear how much this addition affected the results. The reason for this is because only one rat was used to collect all of the data. Different sized rats would need to be used in the device to test whether or not the risers have an effect on the data. The additional ramp did seem to help a lot with the consistency of the device however. The original ramp on the device was too narrow for the rat's arm which caused the arm to slip off during flexion and extension. The original ramp also seemed to be placed too far to the side of the rat's arm which also encouraged the arm to slip off. The additional ramp allowed the arm to sit in a better location while the device ran. Offsetting the ramp forward was also crucial because it allowed the arm to comfortably flex and extend at the elbow without getting caught on the ramp. While the additions to the RatFlex device yielded much more consistent results, there are still some inconsistencies in the data.

Next Steps:

One of the reasons for the inconsistencies within the device could be that the upper arm moves too much, especially during extension. During extension, the entire arm seems to get pulled forward rather than just extending the elbow. This may be one of the reasons the extension values fluctuate more than the flexion values. Because of this, there needs to be a way to lock the upper arm in place so that it can't be pulled forward. Future plans on the device would work towards this goal. One idea involves 3D printing a hollowed-out version of the second ramp. This would allow for some type of zip tie or strap to be wrapped around the upper arm and ramp to keep the arm in place during flexion and extension. An example drawing of what this ramp could look like is shown below.

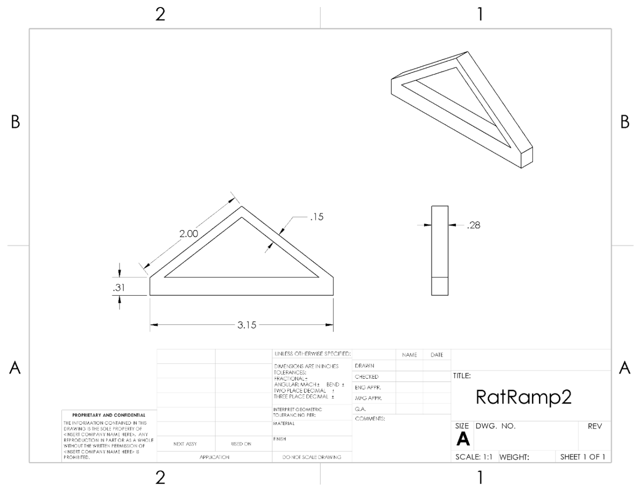

Figure 7: Example drawing of modified ramp

Other plans would include testing different sized rats on the device to determine whether or not the risers are effective. This is important since the point of this device is to measure the ROM of the elbow throughout recovery, which also includes the rats growing in size.

Conclusion:

The additions to the RatFlex device have allowed it to take more consistent data, but it is still not perfect. The additional ramp added to the device has definitely allowed for smoother flexion and extension at the elbow and thus more consistent measurements. The effect of the risers on the device is still not super clear, and requires more testing with different sized rats. One of the issues the device still seems to have is that there is nothing stopping the upper arm from moving during flexion and extension. Especially during extension, movement of the upper arm seems to affect the consistency of the device. If this issue is solved in the future, the RatFlex device will be able to measure elbow ROM much more consistently in live rats.

References:

S. P. Lake, R. M. Castile, S. Borinsky, C. L. Dunham, N. Havlioglu, and L. M. Galatz, “Development and use of an animal model to study post-traumatic stiffness and contracture of the elbow,” J. Orthop. Res., vol. 34, no. 2, pp. 354–364, 2016, doi: 10.1002/jor.22981.

Arun Movva, “In-Vivo Tracking of Injury Recovery in Rat Elbows,” 2023.