Thesis Portfolio

Novel Distraction-Unloader Knee Braces for Medial Compartment Knee Osteoarthritis

(Technical Report)

Knee Braces Alleviate Osteoarthritis Disparities

(STS Research Paper)

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Sociotechnical Synthesis

Knee osteoarthritis is the most common orthopedic disorder, affecting around 1 in 3 adults over their lifetime. Characterized by the progressive destruction of connective tissue and cartilage, knee osteoarthritis has no cure. While total knee replacement (TKR) is the current gold-standard treatment with an estimated 90% satisfaction rate, many patients face insurmountable barriers to accessing this major surgery (Lespasio et al., 2017). These obstacles have exacerbated healthcare disparities regarding osteoarthritis outcomes across many intersecting power structures, namely race, gender, class, geography, and disability. Because many of these obstacles stem from the nature of surgery itself, there is a high demand for improving non-surgical alternatives. Due to the highly customizable and manufacturable design of knee braces, I propose them as promising non-surgical options for mitigating healthcare disparities in osteoarthritis outcomes. My Science-Technology-Society (STS) research analyzes the underlying causes of TKR access barriers and how knee braces can avoid them. My technical research evaluates the clinical efficacy of a novel type of knee brace, known as a distraction-unloader brace, for osteoarthritis patients.

My technical research had 3 main objectives: (1) launch a clinical trial to assess the distraction-unloader brace's efficacy, (2) optimize its behavioral design and ease of use, and (3) build a biomechanical leg model to measure how different brace designs impact force distribution in the knee. We collaborated with Icarus Medical, the University of Virginia (UVA) Health Prosthetics & Orthotics Department, the UVA Department of Orthopedic Surgery, and the Virginia Commonwealth University (VCU) Department of Physical Therapy to establish a 6-week single-arm trial for patients with medial compartment knee osteoarthritis wearing distraction-unloader braces. The trial will assess patient-reported outcomes, such as quality of

life and brace satisfaction, and objective measures like knee joint-space width via ultrasound imaging and gait analysis. Additionally, we designed a new clip-strap system that reduced the number of clips users needed to manage, improving ease of use but slightly limiting range of motion. Lastly, we developed a basic biomechanical leg model to measure vertical loads across the medial and lateral knee compartments for testing brace designs. By enhancing the design and testing of distraction-unloader braces, our work aims to expand more accessible and effective non-surgical treatment pathways for knee osteoarthritis.

My STS paper applied the STS theory of user configuration—which emphasizes how a designer's assumptions about the users influence the resulting technology—to juxtapose the design of surgical TKR technology with that of knee braces. I analyzed the faulty assumptions behind TKR surgery that have contributed to its access barriers and explored how knee braces can avoid these barriers to help bridge osteoarthritis disparities. Additionally, I applied user configuration to outline several current limitations in the knee brace design process. I concluded with recommendations for engineers and clinicians on optimizing the research and development process of knee braces, which include: (1) standardizing brace design guidelines, (2) conducting more high-quality, long-term clinical trials, (3) clearly explaining and testing the rationale behind different brace designs, and (4) prioritizing patient satisfaction and ease of use during clinical studies. These enhancements will make knee braces more effective and appealing for both patients and providers, allowing them to better address the healthcare disparities that TKR alone cannot.

While my technical research successfully established a short-term, single-arm clinical trial, developing a longer-term, randomized-controlled clinical trial was challenging due to a limited patient population and the absence of a suitable standard-of-care brace that could serve as

a control. We also piloted a basic biomechanical leg model; however, further work is needed to refine the artificial leg model and test additional brace designs. On the social side, future work should establish better communication methods between knee brace designers—which include the engineers and clinicians—to streamline brace development and clinical trials. We should also identify the most effective methods for incorporating subjective patient feedback through the design and testing process. As user configuration theory emphasizes, keeping designers closely connected to users reduces harmful assumptions and improves satisfaction.

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