# ADDITIVE MANUFACTURING OF DYNAMIC ANKLE BRACE

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## ABSTRACT

Engineered for athletes, by athletes, an ankle brace (SIQ Ankle Brace) was designed specifically for soccer players to limit inversion and eversion ankle sprains but allow natural range of motion. The current prevention methods are ineffective due to bulkiness, restriction, and lack of comfort. Motions greater than 40º inversion and 10º eversion can cause lateral and medial ankle sprains. The purpose of this project is to further develop and improve the SIQ Ankle Brace which is strategically designed to be thin and purposely allows natural range and movement while wearing soccer cleats. The idea is to test the ankle brace on humans as well use a physical ankle model with ligaments. The human testing will involve athletes mimicking soccer movements while wearing the 3D printed brace. During the testing with the physical ankle model - a torque will be applied to simulate twisting an ankle. The data collected will include the angles and forces applied to the ankle model with and without the SIQ Ankle Brace. With this data, improvements to the ankle brace can be made through alterations of thickness, materials, and dimensions to meet design requirements.

## BACKGROUND

Ankle sprains are the most common injury in soccer for youth and professional players. Sprains account 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 joint. Current ankle sprain prevention methods such as ankle braces and athletic ankle taping are ineffective due to bulkiness, restriction, and lack of comfort.

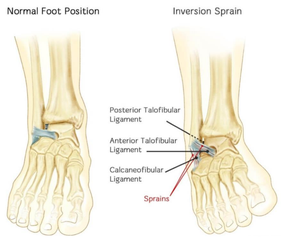


Figure 1: View of the most common ankle sprain to lateral collateral ligaments in the frontal plane [2].

## DESIGN PROCESS

To create an ankle brace that reduces the occurrence and severity of ankle sprains, research was conducted on ankle injuries, causes, types of material, customization, and manufacturing to clearly identify 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 [3].

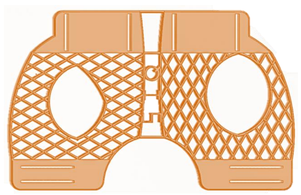

Figure 2: Concept of the ankle brace and SolidWorks CAD file of the first prototype.

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

## RESULTS

- An updated prototype was developed with a brace thickness of 0.175 cm, weight of 30.5 grams, and it was 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 a zipper in the back to enable user-friendly application.
- 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 subject's foot.

## VALIDATING EXPERIMENTS

To validate the design of the ankle brace, a testing rig has been built to simulate the forces applied on an ankle's motion of twist. A physical ankle model will be used to replicate an ankle sprain as a torque sensor will be applying forces to the system. The test will be performed both with and without the SIQ ankle brace along with commercial market braces. The data collected will be comparing the angles of inversion and eversion of the model. Additionally, the test will record the amount of torque applied to the system.

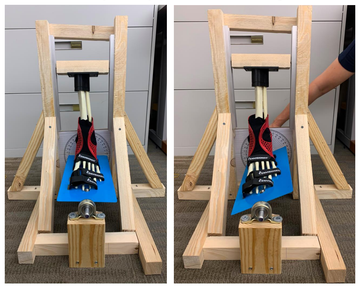

Figure 4: Ankle model in testing rig before and after torque is applied.

Applying a steady torque to the testing rig with an ankle model, the following results were concluded.

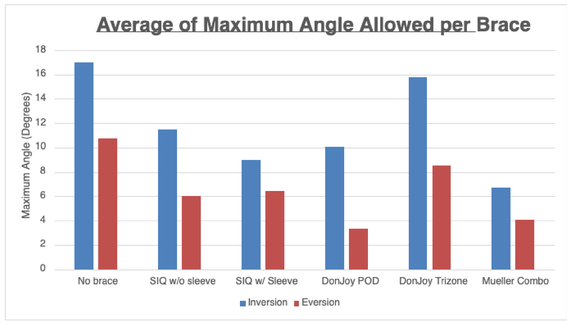


Figure 5: Maximum angles of inversion/eversion of SIQ brace compared to other braces

As seen in Figure 5, inversion and eversion resistance testing where the SIQ ankle brace is compared to other braces currently on the market indicates that the SIQ brace, for the torques applied, resists comparatively with the ones on the market.

## DESIGN IMPROVEMENT

Enhancing the prototype involves design experimentation such as adding a trialing resin printing and adjusting the stiffness of the mesh geometry or altering the shape size. Additionally, there will be added a BOA lacing system to the brace which will allow for adjustability and more comfort. The results of the validation experiments will aid in determining future design implementations.

## FUTURE WORK

In spring 2021, human testing will be performed within the soccer program at ERAU. The athletes will be asked to perform a series of exercises with the 3D printed ankle brace. Afterwards, the athlete will be asked to answer a questionnaire that will give constructive feedback on the ankle brace which will be used to further improve the brace.

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.

## REFERENCES

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