Passive Transtibial Prosthetic Design for Amputee Soccer Players

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THE DESIGN PROCESS

RESEARCH & DEVELOPMENT

Constraints

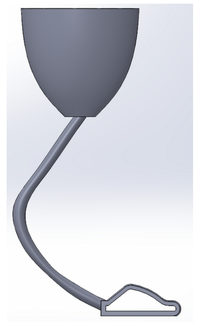
To begin our design process, we first created a list of requirements that our prosthetic needed to fulfill. These requirements included:

- Supporting the athlete's weight
- Allowing for natural mobility
- Enabling the athlete to kick a soccer ball
- Providing ease of walking, running, and kicking

Next, we developed specifications for a theoretical patient, whom we named Bernard. Bernard is an average 27-year-old male who is 6 feet tall, weighs 171 pounds, and is an intramural soccer player with a below-the-knee amputation on his right leg. We meticulously calculated Bernard's dimensions, which were ultimately essential for our design.

Exploring How Blade Prosthesis Work

We used Solidworks to create several blade models and perform stress tests on each design. Our main focus was on C-shaped and J-shaped running blades, as we aimed to compare their features and determine which shape would best suit our project's requirements. For a more detailed analysis of our comparison between C-shaped and J-shaped blades, please refer to the section titled 'C-shaped vs J-shaped Running Blades'. After careful evaluation, we ultimately chose a J-shaped blade design as it provides greater athletic mobility for the user.



Our preliminary design of a running blade

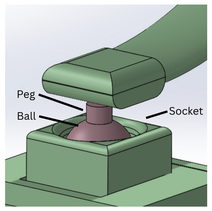
Designing the Foot

We based our design around some already existing designs, specifically Ottobock's 1C30-1 foot prosthetic known as Trias. We chose this prosthetic as our reference for several reasons but our main reasons are the strength, durability, and the versatility that the design provides to the wearer.We focused most of our efforts on perfecting the leaf-springs located at the arch and the Achilles heel. These components are key to ensuring our prosthetic can withstand intense amounts of forces while the athlete is running, kicking, or jumping.

Ottobock 1C30-1 Trias

Designing the Ankle

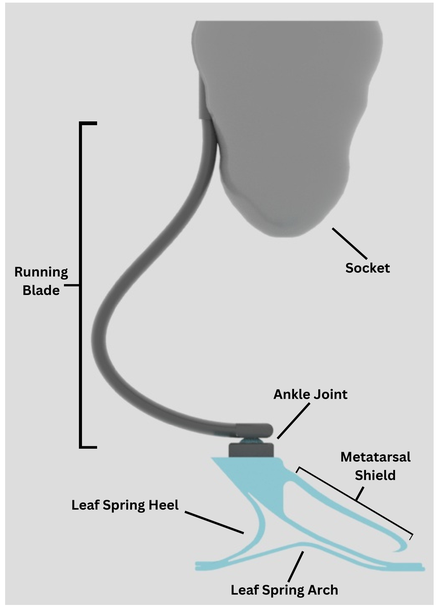
Beginning with a standard ball-in-socket design, we made several modifications to optimize the ankle's range of motion. Among the most significant changes were the integration of a spring at the center of the ball, linking the ball-peg to the socket. This addition allows the ball-peg to return to its resting position when the athlete is between steps. Additionally, we incorporated an opening in the socket to facilitate the most natural range of motion for the athlete's foot. The size and shape of this opening were precisely calculated based on the typical rotation of the human ankle.

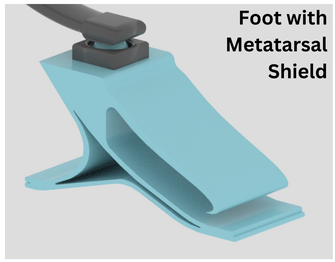


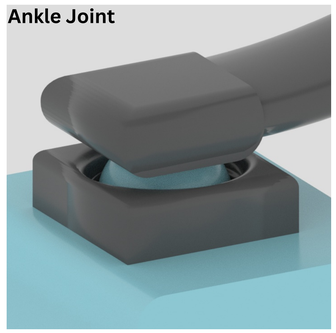
Exploded view of Ankle Joint Assembly without rim cushion.

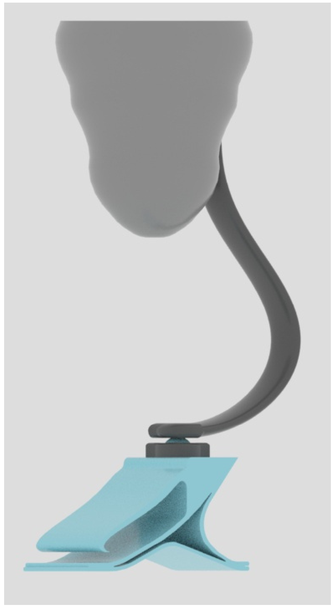
Designing the Metatarsal Shield

The primary goal of designing the Metatarsal Shield was to enable the athlete to kick a soccer ball effectively. After studying footage of players, we discovered that striking the ball with the top of the foot was crucial. So we created a shield to absorb the impact and prevent any unnatural rebound. We had creative freedom with its design and experimented with various shapes and sizes. While the artistic curves and rounded edges of the Metatarsal Shield primarily serve an aesthetic purpose, they nevertheless complement the overall design of the prosthetic foot.



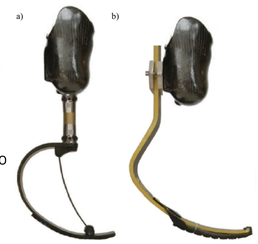






C-shaped vs J-shaped Running Blades

Running blade prostheses are designed to allow amputees to engage in fast-paced activities such as running and jumping. C-shaped and J-shaped blades are two of the most commonly used blade shapes for running prostheses. The C-shaped blade has a single curve that starts from the heel and extends to the toe, while the J-shaped blade has a more pronounced curve that extends beyond the toe. One key difference between the two blade shapes is the amount of energy storage and release they provide. The J-shaped blade is designed to provide greater energy storage and release, making it more suitable for activities that require greater propulsion, such as running and jumping. In contrast, the C-shaped blade is better suited for activities that require greater stability, such as walking and standing. The choice of blade shape ultimately depends on the specific needs and goals of the amputee, as well as the intended use of the prosthesis.



a) Freedom Innovations Catapult (FDM), (b) Össur Cheetah Xtend (OSR)

Acknowledgements & References

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Fig 1.

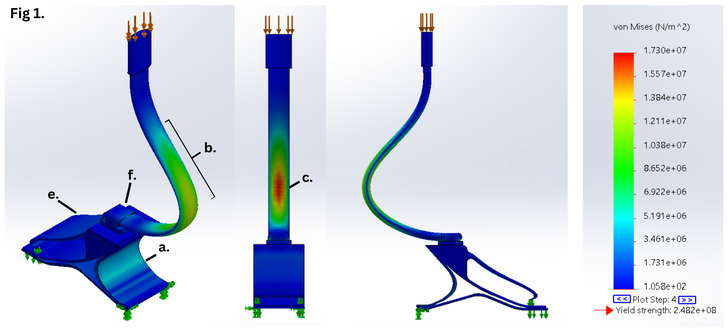
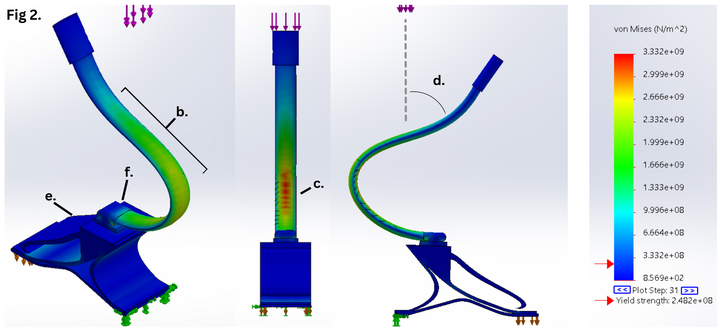


Fig 2.



Stress Testing the Prosthetic Against the Athlete's Weight

This was the first stress test that we carried out to verify that the prosthetic was capable of fulfilling its basic function of supporting the athlete in an upright position. The results of the test were very positive, indicating that our design was successful. The stress analysis showed that the running blade's and the heel spring bore the majority of the stress, in accordance with our design plan.

Stress Testing the Prosthetic Against High Impact Forces

Following multiple simulations, we have concluded that our prosthetic design is capable of supporting a weight that is over eight times that of the athlete. The design's flexibility allows the athlete to store and release energy within the prosthetic, resembling the way in which human legs work.

Stress Testing Results

Weaknesses

- Ankle Joint
  - Problem: The connection between the running blade and the ball-peg was very thin and brittle and would've caused the foot to break off of the athlete's leg.
  - Solution: We developed a washer-like cushion that encompasses the rim of the socket, which effectively distributes stress, relieving pressure on the ankle joint and reducing the risk of fractures. (See Fig 1f. 2f.)

Strengths

- Bottom Leaf Spring
- Leaf Spring Heel
- Running Blade

Overall Highlights

- The prosthetic design can withstand over 8x the athlete's body weight. (See Fig 2.)
- The prosthetic is able to store and release energy in the running blade and various springs (See 1a. 1b. 1c. 2b. 2c.)
- The Running Blade is able to bend significantly allowing the athlete to move with a great degree of freedom. (See 2d.)
- The Metatarsal Shield does not impede natural walking motion.
- The Metatarsal Shield does not receive any significant stress from the athletes weight or movement. (See fig 1e. 2e.)