ADDITIVE MANUFACTURING OF DYNAMIC ANKLE BRACE

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ABSTRACT

Ankle sprains are the most common injury in the world's largest sport; soccer. The current prevention methods such as ankle braces are ineffective due to its bulkiness, excessive movement, and lack of comfort. Engineered for athletes, by athletes, a 3D printed, customizable, and thin ankle brace was designed specifically for soccer players to limit inversion and eversion ankle sprains but allow natural range of motion. The specifications of the improved ankle brace are designed to allow the material properties to apply a restoring force as it reaches the exceeding ranges of motion for ankle sprains without hindering athletic performance. This brace is made to contain a geometric mesh design that combines the benefits of the classic ankle brace stirrup concept with 3D printing and modern material science to produce a customized ankle brace lighter, more malleable, and thinner than competitors and existing approaches while still allowing the athlete to perform at maximum potential. The brace will be tested and worn by soccer players upon completion of the final model. The ultimate objective is to produce a working product to be available in the commercial market for purchasing based on the provided research, experimental testing, 3D printing, and material properties.

BACKGROUND

Ankle sprains are the most common injury in soccer for youth and professional players. This accounts for 85% of all sprains [1]. Sprains can potentially weaken ligaments and muscles, however with a proper brace, prevention can be enhanced by creating stability within the ankle bones. Current ankle sprain prevention methods such as ankle braces and athletic ankle taping are ineffective due to its bulkiness, restriction, and lack of comfort.

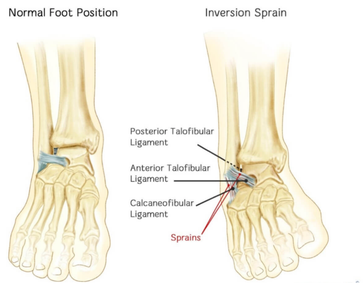

Figure 1: View of the most common ankle sprain to lateral collateral ligaments in the frontal plane [2].

DESIGN PROCESS

To create an ankle brace to reduce the occurrence and severity of ankle sprains, research was conducted on ankle injuries, causes, types of material, customization, and manufacturing to clearly understand the problem. The design requirements and concepts were generated around the lack of effectiveness of the current methods and designs. The specifications of the brace includes resisting motion greater than 40º inversion/10º eversion, thin, self-applicable, and comfortability.

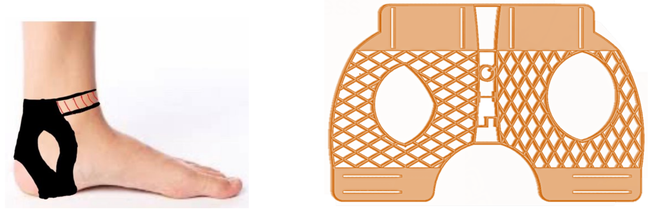

Figure 2: Concept of the ankle brace and SolidWorks CAD file of the ankle brace.

A concept was developed through multiple design iterations, modeled in SolidWorks, and produced by a Makergear M2 3D printer using thermoplastic polyurethane (TPU).

	Settings
Filament Type	Thermoplastic polyurethane (TPU)
Extruder Temperature	235°C
Print Bed Temperature	40°C
Skirt Layers	8
Skirt Outlines	10
Infill Percentage	100%
Infill Angles	45°, 0°, -45°
Print Speed	2000 mm/min

Table 1: Makergear M2 3D printer settings to produce the ankle brace.

RESULTS

- A prototype was developed with a brace thickness of 0.175 cm, weight of 30.5 grams, and customized to conform to the subject's foot.
- The brace uses the diamond mesh geometric layout made from TPU that provides a restoring force due to material properties to protect the ankle from over-inversion.
- The brace provides holes around the distal malleoli for ergonomics and comfort purposes. Assembled using user-friendly velcro straps at two anchor points; one on the distal shank and one on the arch of the foot.
- The lateral side has a horizontal diamond mesh geometry and the medial has a vertical diamond mesh geometry to restrict range of motion.
- The brace fits comfortably inside a soccer cleat and is easy to don and doff.

Figure 3: Prototype of ankle brace on and off subject's foot in a soccer cleat.

VALIDATING EXPERIMENTS

To validate the design of the ankle brace, the in-progress analysis plan includes performing a drop test to determine the amount of torque produced on the ligaments of the ankle, simulating a dynamic response of a lateral ankle sprain. The trials will be performed with and without an ankle brace applied to the model. This preliminary design test will show how the ankle brace will aid in force restoration and ankle sprain prevention.

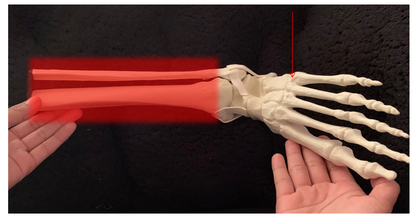

Figure 4: Ankle model experimentation plan: shaded red is a fixed region and red arrow is falling object path to reproduce dynamic response of lateral ankle sprain.

DESIGN IMPROVEMENT

Enhancing the prototype involves design experimentation such as adding a compression sleeve, trialing resin printing, and adjusting the stiffness of the mesh geometry or altering the shape size. The results of the validation experiments will aid in determining future design implementations.

FUTURE WORK

The team is expecting to dedicate the next phase of the project to developing 3D scanning technology for ease of customization and additional experimentation such as tensile testing and fatigue testing. The team anticipates to investigate the application of this concept with 3D printing technology for future medical braces.

Figure 5: Logo design for the ankle brace (SIQ).

REFERENCES

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