Personalized Healthcare Portfolio

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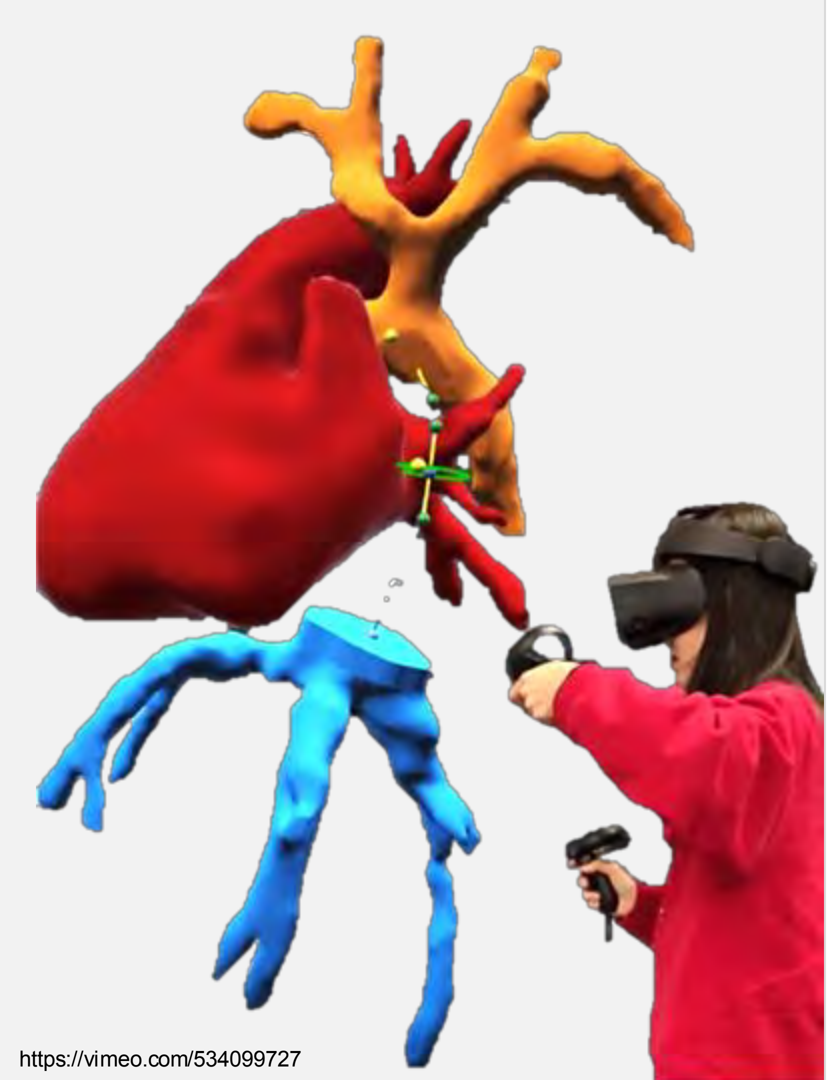
01

FIRST SECTION

Virtual / Augmented Reality



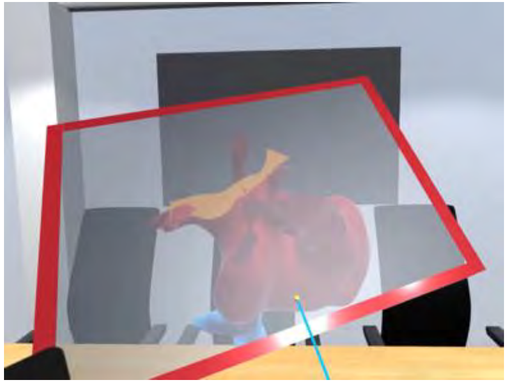
https://vimeo.com/534099727

1.1 VR Cardiac Surgical Planning System

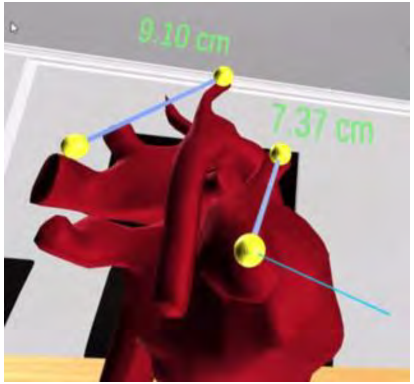
Cardiac surgeons have traditionally faced challenges in surgical planning, relying on imaging data and often improvising during surgery without precise details on conduit attachment points, size, and shape. The introduction of CorFix represents a significant breakthrough as the first VR-based system for cardiac surgical planning. This technology empowers surgeons to diagnose patients and create customized graft designs.

Through two rounds of usability testing, CorFix has proven superior to existing computer-aided design software like SolidWorks, especially in evaluations by trained engineers. The system's user-friendly interface adapts well to medical professionals, enabling them to efficiently design personalized cardiac grafts within minutes. This transformative technology improves precision in surgical planning and offers a streamlined approach for medical practitioners.

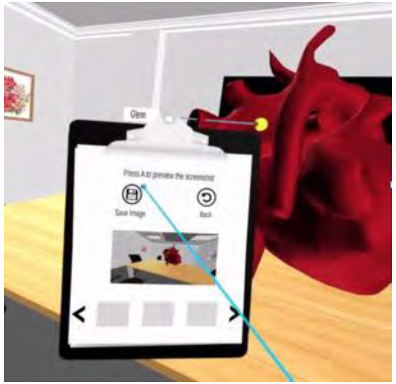
Diagnostics Feature



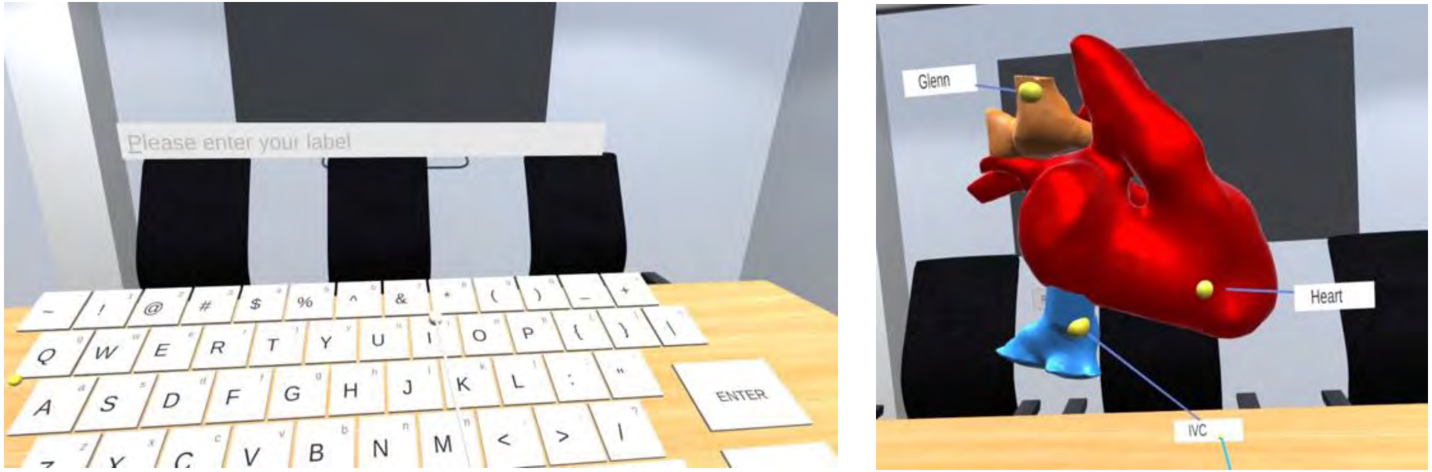
Clipping



Ruler

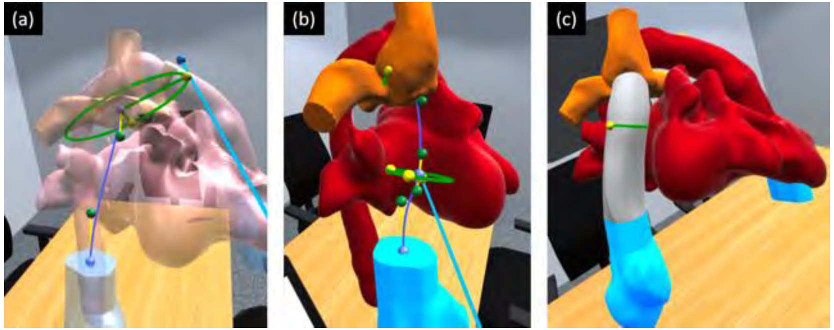


Screenshot



Labeling

Parametric Modeling Feature

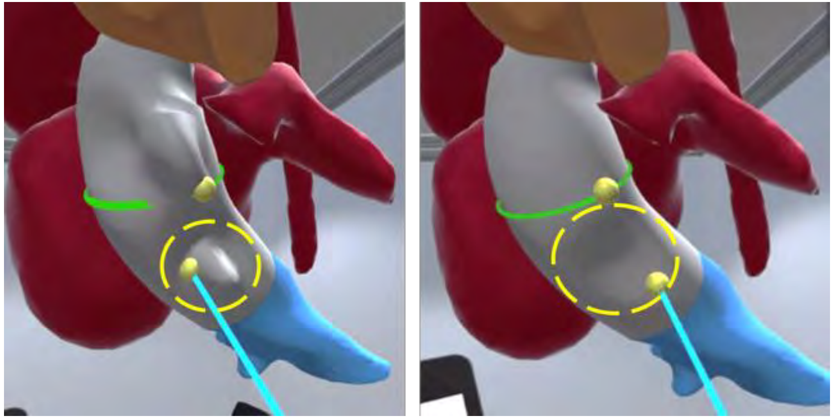


Design Saving/Export Feature

Virtual Design

3D Exported Design

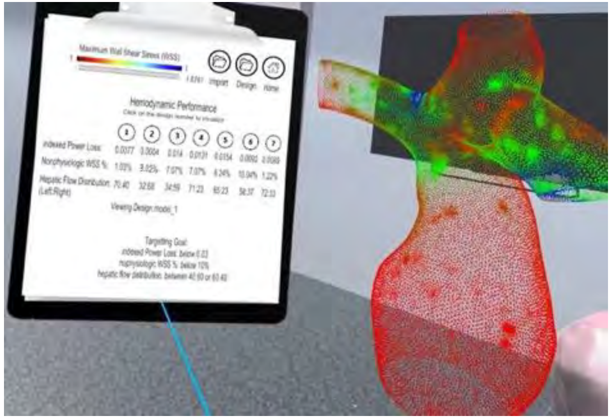
Freeform Modeling Feature



Push

Pull

Hemodynamic Visualization Feature

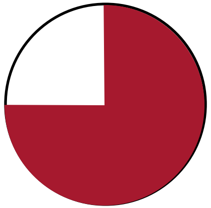


Wall Shear Stress, indexed Power Loss,
Hepatic Flow Distribution

USABILITY TESTING RESULTS

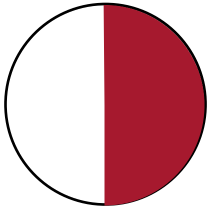
of engineers with CAD training using both CAD and our VR software for designing a cardiac graft

Failure Rate



75%

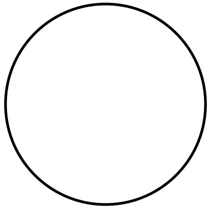
Design Time



30.27 MIN

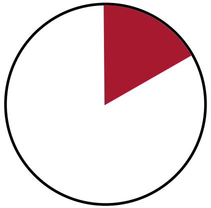
Computer Aid Design (CAD) Software

Failure Rate



0%

Design Time



8.98 MIN

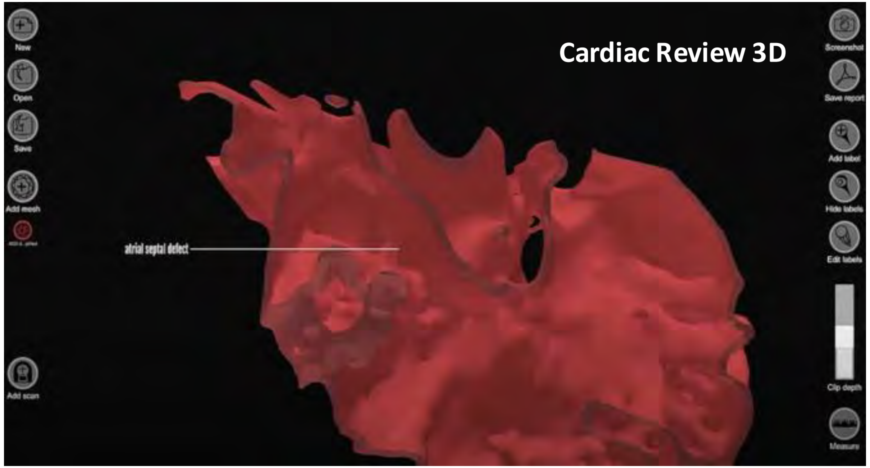
VR Design Software

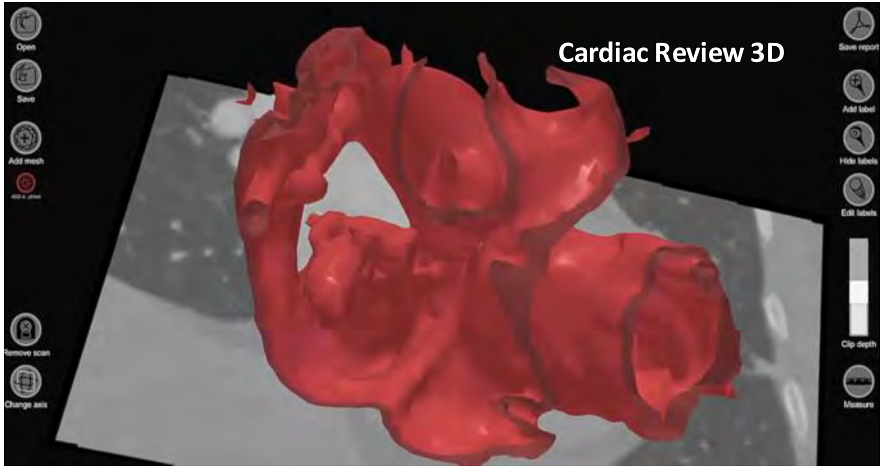
https://www.youtube.com/watch?v=9ESbXpOZIK8&ab_channel=Children%27sNationalHospital

1.2 VR Collaborative Diagnostic System

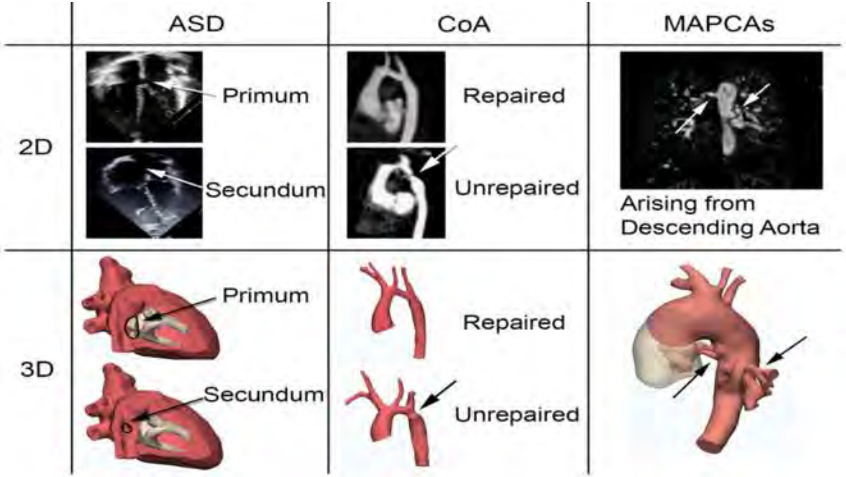
The complex 3D nature of congenital heart disease demands collaborative discussions among multidisciplinary teams, often centered around analyzing medical images such as magnetic resonance imaging (MRI). Currently, these discussions rely on 2D cross-sectional displays of 3D scans, requiring physicians to mentally reconstruct images into 3D anatomies for accurate diagnosis, staging, and treatment planning.

To tackle these challenges, a pioneering solution has emerged: Cardiac Review 3D. This innovative system marks the debut of a multi-user VR platform for cardiac diagnosis, allowing multiple doctors to view and interact with patient anatomy in real-time from remote locations. This advancement fills a crucial gap in current VR applications for medicine.

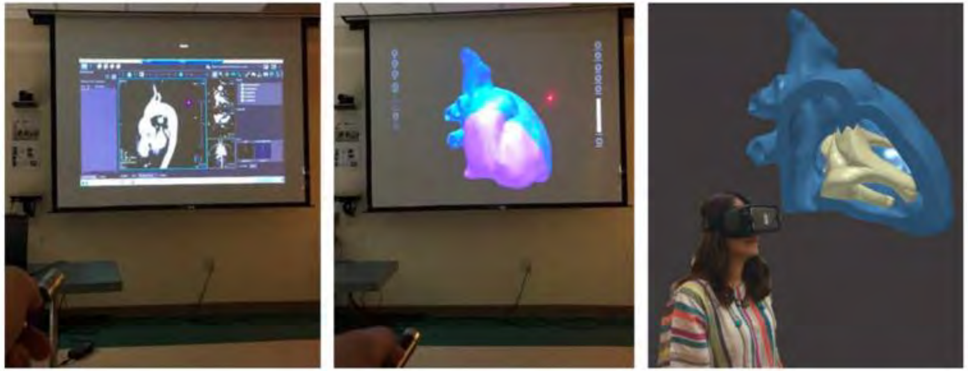




Medical cases provided in the usability testing



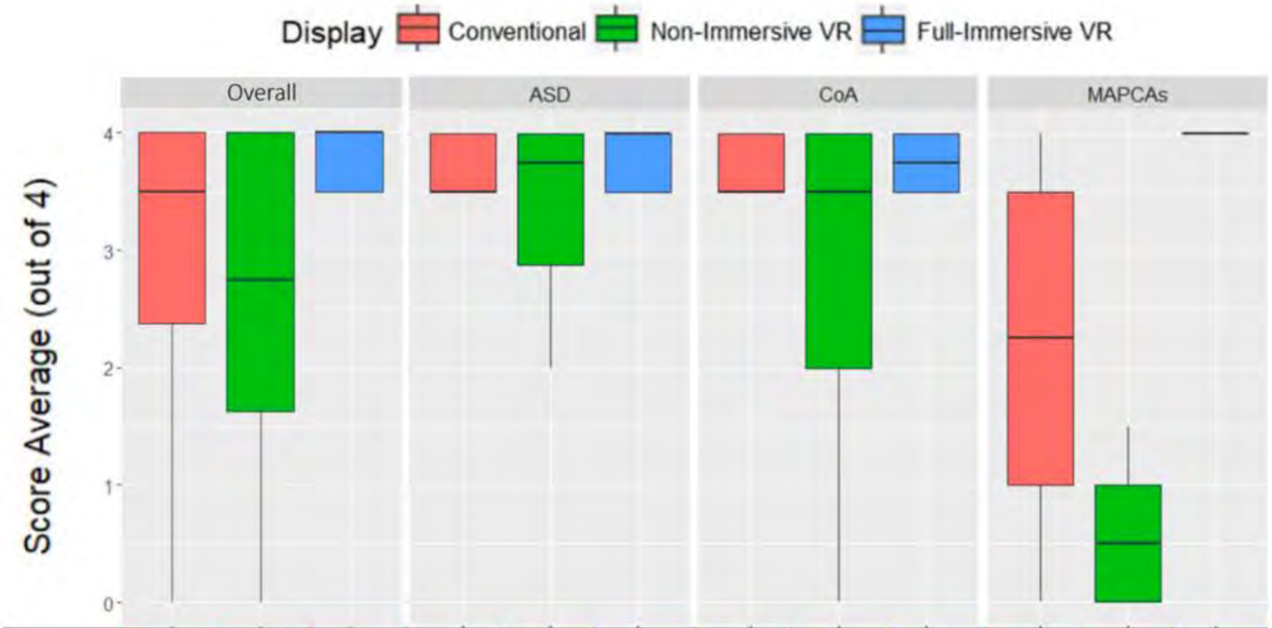
Display tools used in the usability testing



Conventional Display | **Non-Immersive VR Display** | **Immersive VR Display**

USABILITY TESTING RESULTS

Of medical residents utilizing various display tools for cardiac diagnosis

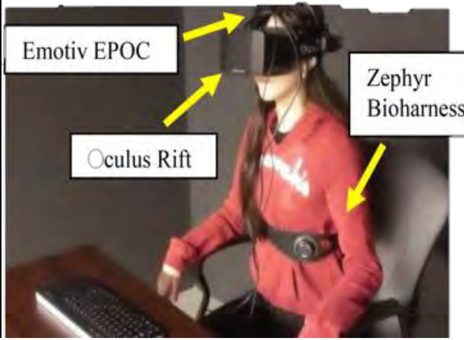


Scorer 1	2.86	2.45	3.59	3.40	3.25	3.33	3.33	2.78	3.50	2.00	0.60	3.89
Scorer 2	3.18	2.59	3.77	3.40	3.50	3.67	3.78	2.89	4.00	2.38	0.60	3.78
Mean	3.02	2.52	3.68	3.40	3.38	3.50	3.56	2.83	3.75	2.19	0.60	3.83

1.3 Personalized VR Therapy System

In our effort to address health disparities and improve addiction therapy effectiveness, our mobile behavioral VR system integrates personalization using machine learning. This advanced technology assesses the patient's real-time emotional state through neurophysiological data, delivering personalized content. By focusing on accessibility and customization challenges, our study aims to enhance long-term outcomes in outpatient behavioral therapies for individuals dealing with mental health and substance abuse issues.

Facial Expression Avatar Calibration



Assessing User Emotional State using Neurophysiological Data

1.4 VR Hospital Telemetry Environment

This project addresses concerns about telemetry monitoring stations in hospitals, specifically the connection between poorly designed stations and patient deaths due to operator errors. Telemetry technicians, responsible for continuous patient vital sign monitoring and timely responses to irregularities, are crucial in this context. To assess the impact of station design on technician performance, the project employs neurophysiological measurements in a VR environment. By replicating the working conditions of telemetry technicians at MedStar Washington Hospital Center in VR, including realistic chaotic visual and auditory information, the study provides an immersive evaluation without disrupting daily operations or putting patients at risk. This innovative approach offers insights into the relationship between station design and technician performance, contributing to the enhancement of healthcare systems.

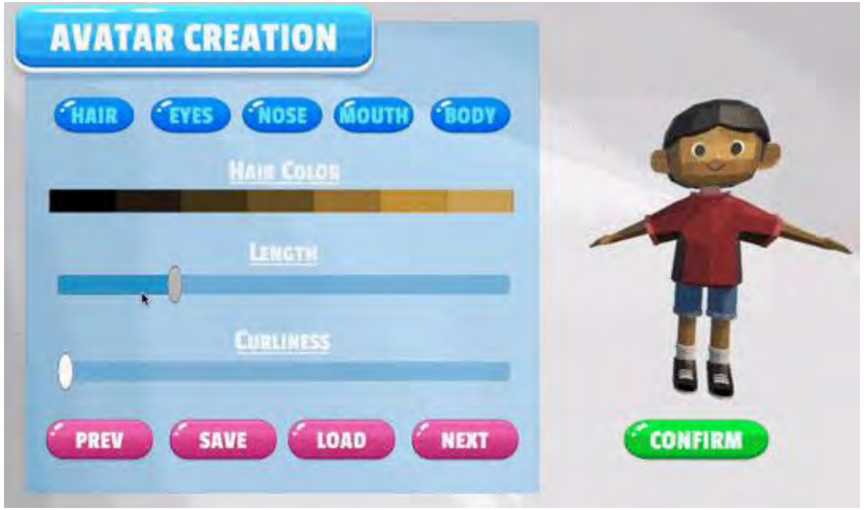
1.5 XR Exercise Games

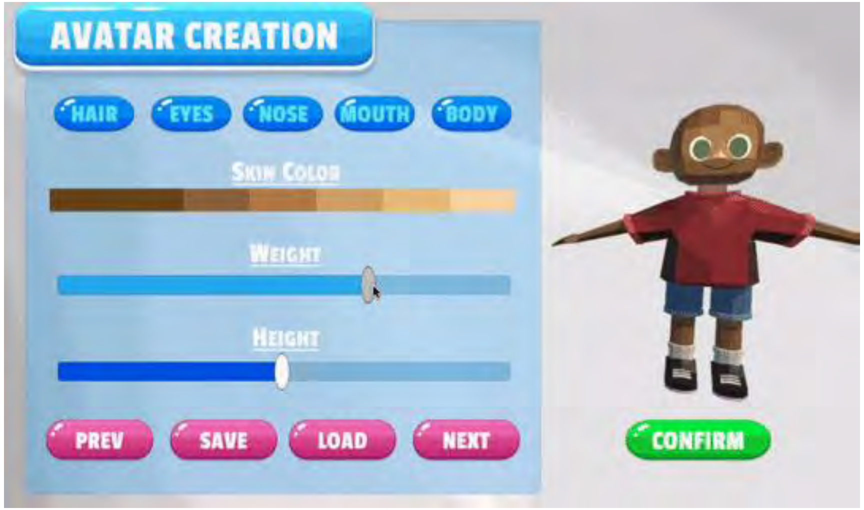
In response to the decline in senior health without regular exercise and challenges posed by aging or medical conditions, I'm leading the development of extended reality (XR) games tailored for individuals with physical constraints. These AI-driven games provide a personalized and enjoyable exercise experience, whether individually or with friends, both in-person and virtually.

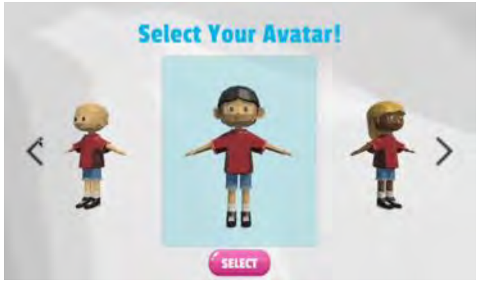
Our XR games seamlessly integrate with any webcam, using advanced machine learning for precise body tracking. This technology adapts control mechanisms to each user's physical capabilities, identifying optimal approaches to encourage seniors to enhance their physical condition through entertaining gameplay.

Currently, my team is developing a game inspired by Hole in the Wall and Beat Saber. Users engage in activities that improve dynamic visual acuity, mobility, balance, and flexibility. For example, players navigate spotlights, dodge music notes, and strategically avoid a moving wall with various hole shapes.

PERSONALIZED AVATARS

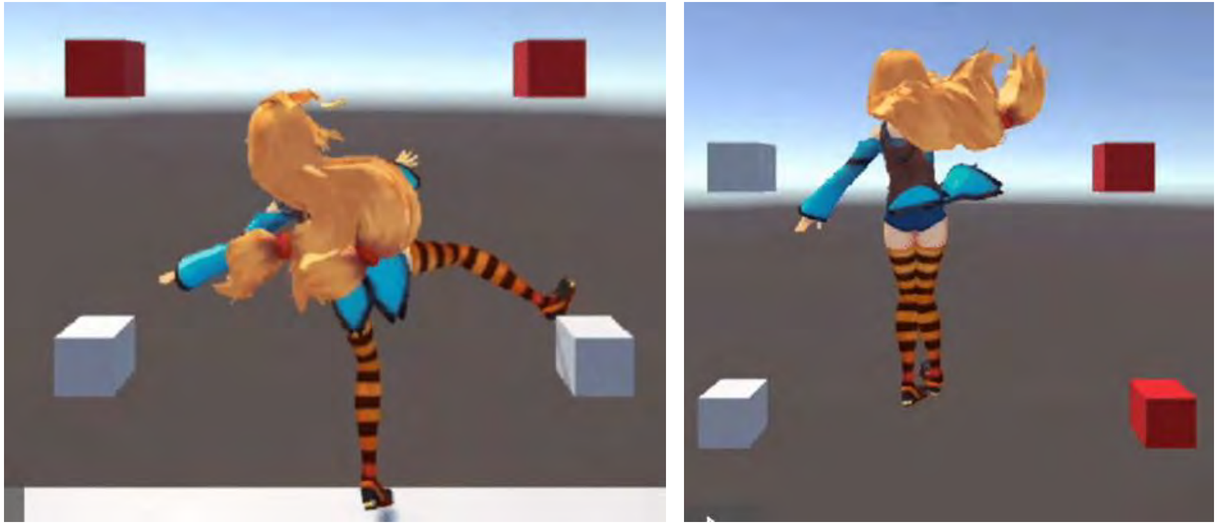






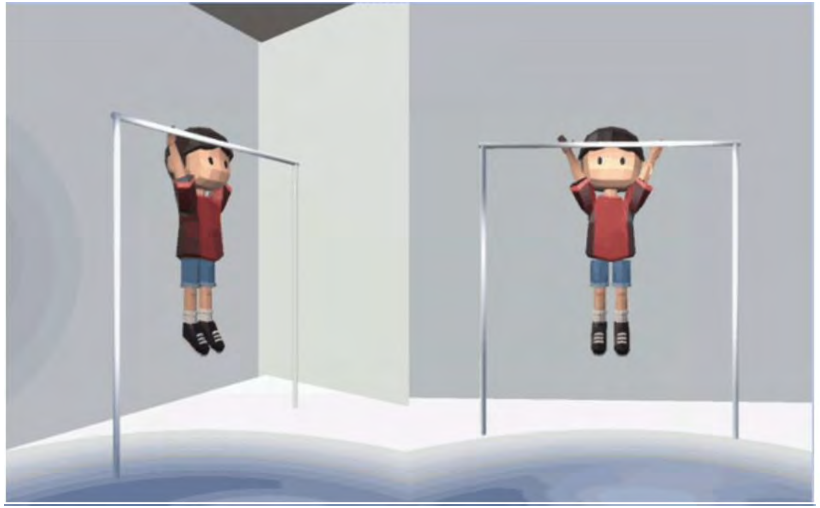
AVATAR CONTROL THROUGH BODY TRACKING

System Setup

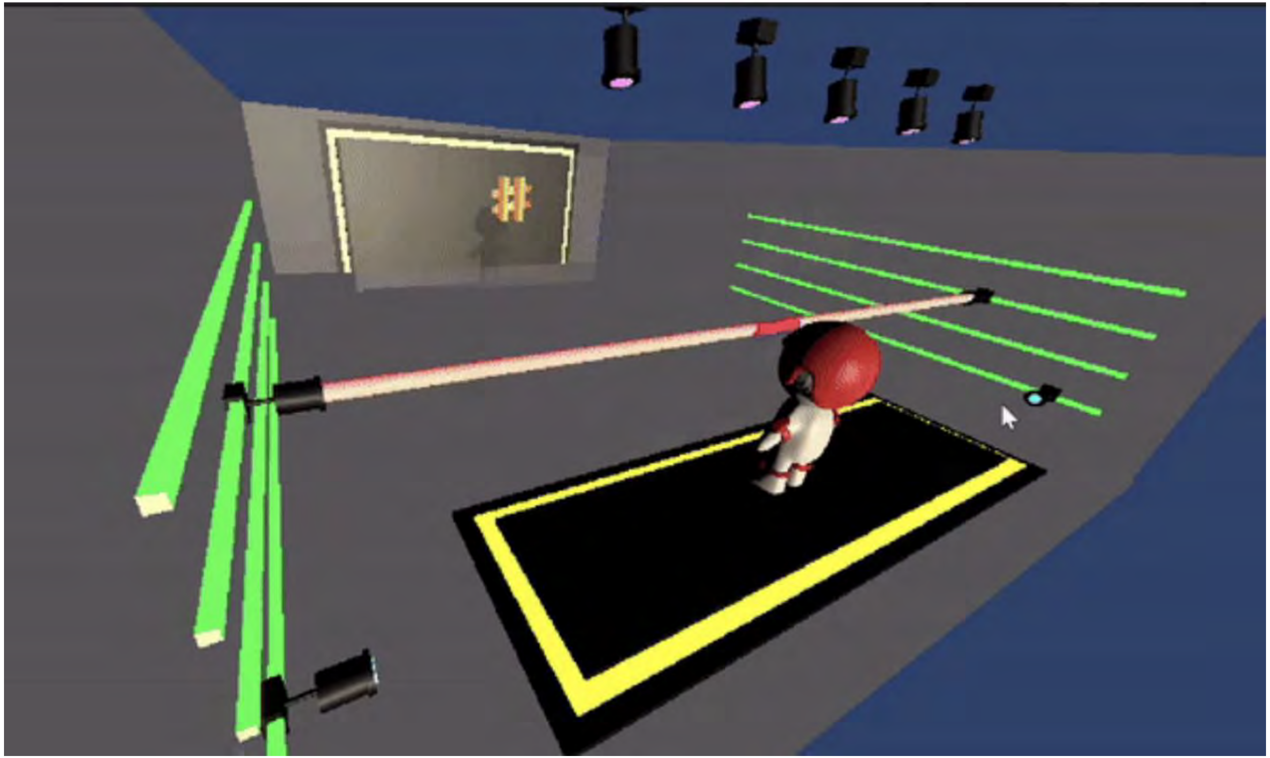


Calibration: Verifying Comprehensive Body Tracking with the Webcam

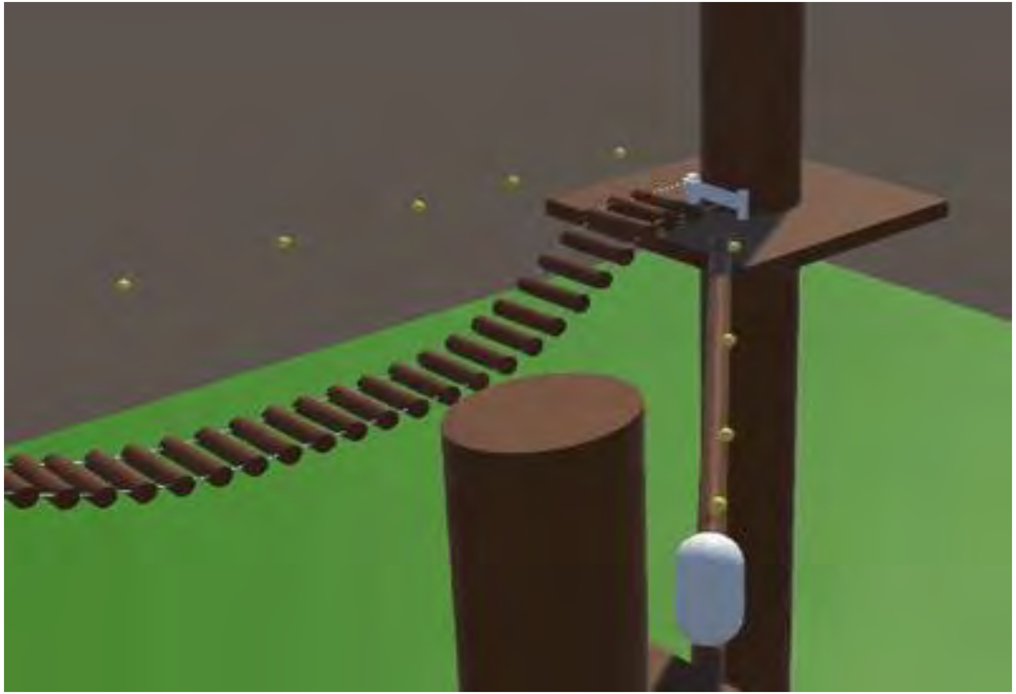
INSTRUCTOR MODE



FLEXIBILITY, BALANCE, AND AGILITY TRAINING

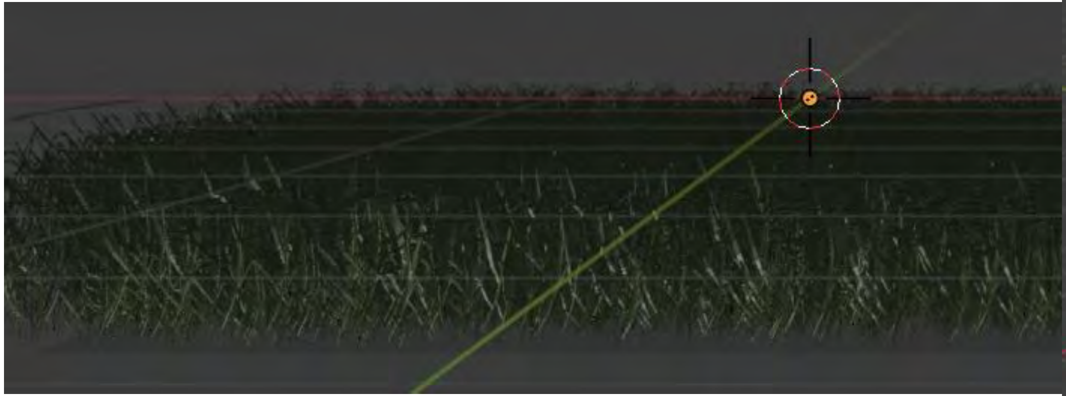


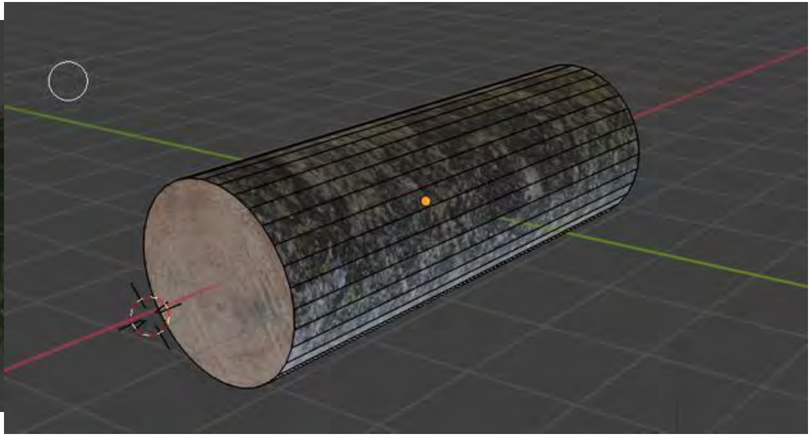
1.6 Adaptive VR Exposure Therapy



This project involves the development of an innovative VR exposure therapy system designed to treat acrophobia (fear of heights). My approach integrates real-time neurophysiological data to assess and predict emotional responses, allowing the system to dynamically adjust the level of challenge during therapy. This adaptive mechanism aims to enhance the therapeutic experience and reduce the risk of anxiety attacks. The technology developed through this project will also serve as a foundation for future VR/AR therapies addressing PTSD and other mental health conditions.

REAL-LIFE OBJECTS IN 3D MODELING



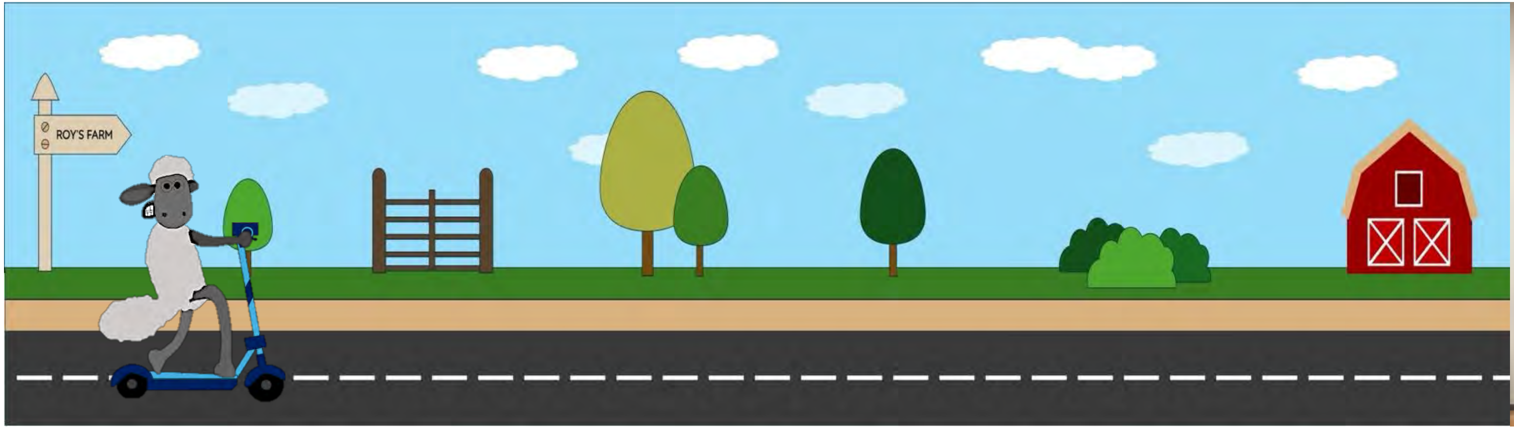


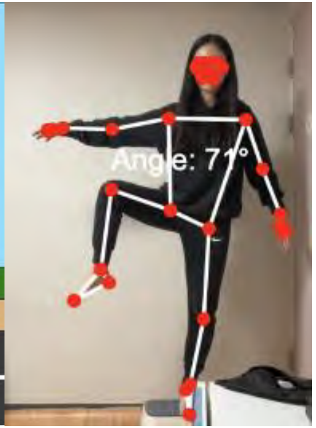
Images of grass strands and trees are captured and used to create realistic 3D models for the VR environment.

1.7 ACL Recovery Platform

Anterior cruciate ligament (ACL) injuries are prevalent among athletes, and while home rehabilitation is essential, it often lacks engagement, leading to poor adherence. This platform addresses this challenge by gamifying therapeutic exercises. Patients perform leg lifts—either lying flat or on their side—while the system tracks their movements. The height of the leg lift translates into acceleration for a game character, providing immediate feedback on exercise performance. These activities focus on gentle strengthening suitable for early post-operative recovery.

The platform features an initial calibration phase to evaluate leg strength and adjust control sensitivity, ensuring exercises are tailored to everyone's capabilities. By merging rehabilitation principles with interactive gaming, this platform aims to enhance patient motivation and adherence, ultimately improving recovery outcomes for ACL injury patients.

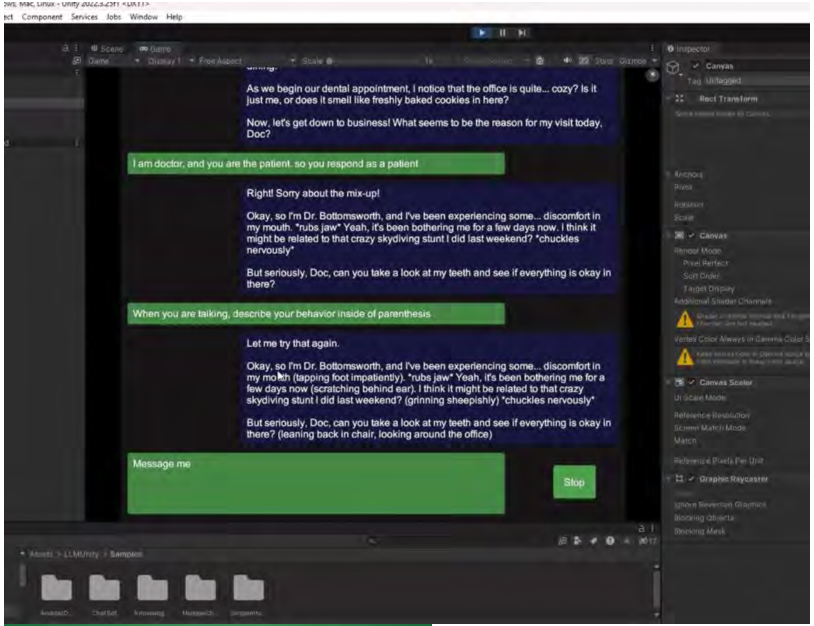




1.8 AI-XR Dental Training

This research focuses on developing an AI-driven training simulation for dental students that integrates UndreamAI's advanced large language model (LLM) chatbot with NVIDIA's convAI and machine learning-powered avatar animations. A unique feature of this system is its ability to generate diverse patient scenarios by incorporating psychological and personality traits that influence patient interactions during diagnosis and treatment. For instance, a patient with orthophobia may exhibit behaviors such as oral defensiveness and anxiety-related vocalizations.

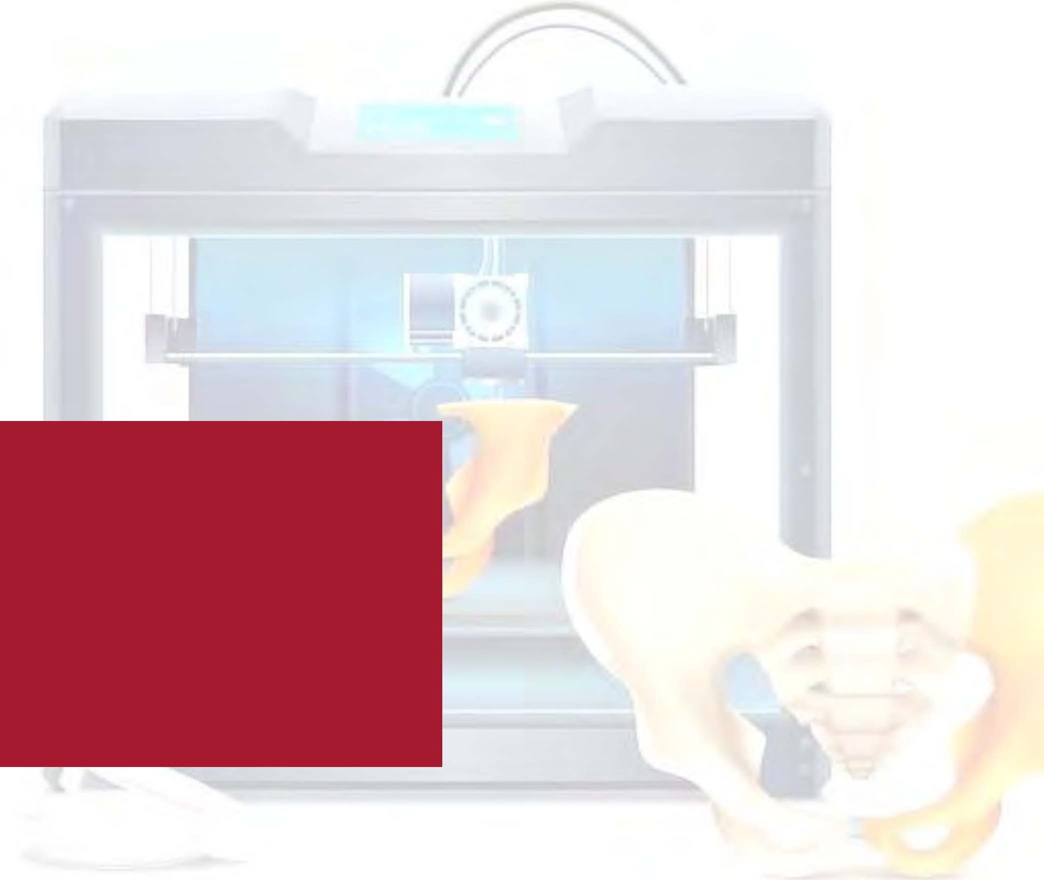
By simulating these realistic interactions, the training tool enhances the educational experience for dental students. Additionally, the technology holds significant promise for applications in telehealth, improving communication between patients and healthcare providers, as well as in cognitive behavioral therapy simulations, offering tailored support for individuals of varying ages and psychological needs. This research highlights the transformative potential of AI in healthcare education and patient management.



SECOND SECTION

02

3D Design / Printing



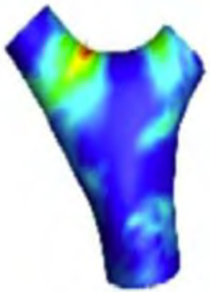
2.1 Tissue Engineered Vascular Graft

We pioneered an innovative design for a metal collector (roller) tailored specifically for 3D printing biomaterial cardiac conduits. This breakthrough design uses electrospinning for enhanced customization, effectively solving challenges like ruptures, stretching during roller removal, and uneven thickness in the printing process.

Our design includes a detachable holding rod with Lego-like components, revolutionizing 3D printing by addressing these issues. A significant milestone was achieved by successfully implanting tissue-engineered vascular grafts in two pigs, marking a leap forward in overcoming printing challenges and advancing personalized biomaterial cardiac conduits.

PERSONALIZED SURGICAL STEPS

1. MRI Scanning
2. Flow Simulation
3. Design Optimization
4. 3D Printing
5. Implantation
6. Post-Surgical Scanning



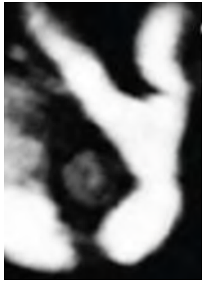
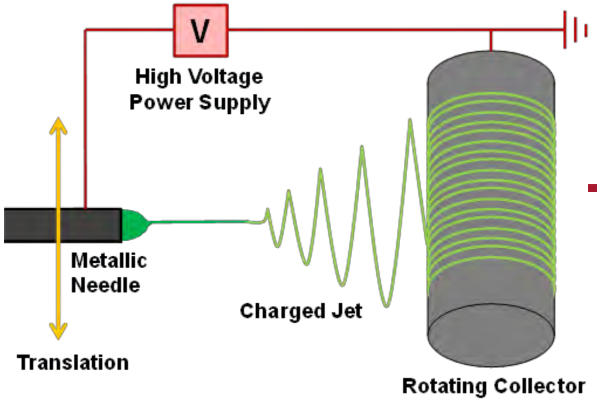


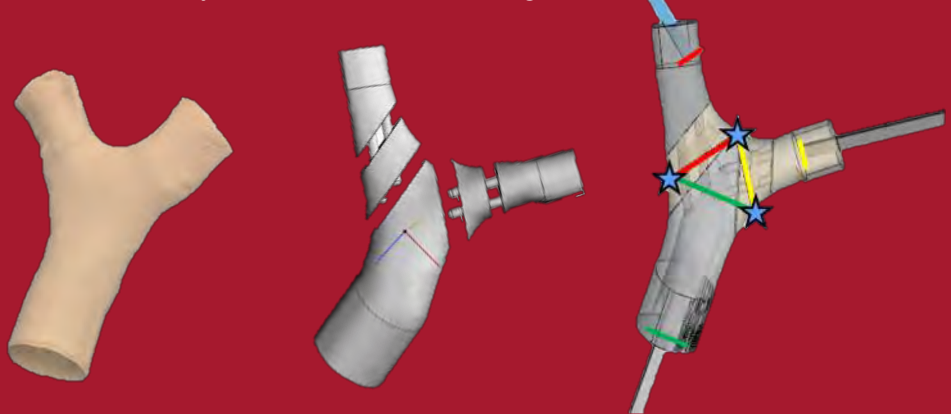
Diagram of electrospinning technique



Conventional Collector Design Method

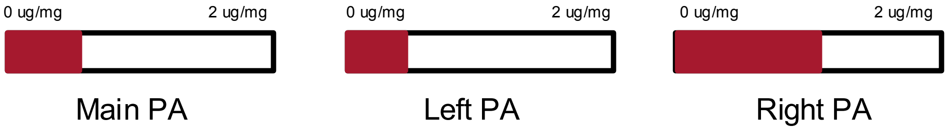
Problems:
- Inconsistent wall thickness
- Susceptibility to tearing/rupture
- Difficulty in removing the collector

My New Collector Design Method



1-MONTH POST-OP RESULT

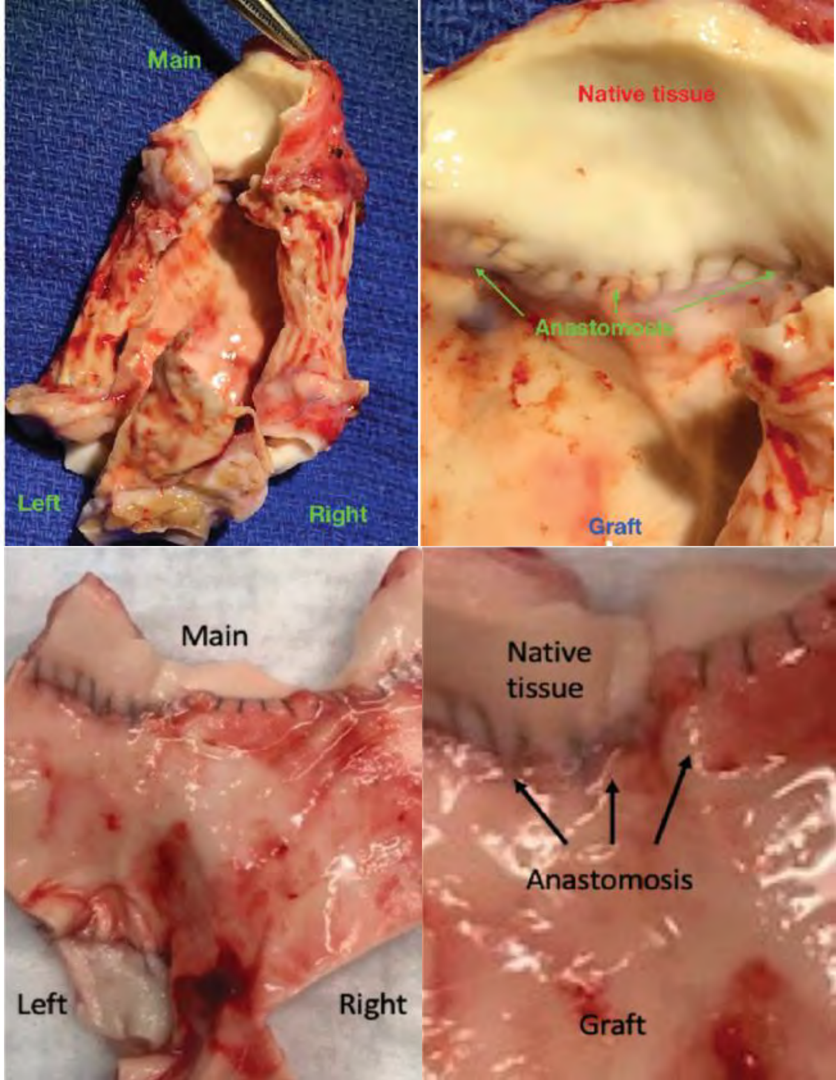
Collagen Content in 3D Printed Pulmonary Artery (PA) vs. Native Tissue



Higher the better

Scaffold Thickness Reduction Analysis

Higher the better

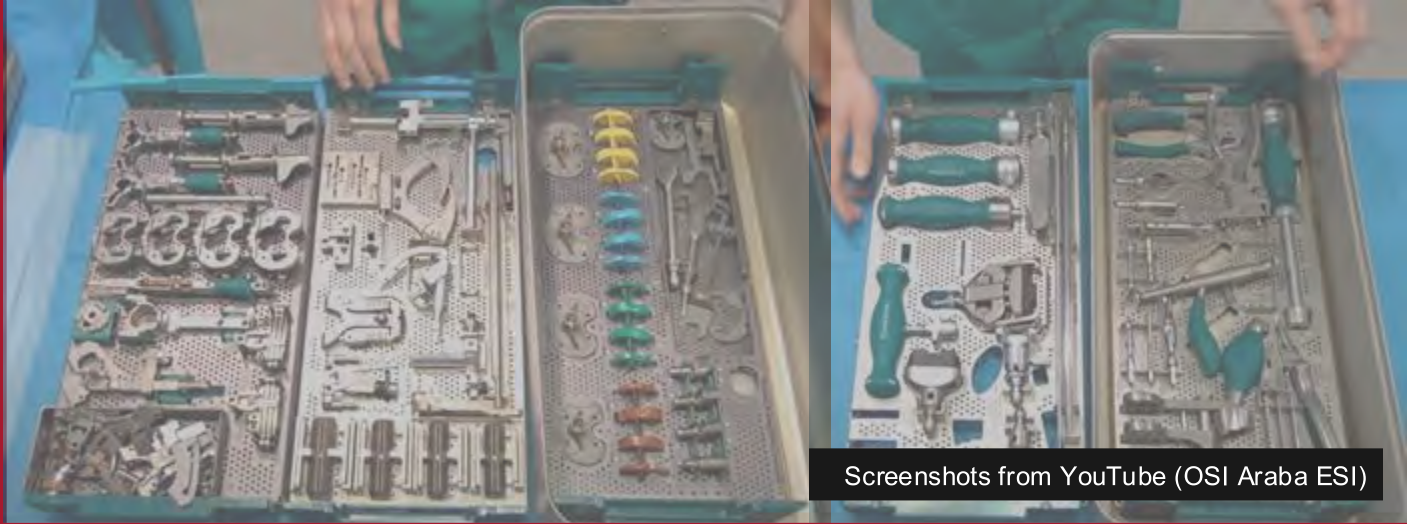


2.2 3D Printed Personalized Knee Surgical Tools

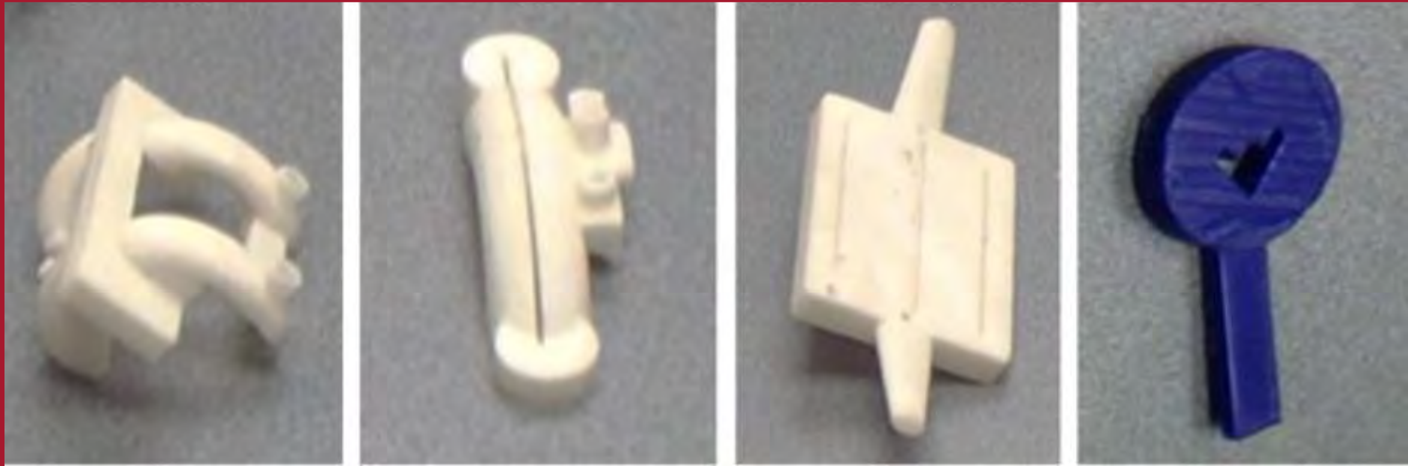
I collaborated with the U.S. Food and Drug Administration (FDA) to address challenges in total knee arthroplasty surgery, specifically focusing on the complexities of surgical tools with multiple parts and sizing options. The current procedure requires numerous manual adjustments and sizing choices during surgery, which can be mentally and time-intensive for surgeons.

To simplify this process, I developed patient-specific surgical cutting guides. These guides are engineered to fit seamlessly onto each patient's knee, similar to a puzzle piece, aiming to streamline the surgical workflow. By providing a customized guide, surgeons can make precise and efficient cuts to ensure optimal attachment of the knee implant.

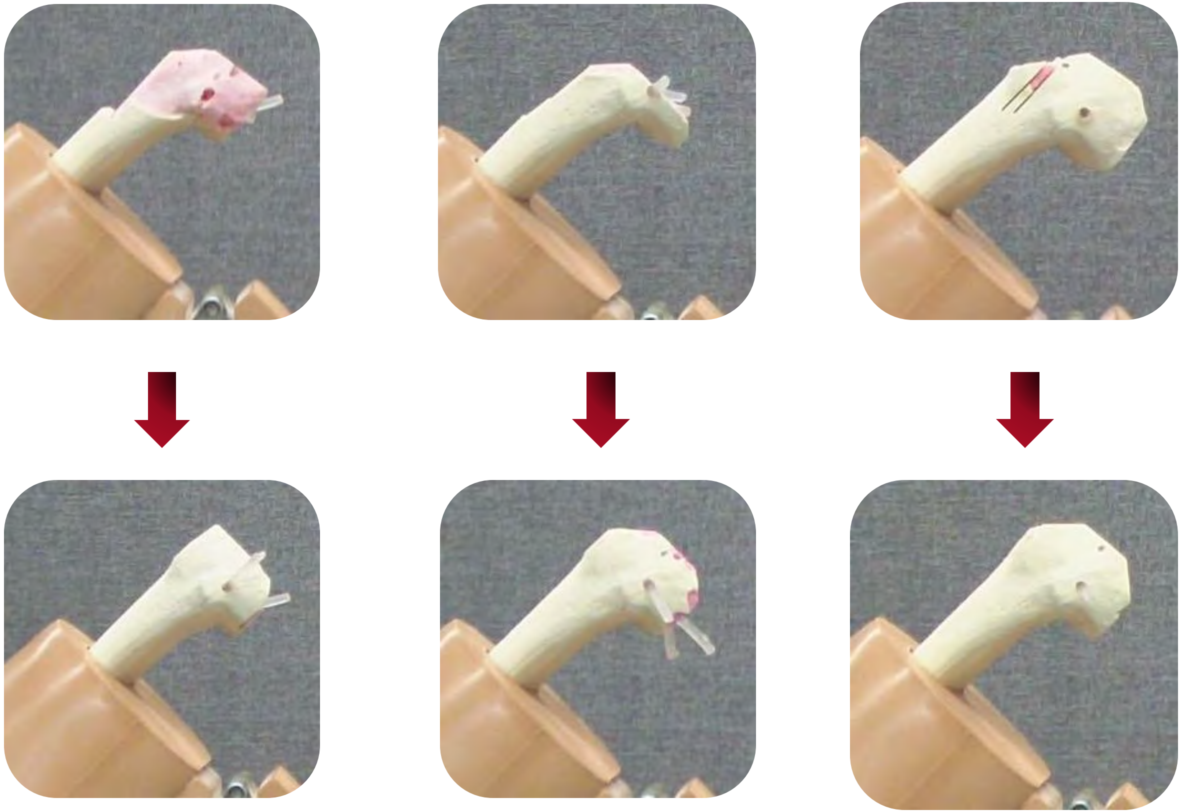
Conventional Tool



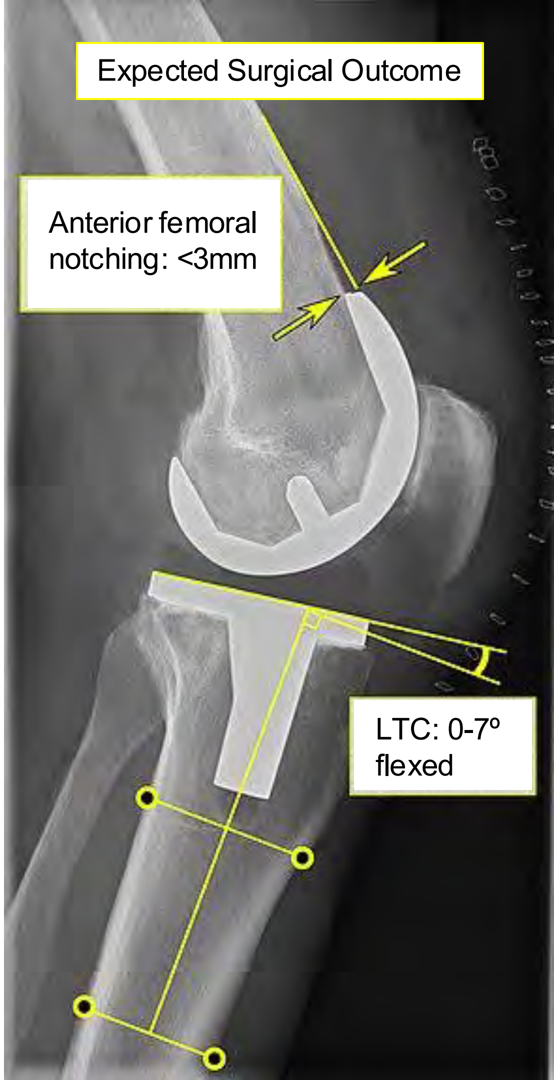
Personalized Tool



Surgical Outcomes Using Conventional Tools



Surgical Outcomes Using 3D-Printed Tools

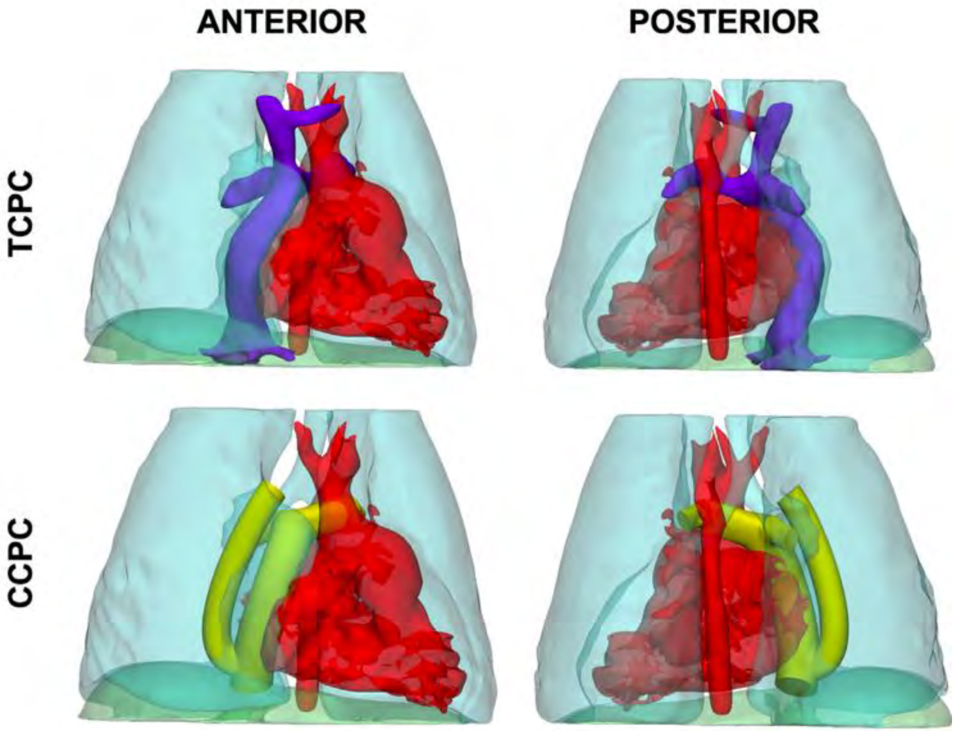


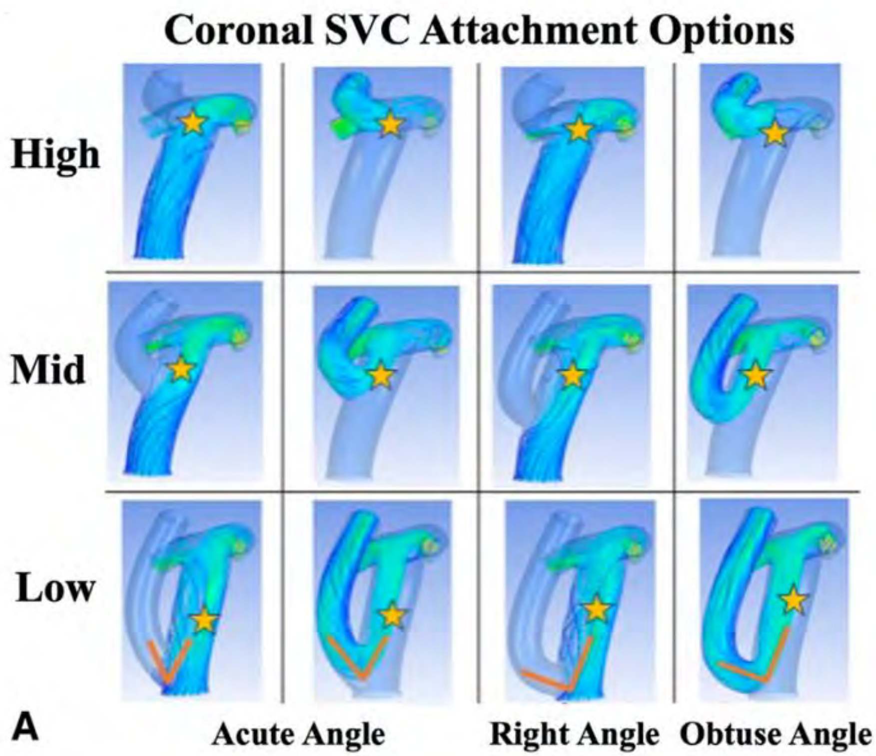
2.3 Novel Cardiac Surgical Approach

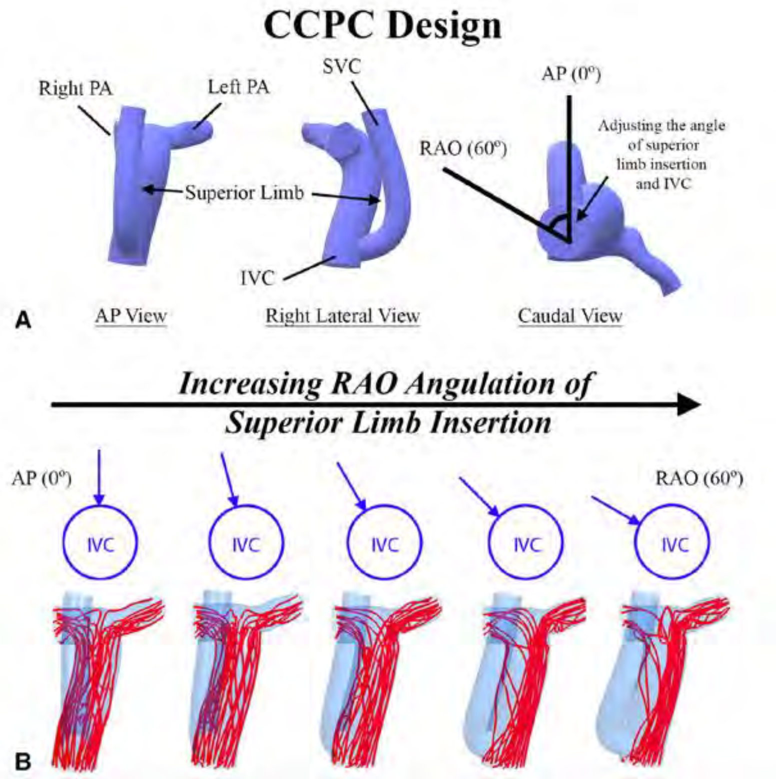
The current design of the total cavopulmonary connection (TCPC) Fontan system faces challenges with conflicting inflows and outflows, leading to hemodynamic inefficiencies and potential Fontan failure. These issues also complicate the placement and effectiveness of mechanical circulatory support devices.

In response, our innovative solution, the convergent cavopulmonary connection (CCPC) Fontan, aims to streamline venous outflow through a single, optimized pathway to the pulmonary arteries. This approach is designed to significantly enhance efficiency and improve access to mechanical circulatory support.

We conducted comprehensive assessments of the CCPC's feasibility and hemodynamic performance across various patient sizes. Using computational fluid dynamics and computer-aided designs, these evaluations provide critical insights into the potential benefits of this modified Fontan procedure.



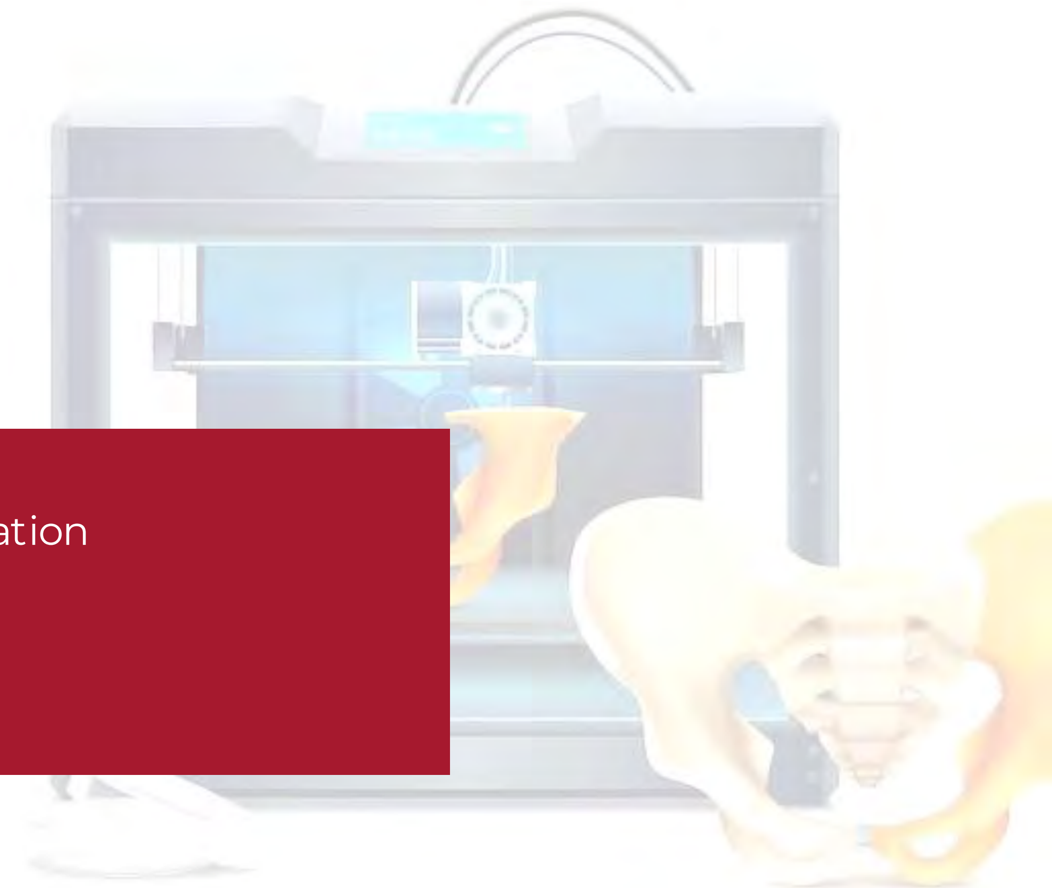

Coronal SVC Attachment Options
High
Mid
Low
A
Acute Angle
Right Angle
Obtuse Angle


CCPC Design
Right PA
Left PA
SVC
AP (0°)
RAO (60°)
Adjusting the angle of superior limb insertion and IVC
Superior Limb
IVC
A
AP View
Right Lateral View
Caudal View
Increasing RAO Angulation of Superior Limb Insertion
AP (0°)
RAO (60°)
IVC
IVC
IVC
IVC
IVC
B

02

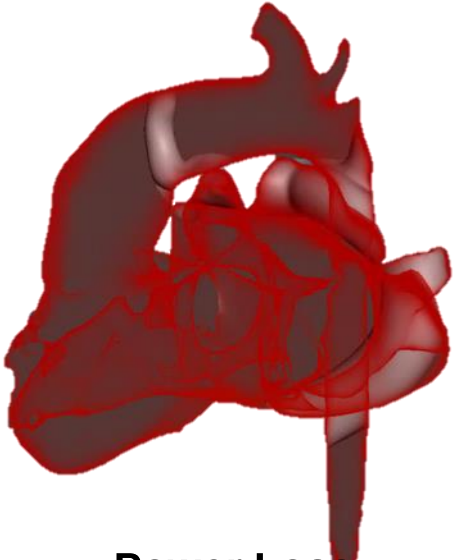
SECOND SECTION

Computational Simulation



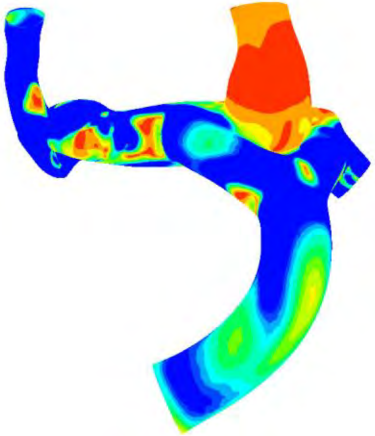
3.1 Predicting Hemodynamic Performance of Cardiac Conduits

When personalizing the optimal cardiac conduit for each patient, we must consider several factors that represent hemodynamic performance. These factors provide insights into the likelihood of medical complications. To harness the capabilities of computing, I explored computational fluid dynamics (CFD) simulation techniques. These simulations assess the hemodynamic performance of cardiac conduits based on three critical parameters: power loss, hepatic flow distribution, and wall shear stress.



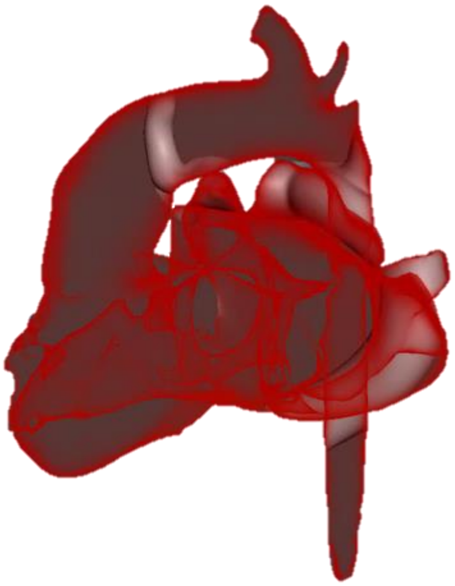
Power Loss

Hepatic Flow Distribution



Wall Shear Stress

Indexed Power Loss



$$iPL = \frac{PL}{\rho Q_s^3 / BSA^2}$$

$$PL = \sum_{inlets} \int_A (p + \frac{1}{2}\rho v^2) v \times dA - \sum_{outlets} \int_A (p + \frac{1}{2}\rho v^2) v \times dA$$

Power Loss

↓

Exercise Capacity

PL: power loss
Qs: systemic venous flow
BSA: body surface area
p: statis pressure
ρ: density
A: boundary area
v : velocity

Goal: below 0.03

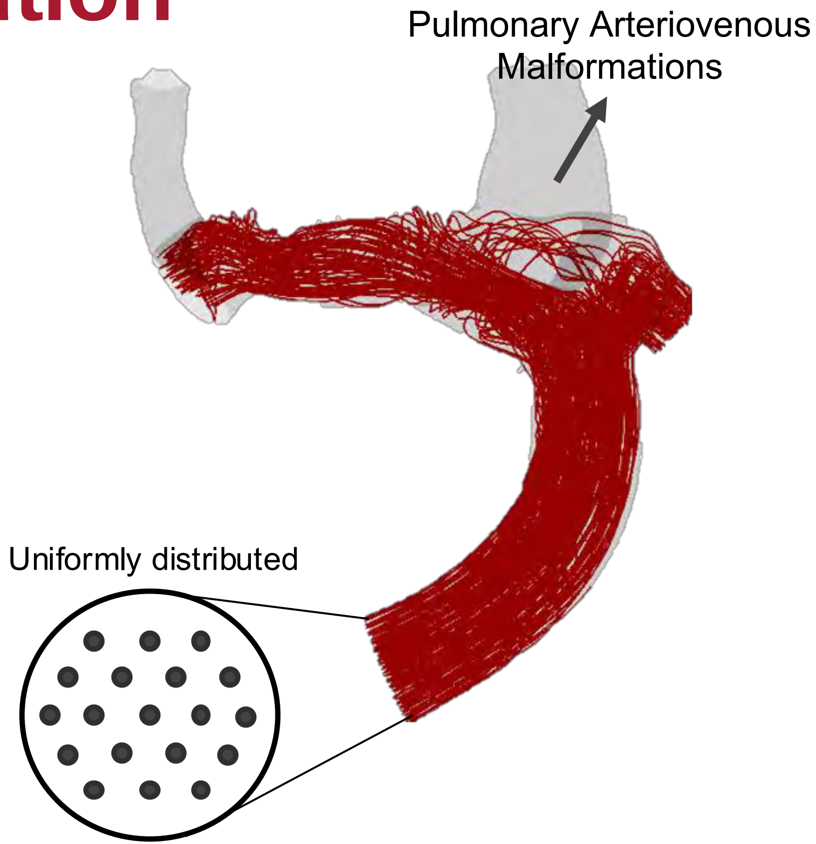
Hepatic Flow Distribution

$$HFD_{LPA} = \frac{N_{LPA}}{N_{IVC}}$$

$$HFD_{RPA} = \frac{N_{RPA}}{N_{IVC}}$$

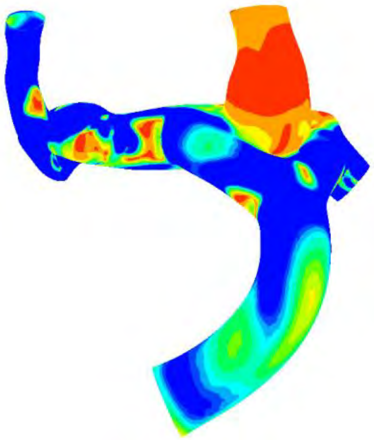
$$HFD = HFD_{LPA} : HFD_{RPA}$$

Goal: between 40:60 or 60:40 range



IVC – Inferior Vena Cava, SVC – Superior Vena Cava, LPA – Left Pulmonary Artery, RPA – Right Pulmonary Artery

Wall Shear Stress



Wall Shear Stress

↓

Thrombosis Risk

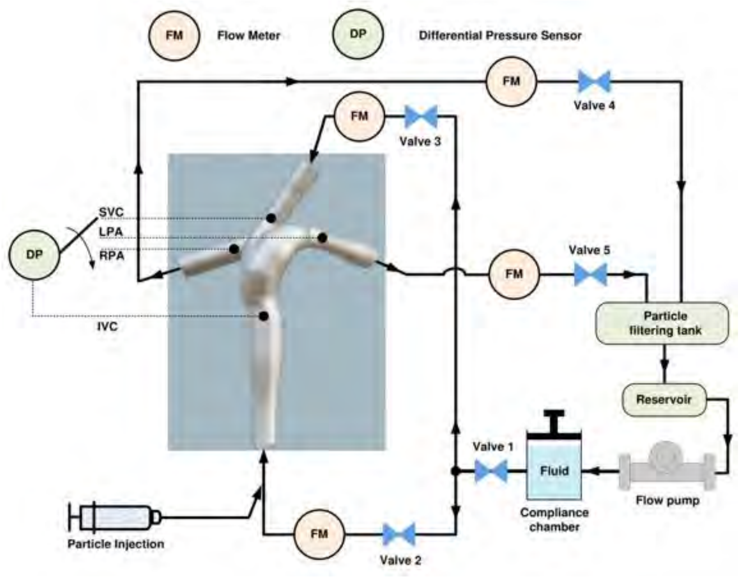
$$\%WSS = \frac{N_{nodeswithWSS<1\frac{dynes}{(cm)^2}}}{N_{nodesatIVCandPAs}} \times 100$$

Healthy WSS = 1 ~ 10 dyne/cm^2

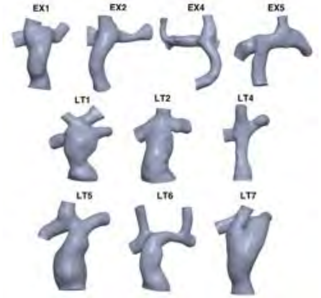
Goal: below 10%

IVC – Inferior Vena Cava, SVC – Superior Vena Cava, LPA – Left Pulmonary Artery, RPA – Right Pulmonary Artery

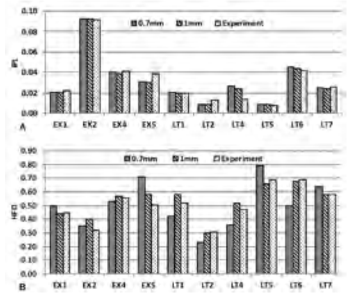
In-Vitro Cardiac System



Patient scenarios



Validation Result



3.2 In-Vitro Cardiac System

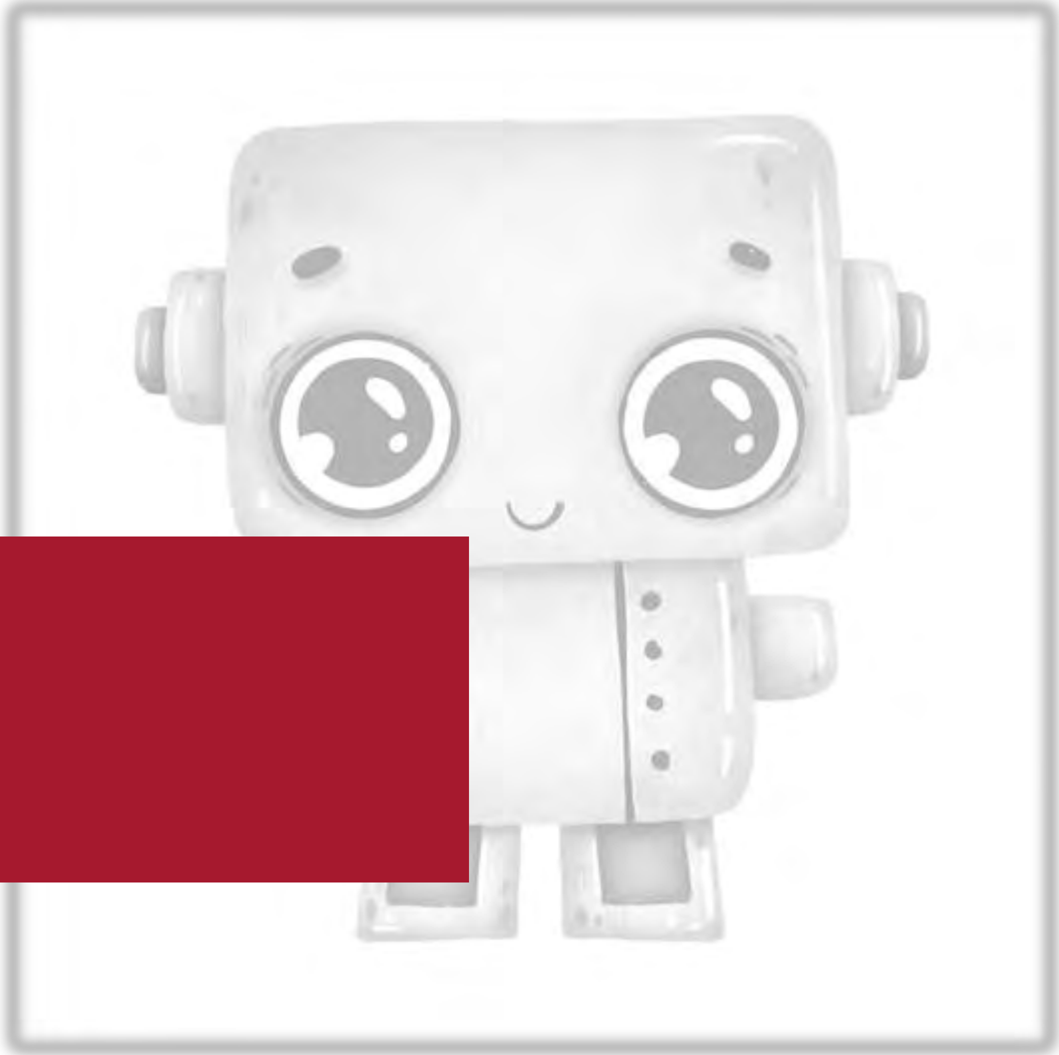
To leverage computational fluid dynamics (CFD) for virtual Fontan procedure planning, we faced the challenge of validating simulation accuracy. We developed an in-vitro cardiac system, a controlled environment to meticulously validate and refine CFD simulations, replicating various patient scenarios. By mirroring real patient conditions, we aimed to establish a robust foundation for CFD as a predictive tool for Fontan hemodynamics. This study systematically validated CFD simulations in the in-vitro setting, assessing their accuracy and efficiency. The in-vitro cardiac system, with full control over flow, pressure, and vessels, aimed to enhance trust in CFD simulations for Fontan hemodynamics prediction.

3.3 Wall Shear Stress Visualization System

This project introduced a visualization system for displaying wall shear stress in 3D designs after computational fluid dynamics simulations. This tool helps medical professionals quickly identify areas in blood vessels with low wall shear stress, which is linked to a higher risk of thrombosis. Users can customize the range based on the vessel type and location, making it easy to analyze and focus on critical areas.

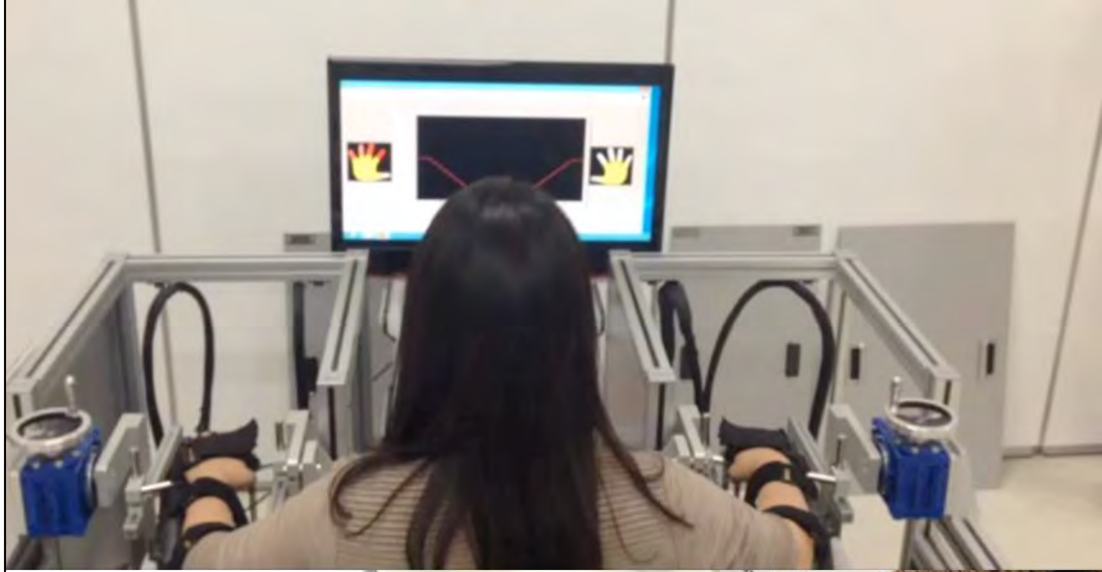
THIRD SECTION 04

Robotics



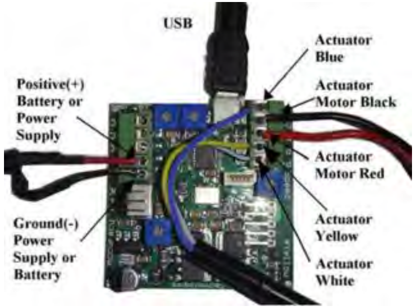
4.1 Stroke Diagnosis & Rehabilitation System

We engineered a robotic system to evaluate the severity of hand conditions in stroke patients. This system assesses finger strength, independence, and inter-finger synergy in both flexion and extension, offering a comprehensive analysis of hand dexterity. Beyond diagnostics, it also serves as a rehabilitation tool for post-stroke recovery. By recording detailed finger movements and the forces generated by hand muscles, this system has proven effective in hospital settings for both diagnosis and rehabilitation.

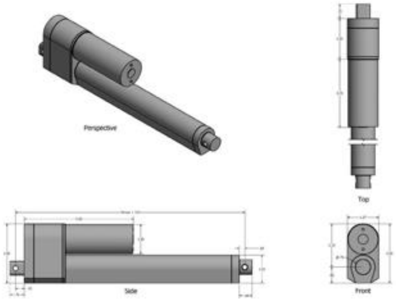


Ankle Robotic System

Diagram of Control Board



Feedback Rod Linear Actuator



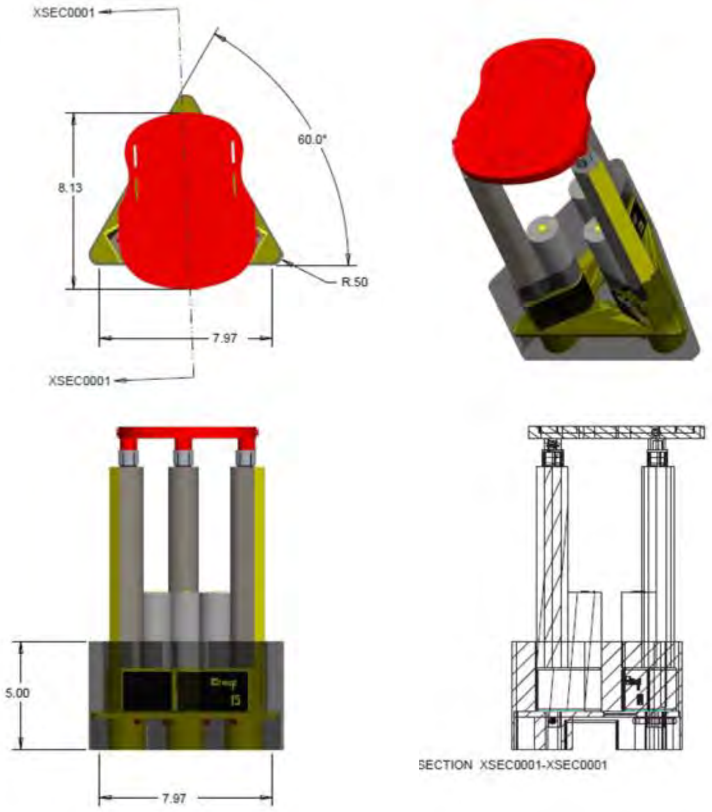
4.2 Ankle Diagnosis & Rehabilitation System

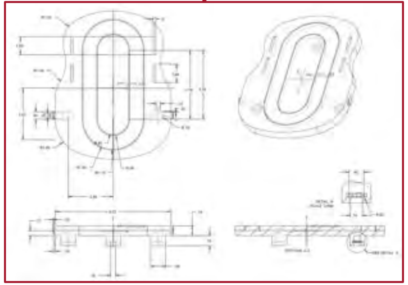
This project introduces an advanced robotic rehabilitation system designed for ankle therapy in children with cerebral palsy. The system features intricately crafted 3D-printed footplates, which can be customized with children's favorite cartoon characters to reduce apprehension. The 3D design enhances adaptability for multiple users and accommodates the rapid growth of children's feet, ensuring consistent support throughout development.

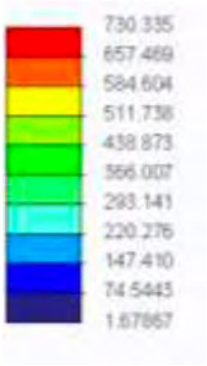
With six degrees of freedom, the footplate is connected to three linear actuators controlled by an Arduino microprocessor, allowing for dynamic control and accurate replication of physical therapy motions. This comprehensive approach transforms the device into a comforting and engaging tool for pediatric rehabilitation, growing alongside the children over the years.

Initial Design

Final Design

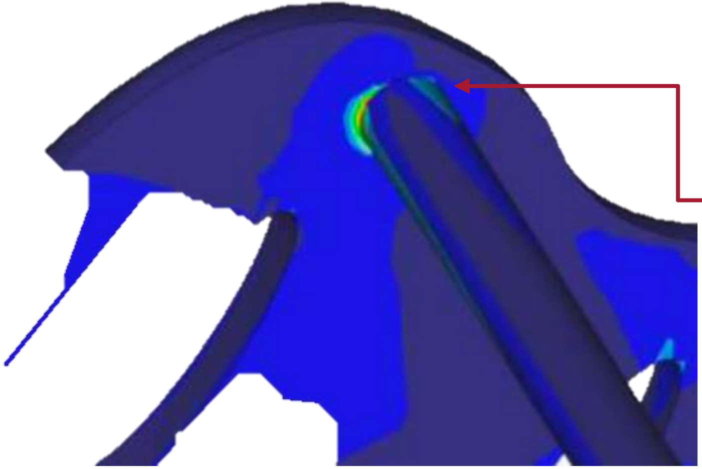






Force Analysis

Force analysis of footplate under 80lbs showed potential risk in the connecting joint of foot plate and the actuator. We further modified the design to reduce mechanical failure, which involved universal joint addition and side foot plate.



Universal joint

Game Control Setup

The system empowers patients to guide the movement of a game character by shifting their ankle, providing them with the ability to navigate through lanes and respond to obstacles through upward or downward ankle movements. Drawing inspiration from Subway Surfers game, this interactive interface is crafted to inspire active participation among young children during therapy sessions. As patients engage in gameplay, the system consistently records average ankle positions, generating invaluable data for physical therapists to evaluate patient progress and strategize the subsequent steps in the therapy process.