Designing an Accessible and Inclusive Simulator for Distal Radius Fracture Reduction

Understanding the Disparities Caused by Medical Technology

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By
Natalie Bretton

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Technical Team Members: Brian Garmer, Ethan Norris, Greer Matthias, John Murphy, Katya Napolitano, Lauren Elliff, & Ryan Deloach

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.

ADVISORS

Rider Foley, Department of Engineering and Society

Michael Momot, Department of Mechanical and Aerospace Engineering

Jason Forman, UVA Center for Applied Biomechanics

Dr. Aaron Freilich, MD, Department of Orthopaedic Surgery

Introduction

Distal radius fracture (DRF) accounts for one-sixth of all emergency department visits and is the most common long-bone fracture in the United States (MacIntyre & Dewan, 2016). DRF is seen across all age groups, with recreational and athletic activities being a major cause of fracture in younger demographics and falls causing many fractures in the elderly population, especially those with osteoporosis. This type of fracture occurs when the long bone on the thumb side of the forearm breaks close to the wrist. One of the most common distal radius fractures is the Colles fracture, shown in Figure 1, where the broken radius fragment tilts upwards and often requires reduction to correct its positioning (American Academy of Orthopaedic Surgeons, 2022).

Figure 1. X-ray of a Pediatric Distal Radius Fracture. This image shows an example of a Colles Fracture. Figure source: (Pediatric Imaging, 2021)

Currently, many medical students get their first hands-on experience manually setting a wrist fracture by performing the procedure on an injured patient under guidance from an experienced doctor. Although a few DRF reduction simulation devices are on the market, the more realistic models range from $800 to $2700 (GTSimulators, 2024; Limbs & Things, 2024). Additionally, some of the more popular devices are designed after a 6’2 male (GTSimulators, 2024), which is not representative of the general population that experiences DRF. This can be described by the principle of in-group favoritism, which exists in the STEM field (Friedmann & Efrat-Treister, 2023). In-group favoritism is defined as the tendency to favor members of one's own group over members of another. When men are the main subset of the population designing products, these products will likely have the best interests of men in mind (Friedmann & Efrat-Treister, 2023). Furthermore, because the design industry is male-dominated, everything from medication safety, to seatbelt design, and even the temperature of office spaces are biased towards men (Ely, 2016). Not only should DRF reduction simulation devices represent both men and women of various builds, but the thickness of the outer flesh should also be flexible, a feature that is not currently available. The Children’s Hospital of Philadelphia conducted a study to determine if high BMI increases the risk of loss of reduction (LOR), which occurs when the set fracture returns to its displaced location. Subjects underwent manual reduction for DRFs and a positive association between obesity and LOR was found (DeFrancesco et al., 2018). This emphasizes the importance of ensuring the simulator accounts for different body types, as some patients might be at more risk for complications.

Because DRF is a common injury experienced across all age groups, body types, and demographics, it is integral that medical students have access to the most inclusive training methods possible, not just expensive models based on the 95th percentile male. This report will focus on the design of an affordable and representative distal radius fracture reduction device, while exploring the ways that medical technology can perpetuate disparity, to ensure an inclusive product.

Designing a DRF Reduction Simulator

Due to the anatomy of the forearm, several forces act on the distal radius fragment and cause it to displace (Lieber et al., 1992). Extensor and flexor tendons are largely responsible for exerting a pulling force along the bottom and top of the forearm. In addition, the brachioradialis is a muscle used to flex the forearm that connects directly to the distal radius fragment, pulling the fragment towards the thumb side of the hand (shown in Figure 2). Because of the many different forces affecting the positioning of the bone, the reduction process involves a precise, practiced motion (A. Freilich, personal communication, September 16, 2024). It is known that simulation-based mastery learning (SBML) in medical education consistently improves clinical skills across many medical contexts, especially for complex procedures. One study on lumbar puncture SBML conducted pre and post-simulation skill tests where average scores went from ~ 40% to greater than 85% after just 3 hours with the SBML (McGaghie et al., 2014). Creating an inclusive DRF reduction simulator has the potential to be similarly beneficial.

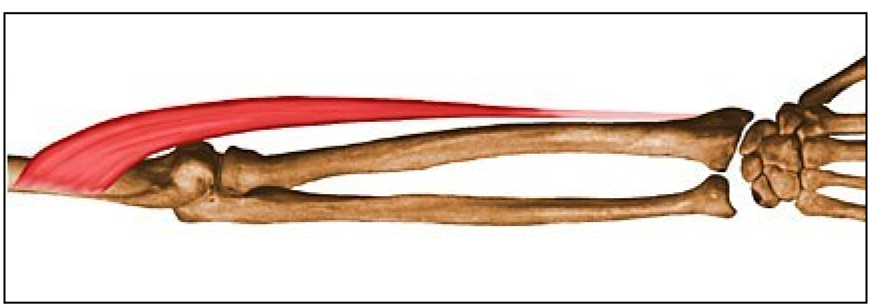

Figure 2. Brachioradialis Muscle. This diagram shows the direct connection of the brachioradialis to the distal radius. Figure source: (Medbullets Team, 2018)

This project aims to design an accessible and inclusive simulator that accurately replicates the physical feel of a fractured wrist for a diverse group of patients. Students must be able to practice a DRF manual reduction on the simulator and set the arm with similar motions and forces to a real DRF. Additionally, the force necessary to reduce the model must be adjustable such that it can model an accurate muscle force for patients of varying builds. Moreover, the thickness of the skin should be made flexible to account for patients of different body types. Lastly, the design must be distributable in a manner that would cost someone less than $150 to replicate and can be done using a 3D printer and materials that are available to the public.

When it comes to manufacturing the model, the bones will be 3D printed and will remain scalable to different dimensions (Seeley et al., 2017). Computer-aided design (CAD) files that represent an anatomically correct radius and ulna will be retrieved from an open-source website (HandOT, 2016). The proximal end of the radius and ulna will be removed and small holes will be added to the bones so that pins can be used to attach elastics (representing tendons and muscles). For the final version, wingnuts will be added to adjust the tension in the elastics and control how much force is needed to perform the reduction. The flat end of the bones will be attached to a base representing the elbow, and the distal end will be attached to a hand block so the user has something to hold and manipulate (shown in Figure 3).

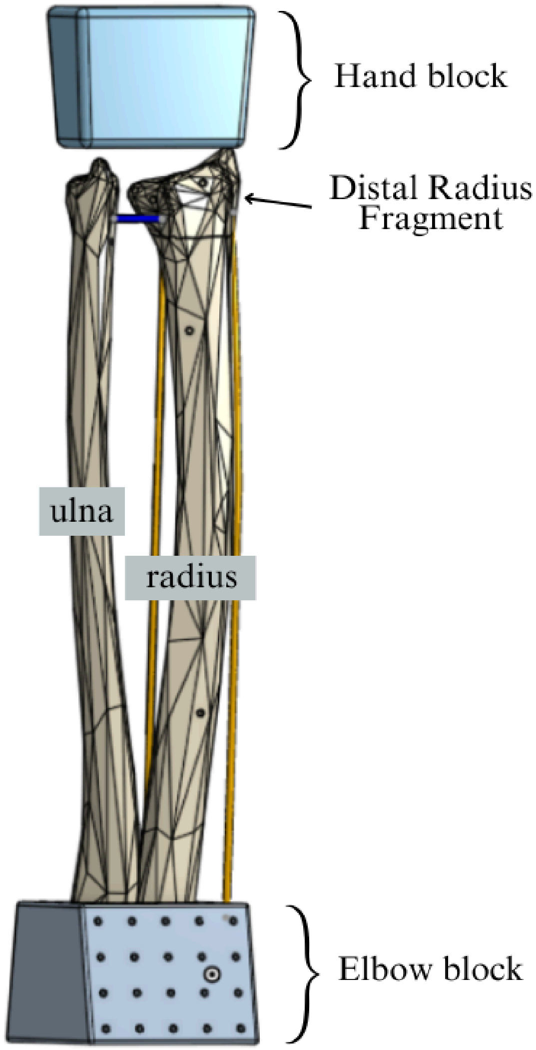

Figure 3. A simplified version of the reduction model (top-down view of left hand) to help with visualization. In the final version, the hand block will have the anatomy of the lower wrist and will be semi-elastically attached to the bones.

The flesh will be developed by making a negative mold of a hand of any chosen size (to include many body types), inserting a 3D printed contour of the bone model, and then casting a hollow sleeve of silicone flesh inside (Powell et al., 2019). By developing a model that has variable flesh thickness, bone size, and reduction force, the social issue of uninclusive DRF reduction devices is being addressed and an attempt is being made to design a medical technology for all patients.

The Social Implications of a DRF Reduction Simulator

John Ikerd (2022) argues that while technology itself is not good or bad, its net effects on society will be one or the other, and this outcome is determined by the attention or inattention involved in its development. This ideology can be observed across many different technologies. For example, seat belts and cars were designed with the 50th percentile male in mind, and consequently, women have 73% higher odds of serious injury in motor vehicle crashes (Brumbelow & Jermakian, 2022). This does not mean that seatbelts are entirely bad, however, it does mean that they actively perpetuate gender inequality. Injustice stemming from technology is not only present in the automotive industry but also has a huge impact on the medical field. One article claims that the medical field has been designed by men and for men and, as a result, "the male body has been treated as the biological default" (Bartlett, 2024).

Gender disparity is not the only type of inequality that medical technology has perpetuated. One example of racial bias in medical technology is oximeters and spirometers. Pulse oximeters miss hypoxia three times more often in black patients compared to white patients, and spirometers have historically underdiagnosed lung issues in black patients as they were initially calibrated on only white patients (Liao & Carbonell, 2023). While it is obvious that current DRF models demonstrate gender bias in being based on 6'2 male anthropometry, racial bias appears to be less evident. Nevertheless, almost all of the models on the market have silicone flesh that is a light tan color. Many might find this issue unimportant, however, it shows that it is not just men that are the biological default, but white men. Not too long ago

Merriam-Webster's definition of the word "nude" was defined as having the color of a white person's skin. It was argued that this was inherent racial bias as the word nude is a state of being and not a specific skin tone. Instances like these can be referred to as microaggressions and can be psychologically damaging to those who are ostracized (Miller, 2015)**.**

To account for the ways that the DRF reduction simulator might inadvertently cause bias, Pinch and Bjiker's Social Construction of Technology (SCOT) framework will be utilized. SCOT argues that technological progress occurs based on the competing needs and desires of various stakeholders (Pinch & Bijker, 1984). SCOT emphasizes that as technology is developed, various social groups assign different meanings to an artifact, a concept called interpretive flexibility (Pinch & Bijker, 1984). Since varying social groups see technology differently and have their own set of specific needs, SCOT can help bring to light a variety of necessary design requirements. For example, since the bones will be 3D printed they can be scaled up or down to represent people of various sizes and the infill can be adjusted to simulate various bone densities. Additionally, the users will be able to mold an outer flesh sized specifically for their needs, and one of the goals is to find and recommend a material that is clear or another inclusive color. Furthermore, SCOT explains that design is an iterative process in which stakeholders might have problems with a technology that need to be considered, and understanding this ensures an open-minded, flexible design strategy. Lastly, Pinch & Bijker (1984) mention that closure can be achieved when a given technology addresses the problems that various stakeholders have with it. The ultimate goal of this project is for the DRF device to achieve closure by addressing the needs of not just the 6'2 white male, but of groups like racial minorities, women, children, obese patients, and the elderly.

Research Question and Methods

To understand how to avoid creating a DRF reduction device that has negative social effects, the following research question will be considered: How can medical technology perpetuate disparity? As previously evidenced by the case study on oximeters and spirometers, medical technology is not always designed in a manner that benefits all of its users equally. To understand how to design equitable technology, several case studies of medical technologies perpetuating specific disparities (eg. gender, race, socioeconomic status, or age) will be presented. The stakeholders of these technologies and their specific needs will be considered under the SCOT framework, and the disparity, its contributing factors, and its effect on society will be identified. For example, one case that could be used to represent racial disparity was the previously mentioned pulse oximeter study. A major contributing factor to this disparity would be the lack of African American representation on medical design teams. Hence, the effect on society is that it reinforces a white-centric perspective, and leads to biased diagnosis techniques and healthcare. Moreover, race is a social construct, and the way race is typically construed as binary is flawed (Edmonds, 2018). If oximeters were designed to consider that the amount of melanin someone has in their skin is a continuous spectrum, systemic oximeter underdiagnosis might not exist. Choosing a handful of case studies to represent different categories of disparities can help identify how medical technology can contribute to inequality. Furthermore, the SCOT framework can help identify what problems different stakeholders have with a technological artifact and how their various needs could be addressed in future technologies.

Conclusion

Current models for distal radius fracture reduction are expensive and uninclusive of the diverse population that experiences DRF. To address this, an affordable, inclusive model is being developed that allows users to design and 3D print a model that fits their needs. This model can be made in many different sizes, has elastic that controls the required force for reduction, has life-like flesh of variable thickness to create a realistic experience, and is an inclusive color. These are all major improvements that will help the DRF device be more representative of patients and allow students to practice a complex procedure. However, to help ensure this medical technology does not inadvertently perpetuate inequality, the SCOT framework will be used to study disparities caused by previous medical technologies. By being more aware of past technological flaws and the present needs of society, the proposed model can be more inclusive of all patients.

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