Thesis Project Portfolio

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

(Technical Report)

Comparison between ACL Reconstruction Surgery and Rehabilitation

(STS Research Paper)

An Undergraduate Thesis

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Sociotechnical Synthesis

Introduction

There are between 100,000 and 200,00 ACL tears per year in the United States where females and athletes are at greater risk and can often lead to requiring ACL reconstruction surgery. During the surgery, a medical device called the tibial guide is used to replace the damaged ligament with a graft by drilling tunnels in the femur and tibia. However, the current tibial guide yields inaccurate and inconsistent bone tunnel location, negatively affecting the clinical outcomes. The technical portion of the paper focuses on making an adjustable device for identifying the target location for, and placement of, a bone tunnel to improve the clinical outcome of ACL reconstruction surgery. The STS portion is clearly related to the technical portion as it focuses on other challenging factors such as the societal and economic impact of ACL tears, especially comparing and contrasting the nonsurgical and surgical ACL injury treatments.

Project Summaries

The goal of the capstone design project is to redesign the tibial guide used during anterior cruciate ligament (ACL) reconstruction surgery in order to reduce variability in the location of the drilled bone tunnels and improve postoperative knee stability. We will identify mechanisms to incorporate the patented features while maintaining the clinical usability of the device by comparison to current models, namely the Arthrex AR-1510T. The newly designed guide will increase the precision of the total distance across the tibial plateau and bone tunnel placement. This will be done by the 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 for better placement; and creating a retractable hinge to set the drill in a specific angle for drilling the bone tunnel. Specific quantitative design constraints were determined for each part of the tibial guide to determine the ideal parameters after talking with our advisors and other secondary resources, shown in Figure 1. By implementing the specific considerations, our end goal was to redesign several prototypes using computer-aided design (CAD) software and 3D printing and to test it on knee models.

Need #	Design Constraint/Metric	Unit of Measure	Marginal (Acceptable)	Ideal Value
1	Bone Tunnel Location Accuracy	Millimeters	± 5	3
2	Angle Accuracy of Tunneling	Degrees	± 5	3
3	Weight of Guide	Grams	90-120	110
4	Grip Handle/Second Arm (*19) Length	Centimeters	8-12	10
5	Max Upper/First Arm (13) Length	Centimeters	12-16	12
6	Max Length Adjustment of Hinge/ Working Arm (27)	Centimeters	4-8	8
7	Angle Adjustability of Guide Pin (43, 33) to Targeting Arm (15)	Degrees	10	5

* The numbers represent their respective labeling in the patent

In my STS research, I investigated the societal and ethical factors that need to be considered within having the reconstruction surgery. In this paper, I evaluated the cost of ACL surgery, the recovery period, its effectiveness, and more. As having reconstruction surgery is costly, the differences between having reconstruction surgery or rehabilitation only were some of the discrepancies among the patients. The cost-effectiveness and the quality-adjusted life years (QALYs) were looked at to compare getting the surgery and getting only the rehabilitation. A cost-utility analysis was also researched to look at early reconstruction (ER) and compare it to delayed reconstruction (DR). The data showed that early reconstruction is more effective and less costly than rehabilitation in both situations, clearly showing the importance of getting reconstruction surgery for patients with ACL tears.

Conclusion

From the technical and STS research projects, I was able to see both the doctor's and patient's perspectives and how critical it is to consider both. From the technical project, I learned

that the current ACL medical device can lead to reinjury among patients after surgery in about 10% of the patients. Therefore, this led my team to focus on redesigning a more improved medical device for the doctors and surgeons to more accurately proceed during the reconstruction surgery. This will help to reduce the failure rates of the surgery and provide better knee stability for patients who had experienced an ACL injury. In addition, it was also important to see the ethical aspects such as patient safety, confidentiality, and honesty when designing a medical tool. From the STS research paper, I learned more about the societal and ethical factors the patients are facing when deciding to do surgery. For instance, the cost, the recovery period, and the quality-of-life aspects are some of the key factors. Therefore, if reconstruction surgery has lower failure rates and improved knee stability, this would influence the patients to more willingly proceed and trust the reconstruction surgery, which is necessary for patients who have ACL tears. Therefore, both projects are very intertwined with each other. Through the two research projects, I was able to understand the ethical implications of what patients need to consider when deciding upon getting an ACL reconstruction surgery and what engineers are faced with when designing and improving a medical device in order to provide more patient comfort and care.

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