A Patient-Specific Computational Model for Optimizing Surgical Planning to Treat Patellar Instability

Assessing Factors Attributing to Gender Disparity in Orthopedic Surgery

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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

Orthopedic surgery is the medical discipline concerned with musculoskeletal deterioration and disorder; this includes, bones, joints, ligaments, tendons, muscles, and nerves, all the components which keep the body moving. Surgery branches into specific subspecialties, such as sports medicine or distal extremities, but all require a rigorous education, typically including four years of undergraduate school, four years of medical school, five years of orthopedic residency, and one or more years in a specialized fellowship ("Orthopaedics - Orthopaedic Surgeons - OrthoInfo - AAOS," 2022). Despite the extensive history of orthopedic surgery as a surgical discipline, time and evolution of the specialty has failed to fix a flaw of the system. Currently, the number of female medical candidates and residency applicants has surpassed that of men; the 2019-2020 application cycle was made up of 53.5 % women and the percentage of matriculating students was 53.7% women (Murphy, 2021). However, orthopedic surgery continues to have the lowest percentage of female residents and physicians (Larson, 2021). As females age, and specifically during menopause, they produce decreased levels of regulatory estrogen. This causes declined bone mineral density, bone loss, and a higher risk of fracture and osteoporosis (Cauley, 2015). This leads to the question, if women have higher rates of orthopedic intervention and thus presumably higher interest in orthopedic conditions, what has prevented their inclusion in orthopedic surgery?

The problem with low inclusion rates of women in orthopedic surgery is the same as is with any medical discipline; it blocks out an important perspective during treatment and research and lowers the ability of the field to create innovative and inclusive designs. Results from a collection of research studies which related diversity to financial and quality outcome, showed that more diverse teams led to patients faring better, improvements to innovation due to

improved communication and risk assessment, and increased financial performance (Gomez & Bernet, 2019). Another study showed that sex-specific outcomes are significantly more likely to be reported in journal articles if a woman is the first or last author (Stumpff, Hadley, Corn, & Templeton, 2021). Performing sex-specific reporting is important to identifying differences in prevalence, risk factors, and presentation of orthopedic disorders. The two aforementioned studies only scratch the surface of problems with a lack of gender diversity in medicine; if the female outlook is not present when addressing patient concerns and issues, it lowers the emphasis on sex differences, decreases innovation, and limits personalized patient care.

My technical portion will focus on an innovative solution to address subjectivity for patellar instability surgical planning. This condition is a musculoskeletal disorder in the knee with high reoccurrence rates. It is one of the many orthopedic cases which could have improved treatment if women had a larger role in the surgical discipline and diversity of perspectives was increased. In today's healthcare system, there is a positive feedback cycle in orthopedics which continues to limit the incentives and opportunities for women to join. The lower financial incentives to female orthopedic surgeons in research and consulting payments ("A Check-Up on Gender Disparities in the Field of Orthopedic Surgery," 2020), the lack of mentorship and implemented support systems (Walker & Hubbard, 1993), the unproportional sizing of surgical equipment made for male dimensions (Balch, 2022), and other extensive flaws to the system continue to drive men into influential positions while exiling women from this "boys club" (Ahmed & Hamilton, 2021). By discovering the most influential factors causing gender-based attrition from orthopedic surgery, the gender disparity can be corrected, and a new female perspective can create innovative designs for treatment of musculoskeletal disorders.

Design of a 3D Computational Model for Patellar Instability Surgical Planning

Patellar instability/subluxation is a musculoskeletal condition characterized by the recurrent dislocation and immediate relocation of the patella outside of the trochlear groove of the femur. The dislocation typically occurs in the lateral direction, but in rarer cases can present medially. Many factors can contribute to the disorder, some of which include genetic anatomical variations and torn stabilizing and dynamic ligaments. The injury most commonly presents in adolescent females and athletes, and has an overall incidence of 5 to 7 per 100,000, but an incidence in 10-17 year old populations as high as 29 per 100,000 (Hayat, Bitar, & Case, 2022; Thompson & Metcalfe, 2019). Treatment for the disorder depends on severity; cases of patellar instability will be initially treated with conservative methods such as physical therapy, icing, activity modification, or bracing. If there is evidence for surgical intervention, there are multiple routes which can be taken by the surgeon including muscular reconstruction and bony realignment. Some common surgical procedures are medial patellofemoral ligament repair, lateral release of the knee's lateral retinaculum, osteotomy of the tibial tubercle insertion site (TTO), and trochleoplasty (Hayat et al., 2022). Decision making for the surgical plan is highly subjective. Physicians obtain information from a patient MRI before surgery, but besides these measurements, the planning process is almost entirely reliant on the expertise and previous experience of the surgeon.

The subjectivity of patellar instability surgical planning leads to an incredibly high recurrence rate of 15-44% after the first dislocation, and at least 50% or greater after a second recurrence (Thompson & Metcalfe, 2019). Solutions to combat the subjectivity in surgical planning, such as a computerized tomography (CT) scan, include separate risks to the patient. The CT scan allows imaging on smaller plane angles, less than 30 degree knee flexion, allowing

physicians to find new abnormalities (Dupuy, Hangen, Zachazewski, Boland, & Palmer, 1997). This helps provide information to the acting surgeon, however, CT scans require patient exposure to radiation.

My team's solution to the problem is a 3D computational model of the patella and the forces acting upon it. The model will be created using patient specific data from Springbok Analytics technology to accurately depict the patient's anatomical proportions of the knee without exposing patients to radiation. This tool will be used in preoperative planning for patellar instability surgery to determine the direction and magnitude of the force vector acting on the patella. The model will also be able to compute the adjusted force vector with possible surgical options such as shifting the insertion point of the patella on the tibial tubercle, a Tibial Tubercle Osteotomy (TTO). Quantifying the forces on the patella will provide surgeons more information in surgical planning, reduce the subjectivity in planning, and hopefully, reduce the number of patellar instability reoccurrences post-treatment. This innovative solution to patellar instability is one example of advances in orthopedics which could be driven through inclusion of women and new perspectives to the field.

Assessing Factors Attributing to Gender Disparity in Orthopedic Surgery

Access to surgical careers for women is continuously growing. The proportion of female medical students in the United States started at 6% in 1970, and now female medical students outnumber males (de Costa, Chen-Xu, Bentounsi, & Vervoort, 2018). Despite larger numbers of female applicants and medical students, some surgical disciplines have failed at increasing the percentage of female physicians. Orthopedic surgery's female population has remained stagnant while others diversify. In fact, in the year 2018-2019, the percentage of female residents in

orthopedic surgery was a mere 15.4%, the smallest percentage of women within the ten largest surgical specialties by size of residency (Van Heest, 2020).

Increasing the amount of diversity in healthcare fields is needed to promote problem solving and innovation which considers multiple perspectives and fits the needs of a multi-faceted population. Increased diversity also helps to create a hospital atmosphere which is inclusive and supportive to all patients (Kennedy, 2019). Studies have shown tangible benefits to an increase in gender diversity, specifically for orthopedics. Increasing women in orthopedic academic surgery and research can help to increase sex-based reporting; studies show that articles with sex-specific data were more likely to have either a first or last female author (Stumpff et al., 2021). Sex-based reporting helps provide the most useful and specific information for patient diagnoses, treatment, and risk management. Increasing gender diversity would also benefit patient care emotionally. Patients often prefer to be treated be a physician of the same sex (Sobel, Cox, Ashinsky, Eberson, & Mulcahey, 2018). Women have higher rates of orthopedic surgical intervention but are referred to elective procedures and consent to elective procedures at lower rates then men (Sobel et al., 2018). It would be beneficial to increase the number of female orthopedic surgeons to better comfort and support patients, especially women.

The surgical discipline can be organized into a network of actors, both human and non-human, connected to each other through a series of relationships and connections; this is known as Actor Network Theory (Latour, 1992). Examples of actors include human actors such as surgeons, academic program directors, patients, orthopedic board members, academic professional organizations, and medical device companies, but also nonhuman actors like surgical tools, personal protective equipment, residency program selection criteria, salary, etc. I acknowledge that some of the nonhuman actors I plan to consider are intangible concepts, such

as salary and bias. These are not defined as nonhuman actors by Latour's theory. However, in order to include factors which may sway actors to behave in certain ways or alter relationships, I will expand Actor Network Theory to include them. After studying these actor relationships, I will be able to determine why women avoid or are left out of the orthopedic surgical discipline. I will also utilize Langdon Winner's argument, that artifacts can be inherently political or compatible with a political system, to inspect non-human actors for characteristics which impact accessibility and lower authority of women in orthopedics (Winner, 1980).

By analyzing the factors which contribute to a lack of gender diversity in orthopedic surgery, and addressing them with thoughtful and proactive solution, the surgical field can become a more inclusive and safe environment for all participants (Van Heest, 2020). This benefit would not be limited to just surgeons, but the residents, physician assistants, nurses, and patients with a role in the network.

Research Question and Methods

What characteristics of orthopedic surgery and residency divert women from joining? This question is important because the causes of gender disparity must be distinguished before any solutions can be made. The research method I will use is literature review and synthesis of existing research, interviews, and papers. The goal of the research will be to find the connections and overlapping features of various attrition factors. I will be looking for systematic, physical, and emotional causes for low rates of women in orthopedics. To review the healthcare system, I will analyze the marketing strategy for encouraging orthopedic program applicants, application and acceptance processes for residency, and the hierarchical structure of the healthcare organization's impact on career progression. Physical boundaries to orthopedics will include any

tangible constraint such as inappropriate sizing of materials and equipment, prevalence of injury or disorders from work in men and women, and orthopedic specific procedures which may impact the inclusion of women. Research on emotional causes will analyze how women perceive the field of orthopedic surgery, and in turn, how orthopedic surgery perceives them; examples include, stereotypes of orthopedic surgeons, harassment, misconceptions of strength, etc. Learning more about these human and nonhuman actors will allow me to find relationships which directly and indirectly impact gender diversity rates in orthopedic surgery. I will primarily look for research in the American healthcare system, as well as Canada. It was in 1970 that women started gaining ground in medicine, before then, women had never made up more than 6% of any medical school class in the United States or Canada (Wirtzfeld, 2009), therefore, my time frame will focus on the past fifty years.

Conclusion

The lack of women in orthopedic surgery is disadvantageous to patient care and limits the variety of perspectives working towards innovation in orthopedic disorder treatment and diagnosis; patellar instability is just one of many disorders which could benefit from increased gender diversity. By analyzing the factors deterring women from the specialty, hospitals and orthopedic surgical units can draft and implement policy which directly facilitates access for women. This will be the first step towards shutting down the positive feedback cycle which pushes existing powerful figures, men, into higher positions of authority. I expect that through literature review of existing research, I will be able to categorize the current barriers for female entry to orthopedics allowing for the causes for gender disparity to be identified in existing programs and addressed.

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