REAL-TIME BONE STRENGTH MEASUREMENT DEVICE DURING SURGERY

ANALYSIS OF THE FAILURE OF GOOGLE GLASS IN HEALTHCARE

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By
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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 average person in the United States will fracture approximately two bones over their lifetime (Sequin, 2019). In particular, ankle fractures account for 9% of all fractures, with 25% requiring surgical intervention through open reduction and internal fixation (ORIF) procedures (Court-Brown & Caesar, 2006; Vanderkarr et al., 2022). However, 36% of ORIF surgeries result in complications, and nearly 22% require additional surgical procedures, significantly increasing postoperative morbidity and healthcare costs (Macera et al., 2018). Therefore, it is critical that orthopedic surgeons have the information necessary to make the best possible decisions.

To address this need, I propose, in collaboration with Dr. Joseph Park, a device that measures localized bone strength while drilling pilot holes. My team and I will design and develop an attachment to an orthopedic surgical drill capable of delivering precise, real-time bone strength measurements. By providing surgeons with valuable insights into local bone characteristics, this device aims to enhance the decision-making and improve surgical outcomes.

Developing such a device is only part of the solution. Historical failures of healthcare technologies, such as Google Glass in clinical settings, demonstrate that novel technologies alone do not guarantee adoption or efficacy, especially in the healthcare industry. I will draw on the science, technology, and society (STS) concept of actor-network theory to investigate how the relationships among diverse elements, rather than the sum of isolated components, led to the demise of Google Glass, specifically in the medical field. If similar technical, social, and institutional factors are not addressed in the development of the proposed device, it risks perpetuating key components that contributed to the failure of Google Glass and the resulting inefficiencies during surgery. Because the challenge of orthopedic surgery is sociotechnical in nature, it requires attending to both its technical and social aspects to accomplish successfully. In what follows, I set out two related research proposals: a technical project proposal for developing a device to estimate bone strength in real-time and an STS project proposal that utilizes actor-network theory to examine the associations between technical and social factors that contributed to Google Glass' demise.

Technical Project Proposal

One of the largest challenges in modern orthopedic surgery is the variability in bone quality, which often significantly impacts surgical outcomes. Doctors, especially when operating on elderly patients with osteoporosis, often face uncertainty about the strength of the bone they are working with. Poor bone quality increases the risk of complications, such as hardware failure and improper healing. Fixation failure occurs when an implant, such as screws, plates, or rods used to stabilize bones, is unable to maintain the proper positioning or alignment. This risk arises from the dependence of screw fixation strength on the underlying bone quality and strength (von Rüden, 2016). With quantitative data, surgeons could better determine the strongest spot of the bone and length of the screw that would be optimal for that specific patient. Furthermore, accurate knowledge of local bone strength could help surgeons make more informed decisions regarding post-operative care. To address this gap, it is critical to develop tools that provide surgeons with accurate, real-time information regarding bone strength to inform their decisions and improve patient outcomes.

Bone strength is primarily estimated using its density, which is currently determined using a process called densitometry. This is found by determining the bone mineral density (BMD), which is the average concentration of minerals per unit area. The amount of X-ray energy that the calcium in the bone absorbs reflects the bone mineral content. This value divided by the volume of the bone estimates BMD, and there is a high correlation between BMP and the strength of a bone. Currently, all techniques for estimating bone density are external through the use of X-ray. The most widely used method is dual energy X-ray absorptiometry (DEXA), but other methods include single energy X-ray absorptiometry (SXA), quantitative computed tomography (QCT), and radiographic absorptiometry (Fogelman & Blake, 2000). Furthermore, all these techniques only give an estimate of the average bone density in a region, not the precise local values that would be beneficial.

Presently, densitometry is primarily used to predict the risk of future fracture. A device that gives accurate real-time readings of local bone strength and toughness would help doctors and surgeons make better informed decisions regarding the type of fixation method to use during the operation itself. However, BMD is not currently widely used during surgery as a way to assess the strength of the cartilage. Instead, doctors draw on their experience and expertise to determine the best way to approach a fracture. This can result in plates and screws of incorrect sizes, pitches, and depths being used that often leads to the damage not healing as intended.

The goal of the technical project is to determine a relationship between torque and bone strength and apply that finding in real-time, allowing surgeons to make better informed decisions regarding fixation methods. There are two major tasks the team will undertake in this process. Our first task is to test a wide range of materials with varying densities to find a relationship between the torque applied to drill into a material and the strength of that material. The student team will accomplish this by obtaining a variety of materials with known physical properties including density. We will calculate the density using traditional methods such as dividing measured mass by the computed volume. Then, the team will determine the maximum torque through the use of a digital torque wrench. After gathering the data, we will quantify the correlation between the torque and density through a regression analysis.

Our next task is to design an attachment to existing surgical drills that can measure the torque and convert it to strength in real-time. Although existing off-the-shelf rotary torque sensors exist, they lack the necessary capabilities and exceeded our budget. As a result, the team is developing a custom built torque load cell that will connect to a standard handheld drill chuck. We will accomplish this by utilizing four resistance strain gauges oriented in a Wheatstone Bridge Circuit, a slip ring to allow for rotary motion, a load cell internal structure that we will fabricate out of aluminum, and a data acquisition system that will allow all the elements to interact with each other to output the result in real-time. The wires from the strain gauges will feed through the slip ring, which will prevent them from tangling while the drill is in use. The slip ring will sit atop and attach securely to the torque load cell at the end nearest the drill bit. Additionally, we will place load cells on the drill handle to account for the axial force contribution to the overall torque. This prototype will serve as a proof of concept that the torque applied via a handheld cordless drill can serve as an indicator for bone strength. An effective design will transmit the measured torque to a computer in the operating room and convert it to bone strength in real-time.

STS Project Proposal

Every year, countless new technologies are adapted with the intention of improving lives. In 2022, the United States spent $885.6 billion on research and development to create new products, services, and technologies, with a significant portion dedicated to advancements in the medical industry (Moris & Rhodes, 2024). One of the more recent technological developments that has begun to make its way into the operating room is augmented reality (AR), which overlays computer-generated graphics on top of the real world to provide useful information. Google Glass, which was introduced in 2013, was the first major attempt to integrate AR into surgery, offering hands-free access to important information and the ability to share perspectives with others via its built-in cameras.

Initially hailed as a revolutionary device poised to transform human interaction with the world, Google Glass had its fair share of difficulties, and its initial Explorer consumer version of the product was halted in January of 2015 less than two years after its launch (Luckerson, 2015). Then Google brought the device back in 2017 for businesses as the Enterprise Edition only for it to be discontinued in early 2023 (Axon, 2023). Current discussion surrounding Google Glass attributes its premature demise to a variety of factors: privacy concerns in public, a bulky and uncomfortable design, lack of practical applications, and a society that was not yet open to the idea of wearing a computer on its face (Bilton, 2015). In clinical settings, additional challenges such as ergonomic issues, privacy and security concerns, and resistance from healthcare providers compounded its difficulties (Price, 2023).

While these factors are relevant, they fail to fully explain why Google Glass struggled in the healthcare industry when it showed initial promise there. At first glance, Glass was a much larger success in industries such as healthcare and manufacturing without some of the societal constrictions of the general public. However, a closer examination of the broader surroundings reveals the importance of relationships between social and technical factors. Previous writers have overlooked the importance of these associations and treated components as isolated elements with no influence on each other. This perspective fails to consider the complex relationship between healthcare professionals, regulatory bodies, patients, the general public, and the technology itself, which ultimately contributed to its collapse.

By examining these interactions in depth, one can better understand the reasons why Google Glass failed in the medical industry. I contend that this demise stemmed from a combination of technical constraints, ethical concerns, inadequate ergonomics, and poor support from healthcare providers. More specifically, the physical discomfort of wearing the device, privacy concerns, and difficulties in integrating it into existing medical workflows and training procedures created significant barriers to widespread adoption. When considered in conjunction with larger monetary pressures across industry, these factors contributed to resistance from healthcare professionals and ultimately prevented Google Glass from becoming a common tool in the clinical setting.

To frame my analysis, I will draw on the STS concept of actor-network theory (ANT) developed by STS scholars Michel Callon, Bruno Latour, and John Law. ANT claims that everything can be viewed as a diverse technological network composed of both human and non-human actors associated together by a network builder to accomplish a goal (Cressman, 2009). In addition, I will apply Michel Callon's sub-concept of translation, which describes the process of forming and maintaining an actor network, to examine the roles that key human and non-human actors played in the failure of Glass (Callon, 1986). To support my argument, I will analyze evidence from news articles, scientific journals, anecdotes from healthcare providers, interviews, and hands-on videos which provide information about the rise and fall of Google Glass.

Conclusion

Two related research proposals were presented in this prospectus. The first was a technical project proposal focused on developing a device to measure bone strength in real-time with the goal of improving surgical outcomes by providing surgeons with critical data during procedures. Next, an STS project proposal was introduced exploring the relationships between the factors that led to the failure of Google Glass in healthcare. I will utilize the STS framework of actor-network theory to examine the interaction between social, environmental, and conceptual actors as well as how they relate to technical actors in engineering networks.

Taken together with the specific case of Google Glass in the healthcare industry, ANT provides a constructive framework for analyzing the complex relationships among diverse components of a network while designing the proposed technical device. Insights from the STS project will directly inform the development of the technical device by emphasizing the importance of integrating technical innovations with their surrounding networks. By addressing these sociotechnical interactions early in development, the technical project can reduce potential barriers to adoption and ensure the device's effectiveness and acceptance in clinical settings. Ultimately, considering both the technical and social dimensions will enable these projects to provide doctors with the information necessary to make better informed decisions, ultimately improving the quality of care provided for patients.

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