Quantitative ACL Tibial Guide: Improving Clinical Outcomes of ACL Reconstruction
(Technical Paper)
Ideal ACL Treatment According to Post-treatment Activities and Financial Capability
(STS Paper)

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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

The knee is a complex joint that connects bones, cartilage, ligaments, and tendons. One of the most important ligaments in the knee is the anterior cruciate ligament (ACL). The ACL connects the thigh bone (femur) to the shinbone (tibia) and provides rotational stability for the knee. ACL injuries are one of the most common knee injuries and are typically caused by sudden changes in ligament direction. This often occurs during sports such as soccer, basketball, and football, where sudden stops or changes in direction, jumping and landing causes strain to the ACL and injures the ACL. These injuries tend to be complete or almost complete tears of the ligament. One common treatment mostly used on athletes is ACL reconstruction surgery, which is the focus of our technical topic. During the surgery, an ACL tibial guide will be used to drill a bone tunnel across the tibia. Doctors will be able to replace the torn ACL with the graft tendon, which is usually taken from another part of the patient's knee or a human donor, through the bone tunnel. There are several other ACL treatments such as rehabilitation. My STS topic is to find an ideal ACL treatment for each patient according to their planned post-injury activities and economic considerations.

Technical Discussion

There are between 100,000 and 200,00 ACL tears per year in the United States where females and athletes are at greater risk (*ACL Tear*, n.d.; Friedberg, n.d.). Surgery most commonly occurs in adolescence, specifically in males from age 19 to 25 years old and

females from 14 to 18 years old (Sanders et al., 2016). Although some ACL tears can be treated with rehabilitative therapy, the ligament will not heal or reattach itself without surgery. Thus, the patient can only reduce the swelling and pain; however, the patient will have a drop in performance level when returning to their sport or other activities in comparison to before the injury ("ACL Rehabilitation Without Surgery | MOON Knee ACL Research," n.d.). Additionally, without surgery, long-term effects on the knee can increase its instability, and the risks of other injuries increase. Of the patient athletes that had ACL reconstruction, only 65% can return to their original performance (Golfer et al., 2022). This is often due to failed surgeries which may cause knee discomfort or pain.

ACL reconstruction surgery replaces the damaged ligament with a graft, a piece of the patient's tendon, by drilling tunnels in the femur and 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 location of these tunnels is determined with a tibial guide that utilizes anatomical landmarks, arthroscopy, and the surgeon's discretion for placement. A common 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.). The surgery results are negatively impacted by the large variation in AP distance because the tunnel placement directly affects clinical outcomes and improper placement of the tunnel often

causes failures. 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).

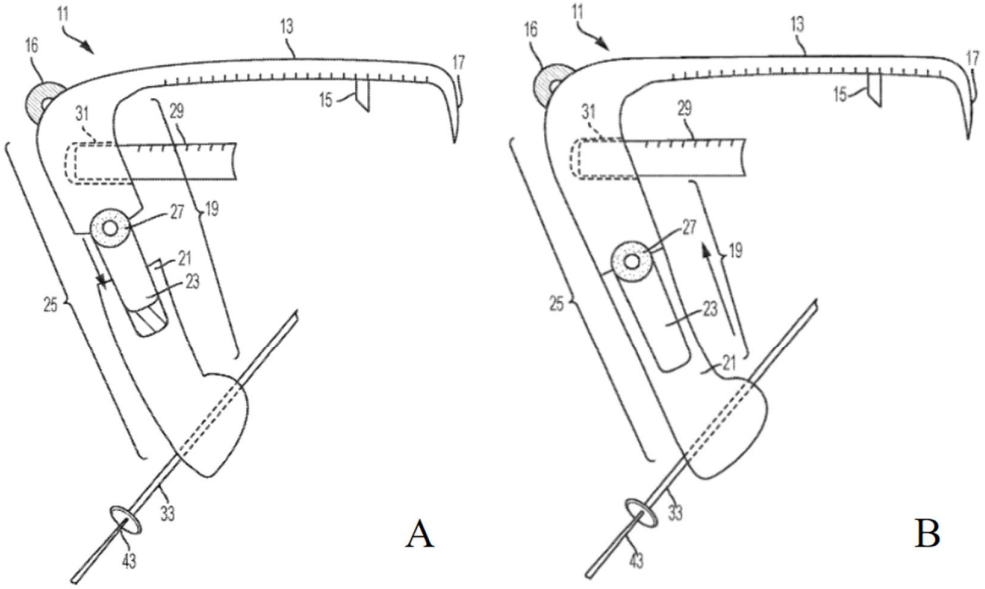

Figure 1: Technical drawing of patented tibial guide design. A and B demonstrates the hinge mechanics.

For the technical project, we are redesigning the ACL tibial guide according to the restraints outlined in the patent and by our advisor. The new design should measure the total distance across the tibial plateau and 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 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 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 goal is to design a tibial guide with these 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. The issues with inconsistent and inaccurate tunnel positions are expected to be reduced because of implementing this device, therefore, creating a more dependable surgical treatment that will have fewer surgical failures. This project will be completed by a team of four students over two academic semesters through 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.

STS discussion

ACL reconstructions are mostly done on athletes since they require high functional stability of the knee to perform high level sports. However, even with surgery, only 65% of the athletes return to their sports at the same level of preinjury. There are also alternative treatments such as rehabilitation therapy for non-athletes that allows them to perform daily tasks and their regular activities, which is why surgery is not always required. When

encountering ACL tears, it is important to find the most suitable option for everyone from the various ACL treatments.

The topic of my project is in the field of orthopedic surgery clinical research, specifically in the sports medicine division since most patients receiving the ACL reconstruction treatment are athletes. With the high incidence rate of 100,000 to 200,000 ACL tears per year as mentioned earlier, there is significance in finding the best treatment that allows the patient to return to their preinjury activities, whether they are athletes or not. There are controversies related to ACL reconstruction as well, including the surgical technique and ligament graft used in the process being impossible to recreate the same rotational stability of the native ligament (Hospodar & Miller, 2009). Research also showed that ACL reconstruction causes larger trauma than the initial injury and that there is no difference in patients' pain level or knee functional stability between conservative rehabilitation and ACL reconstruction surgery (BMJ, 2020).

The unreliability of current surgery methods is one main contribution to the low surgery success rate. Our newly designed ACL tibial guide mentioned in the technical discussion aims to increase the success rate for ACL surgeries so that more athletes can return to their preinjury level of sports. For non-athletes, their age and post-treatment activities are the major factors contributing to choosing their treatment method. Another consideration factor is the cost of the treatment. Research showed that ACL reconstruction is more cost-effective

than non-operative treatments with merely rehabilitation. The cost of graft materials also varies, which leads to variability in the total cost of ACL reconstruction surgery (Saltzman et al., 2015). The improved surgery method from my technical discussion will be evaluated along with the existing treatments to search for the ideal ACL tear treatment method that provides strengthened knee stability and reduced trauma for each patient according to the patient's post-surgery activities and financial capability.

My STS topic is tightly coupled with my technical topic since the technical topic aims to improve the current ACL surgery process with a newly designed ACL tibial guide and my STS topic aims to find the best ACL treatment for individual patients by evaluating social and economic considerations.

Research Question and Methods

The research question for my STS topic is: what is the ideal ACL treatment for patients of different social and economic backgrounds? The most common ACL treatments will be evaluated based on post-treatment knee stability, trauma after treatment, target patients and affordability. Each patient will be classified according to whether they are an athlete, their age, future activity plans, and financial capability. Characteristics of each treatment as well as each patient will be quantified into numerical measurements. The measurements of the treatment will be compared to the values of the patient. A goodness-of-fit model could be used to evaluate the statistical compatibility between the patient data and different treatment

methods to determine the most ideal treatment for each patient.

Conclusion

ACL injuries are a common knee injury, especially within athletes that participate in sports such as soccer, basketball, and football. Current reconstruction methods rely on arthroscopic landmarks and could not achieve accurate tibial tunnel placement. My technical project focuses on designing an ACL tibial guide that allows for consistent and accurate tibial tunnel placement that ensures functional stability of the knee after surgery. My STS project focuses on finding an ideal ACL treatment method that best improves the clinical stability of the knee and minimizes trauma post treatment according to the patient's post-treatment plans and financial capability. These two topics are closely tied together because they both aim to improve ACL treatment outcomes.

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