Quantitative ACL Tibial Guide: Improving Clinical Outcomes of ACL Reconstruction Surgery

Comparison between ACL Reconstruction Surgery and Rehabilitation

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Many individuals are growing passionate when playing sports and there has been an upward trend of more people wanting to be more active in sports or outside activities within this generation (Trasolini & MD, n.d.). Imagine yourself getting injured in the knee even just from a wrong foot landing, leading to limitation or having to completely stop the activities that once brought joy and happiness to you. Our focus is making sure if there is a tear in the ligament, specifically the Anterior Cruciate Ligament (ACL), a full recovery is to be achieved with the newly designed ACL tibial guide device.

ACL is one of the most common injuries and is the ligament that connects the front top of the tibia, which is the lower leg bone, to the rear bottom of the femur, which is the thigh bone. ACL surgery is highly recommended when there is an ACL tear as ignoring it would cause further discomfort which has the potential of causing other injuries. There are between 100,000 and 200,000 ACL tears or ruptures per year in the United States (Friedberg, n.d.). The injuries usually occur in college and high school athletes and are a more common occurrence for females than males due to the difference in physical anatomy. The most common form of injury is non-contact injury and can happen from sudden deceleration or change in direction when moving, pivoting, or landing in a rotational or lateral bending (Friedberg, n.d.)

The current tibial guides use arthroscopic landmarks that currently have inconsistencies in the tunnel placement locations and could lead to unforeseen future consequences within the patient's knee. Therefore, for my capstone project, our optimal goal is to find a way for precise placement of the tibial guide during ACL reconstruction surgery.

ACL Tibial Guide Mechanism

Some ACL tears can be treated with rehabilitative therapy. However, the ligament that is completely torn would not be able to heal or reattach itself. Without surgery, the patient would at most be able to reduce the swelling and the pain but would have a challenging time returning back to their pre-injury sports and other activities. ("ACL Rehabilitation Without Surgery | MOON Knee ACL Research," n.d.). As the knee is involved in almost any movement, from walking, running, swimming, etc., it is important to make sure that you have a healthy knee ("How Does the Knee Work?" 2020). In addition, even with the surgery, only about 65% of the patient athletes that had ACL reconstruction can return to their original performance (Gokeler et al., 2022). There have also been high reports, around 40%, who risk the injury of another ACL injury in athletes when returning to sports. This is often due to failed surgeries which may cause knee discomfort or pain.

ACL reconstruction surgery requires replacing the damaged ligament with a graft. The replacement is done by drilling tunnels in the femur and the tibia. These tunnels are used to position the graft, which is secured to the bones with screws or staples (*Knee Ligament Surgery - How It Is Performed*, 2017). The ACL tibial guide can utilize anatomical landmarks, arthroscopy, and the surgeon's discretion for the placement of the drills. The current problem relates to the landmark. The landmark is the border of the meniscus' front horn, but it yields inaccurate and inconsistent tunnel location. This location has an average anteroposterior (AP) placement distance of 37.0% ± 5.2% and a range of 26.4% to 49.2 (Werner et al., n.d.). Due to the variation in the AP distance, the surgery results could lead to undesirable clinical outcomes and improper placement of the tunnel often could lead to failed surgery. Studies show that an AP distance of less than 40% of the total distance yields improved clinical stability. Our advisor, Dr. Mark

Miller, patented “an adjustable device for identifying the target location for, and placement of, a bone tunnel” to improve the clinical outcome of ACL reconstruction surgery (Miller, n.d.). The patent outlines the novel components and engineering sketches of the guide (see Figure 1).

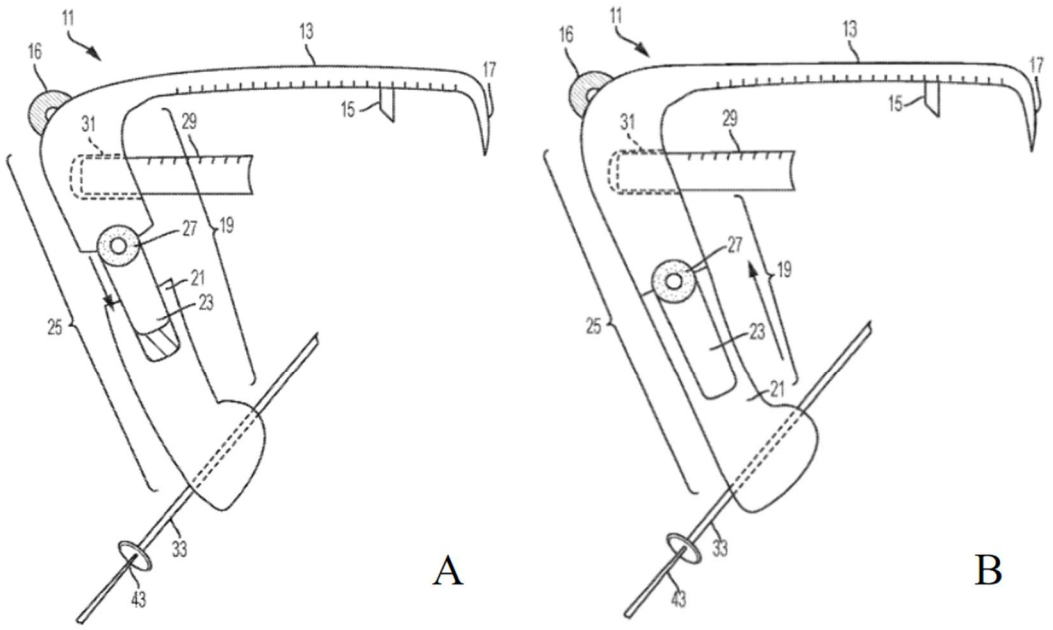

Figure 1: Technical drawing of patented tibial guide design. A and B demonstrates the hinge mechanics.

Our technical project, identifies new components to the ACL tibial guide according to the restraints outlined in the patent and by our technical advisor. The newly designed guide will increase the precision of the total distance across the tibial plateau. It will also help engage the tibial plateau at a precise location based on the optimal AP distance without the use of imaging techniques. This will be done by thew following actions: designing a retractable ruler mechanism using a knob to determine the total AP distance of the tibial plateau, designing a track for the guide’s upper arm to set that distance; creating an adjustable height mechanism in the lower arm, having a shin stopper as an added component; creating a retractable hinge to set the drill in a specific angle for drilling the bone tunnel; and then using computer-aided design (CAD) to model and print prototypes for iterative testing. The primary goal is to design a tibial guide with

these added components and to evaluate the accuracy and consistency of the bone tunnels to optimize ACL reconstruction surgeries.

By creating a tibial guide with an adjustable targeting mechanism, we expect to improve clinical outcomes and increase the success of ACL reconstruction surgery by increasing knee stability. With this device, we expect to reduce fewer surgical failures or having to redo a surgery. This project will be completed in a team of four students over two academic semesters through the courses BME 4063: Capstone Design I and BME 4064: Capstone Design II. Designing the differing tibial guide components, modeling, and printing the guide, and evaluating the guide will be split equally amongst the team.

ACL Surgery and Rehabilitation

The general topic area is within the movement of the knee. The knee has many joint components in it starting from cartilage, tendon, ligament, and bone. There is so much involved with the knee helping us run, walk, swim, support our weight, control our balance, etc (*Knee Range Of Motion*, n.d.). It is critical to figure out if one of the parts is injured and needs a replacement for a functioning knee to happen. Our capstone specifically focuses on the improvement of ACL reconstruction, which requires the replacement of the ACL with a graft and could be potentially helpful for knee injuries.

There are societal factors that need to be considered within having the device. As most devices could be expensive, many patients might not be able to afford the cost of the surgery. Being able to receive this surgery for those in need is critical in going on with their daily lives, but being able to afford it could be another concerning factor. Getting the treatment as quickly as possible could lead to a large difference in short-term and long-term outcomes depending on how

fast they are able to receive the treatment. Without the treatment, the ACL injury could turn into a chronic ACL deficiency and other negative outcomes leading to the knee becoming more and more unstable (*ACL Injury*, n.d.-b).

In this paper "Societal and Economic Impact of Anterior Cruciate Ligament Tears," there were two studies done on the Multicenter Orthopedic Outcomes Network (MOON) and the knee ACL nonsurgical versus surgical treatment (KANON)(Mather et al., 2013). The societal perspective of the costs and benefits of the treatment has shown a huge difference between getting the surgery and getting only the rehabilitation. A lot of the time, the patient is at first sent to physical therapy and rehabilitation to recognize the better movement of the knee (*ACL Injury*, n.d.-a). Then, the orthopedic surgeon would analyze whether the patient needs the surgery but there are still controversies on whether getting the surgery is better or not.

To look at more of the difference between rehabilitation and surgery, more of the cost-utility analysis should be addressed. It would include a lot of the societal factors such as the patient's work status, earnings, and disability. Then, the effectiveness should be measured based on the cost-effectiveness comparison. Having these comparisons could provide the patient with a better understanding and hopefully not avoid the surgery and have a chance to look at the long-term outcomes too.

The anticipated scope of my project is to understand the hindrance or benefit there may be in those who focus more on the treatment surgery versus the rehabilitation. The STS part is tightly coupled to my technical project. Both factors need to be considered when trying to find the ultimate benefit of the device outcome as it is a device that is made to help people feeling knee discomfort. The technical part would focus on the design of the device while the STS part

could focus more on analyzing what societal factors that need to be included when doing the ACL surgery.

Research Questions and Methods

The research question would address the difference of the cost and benefit between receiving the ACL reconstruction surgery and receiving the rehabilitation. Is adding another component within the existing tibial guide device to successfully place the tunnel placements accurately for every patient worth more of the focus rather than focusing on the rehabilitation? The topic is significant because a misplacement of the tissue in place of the ACL could affect knee stability and could lead to other dangerous outcomes leading to long term (Büyükdoğan et al., 2021). Knowing the benefits can ultimately be more helpful for those with ACL injuries to smoothly transition back into their normal life after the injury. The methods I would use is reading articles and research papers about the societal and economic impacts of ACL surgery and rehabilitation. I would try to look more at comparing the cost, the risk of future damage, and the recovery period using a model to compare the cost-effectiveness (Losina et al., 2009). These data would help to clearly answer the question and to be able to recognize whether in which situations an ACL surgery is beneficial and in others when only rehabilitation could be better.

Conclusion

As there has been an increase in the trend towards physical activities, there has also been an increase in injuries in the knee such as the ACL tearing (Kaplan & Witvrouw, 2019). ACL injuries are a common occurrence, particularly from active individuals, and finding and innovating the right treatment is crucial in helping them improve their life quality. For the technical aspect, my capstone group will be working on creating a more accurate tunnel placement of the tibial guide

for anyone who is in need of ACL reconstruction surgery. By developing a device with better accuracy when using the tibial guide, this could be extremely important in being able to successfully help those in need. For the STS aspect, I will look and research more into the difficulties and demand factors that are necessary for receiving the ACL reconstruction treatment they need. The outcome of this project will increase knee stability and create a more dependable surgical treatment for those who suffer ACL tears and reduce the chance of ACL reconstruction failure. Finding a more accurate and reliable design for the tibial guide could be a potential solution for patients and athletes to successfully return back to their sports. In addition, learning more about the distinct differences and benefits of the ACL surgery and rehabilitation would help determine more accurately what would be better for particular patients in a societal and economic aspect.

Word Count: 1922

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