Men’s Football Footwear for Artificial Surfaces: The Role of Thermoregulation

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Introduction

As climate change brings warmer temperatures, football pitches across the United States are changing to artificial turf due to lower costs and ease of maintenance (Myrick, 2019). However, for the male elite athlete, artificial surfaces like turf and asphalt become too hot which causes foot discomfort (Dodd, 2020). Between the ages of 16-22, these emerging athletes compete at college showcases, a critical step when competing for limited spots on National Collegiate Athletic Association (NCAA), Division I football teams. These events are often held during the summer or in locations with warm winter weather. Due to these athlete's condensed schedules, showcases compound stress on the feet (Dodd, 2020). This stress combined with extreme heat creates a need for thermoregulatory footwear solutions. As global warming becomes a greater issue, heat stresses will incrementally impact aspiring collegiate athletes. By developing a football boot and street football shoe specifically to combat the stress of playing on artificial turf and asphalt, players will be awarded comfort and peace of mind which will allow them to compete at the top of their game.

History of Association Football

According to football's world governing body, the Federation Internationale de Football Association, (FIFA), recognizes the Chinese game of Tsu'Chu (Tsu-Chu or Cuju, meaning "kicking the ball") as the earliest game resembling modern football (Crocombe, 2019). As shown in Figure 1, this game was believed to be designed as a training exercise for soldiers, as records date back as far as 206 B.C - 220 A.D. (Crocombe, 2019).

Fig. 1 The Chinese Game of Tsu-Chu (Crocombe, 2019)

From the Han Dynasty to the ancient Greeks and Romans, other countries also claim to have their own form of ball sports around this time. It wasn't until the 9th century, during the medieval period, where the evolution of the game began to take shape (FIFA, 2007). Entire villages challenged one another by kicking a pig's bladder from one opponent's landmark to the next (Crocombe, 2019). This mob style of the game often referred to as "folk football" was banned from time to time during Britain's history. By this time, these large social gatherings were taking place particularly across western Europe (Crocombe, 2019).

At the beginning of the 19th century, many schools in England evolved the game into what it is today (The FA, n.d.). Played on any suitable patch of grass, the laws of the game were disputed between teams each match. On the Monday evening of October 26, 1863, the Football Association (FA) was formed, determining the official rules and regulations of the modern game (The FA, n.d.). Representatives from London and the surrounding suburbs all came together to merge their own versions of the game “for the purpose of forming an Association with the object of establishing a definite code of rules for the regulation of the game” (The FA, n.d.).

Collegiate Football in the United States

By 1820, many colleges around the United States had football teams (Litterer, 2010). However, the competition was not intercollegiate, and the game’s rules were often changed or altered per match (Litterer, 2010). After the Civil War, football became an organized college sport. The newly initiated sport saw both colleges and universities engage in a game that resembled both football and rugby, later deviating between football, rugby football, and American football. (U.S. Soccer, n.d.). The first intercollegiate football match took place on November 6th, 1876, in New Brunswick, New Jersey, featuring Princeton versus Rutgers University. Using the London Football Association's rules from 1863, 25 players took to a field 110 meters x 70 meters, with a 24-foot wide goal. The ball could be moved with any part of the body, including but not limited to carrying, thrown, or batted. The first team to score 6 points won and the game ended in a 6-4 victory for Rutgers University (Litterer, 2010). Ultimately, rules were disputed to a point where many universities adopted rules aligning more closely to rugby, which meant football at the collegiate level would see a decline for many decades after.

Up until 1950, college football was not a sanctioned sport (Litterer, 2010). With its induction into the NCAA, colleges around the country could increase the level of football from club to varsity status. Furthermore, this created a resurgence in interest for the sport and a way for colleges to promote male athletics at their school. From this new addition by the NCAA, collegiate football now had an official championship, ranking conferences against each other and producing a winner by the end of the tournament (Litterer, 2010). In the modern era, collegiate football has seen a steady increase and is one of the largest varsity sports for both men and women around the country.

The Athlete

Of all male soccer players in the United States, those that are 16-22 look to compete for a spot on a college roster. Outside of their high school schedule, they participate in summer showcases and college ID camps for college recruiting. Often being played on multiple artificial turf fields, these showcases are played at large complexes around the country over the course of a week. Teams sign up, bringing in thousands of players and hopefully college scouts that are on the lookout for the newest talent. These players come from club academies or other elite development teams, to expose players to high-level competition and college recruiters (Ertheo Sports Programs, n.d.). Elite ID camps are one of the best ways a player can get introduced to new recruiters. With a combination of college and international scouts, these opportunities can lead to a position on a university’s roster (Next College Student Athlete, n.d.). Condensed to a few days, camps allow coaches to see many players quickly. For players, there is the chance to show their skills and catch the eye of a college recruiter on their shortlist. With a coach recommendation, players can enter camps to familiarize themselves with the program, staff, and school (Next College Student Athlete, n.d.). Once in a Division I program, players should connect with Major League Soccer (MLS) coaches in hopes to be drafted at the MLS SuperDraft at the end of each year (Ertheo Sports Programs, n.d.). All happening within a few days, these showcases are highly competitive and put athletes under immense physiological and mental stress.

Market Size/Potential

As more and more football players reach the age of college eligibility, the level of competition, and the importance of standing out among the crowd grows larger. According to Statista, from the 2009-2010 season to the 2018-2019 season male high school players increased by 85% as shown in Figure 2 (Lange, 2020). Over the past ten years, more schools are adding football programs and general interest in the sport has been steadily growing, thus creating more competition each year.

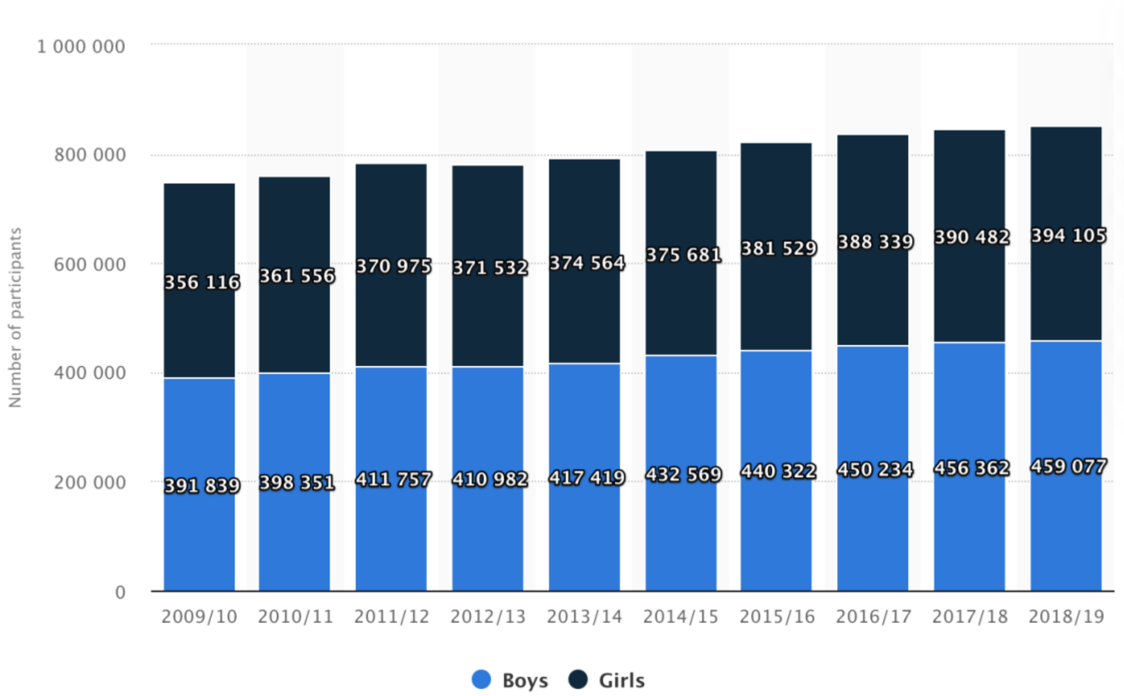


Fig. 2 Number of participants in U.S. high school soccer from 2009/10 to 2018/19 (Lange, 2020)

During the 2018-2019 season, 459,077 male players were reported competing in high school football (Scholarship Stats.com, 2020). In the same season, 34,786 male players were reported playing collegiate level football (Scholarship Stats.com, 2020). Of these male high school football players, nearly 8% move on to play at any college (Scholarship Stats.com, 2020). This includes NCAA, NCIA, NJCAA, and other 2-4-year programs. At the NCAA Division I level, less than 1% of football players go on to play the top level in collegiate football (Scholarship Stats.com, 2020). With an extremely competitive talent pool, players look for advantages and opportunities that can help them reach the next level.

Playing Environment

Attracting athletes from around the world, top football universities like Stanford, Arizona State, and Southern Methodist University invite incoming players that hope to play Division I soccer in the United States. Within the southwest sunbelt, states such as California, Nevada, New Mexico, Arizona, and Texas account for some of the hottest average summer temperatures in the country (Stockdale, 2019). Inside the United States, rapid urbanization and increasing transportation needs are a growing concern for the planet. By 2030, an estimated 5 billion people will live in urban areas of the world, almost 60% of an 8.3 billion population (White et al., 2010). The Heat Island Effect occurs when more urbanized areas remain hotter than rural areas, in part due to synthetic surfaces re-emitting the sun's rays (EPA, 2020). In urban areas, the lack of large water bodies, deforestation, and natural landscapes add an extra 1-7 degrees Fahrenheit daytime temperature, and up to 5 degrees Fahrenheit nighttime temperatures compared to rural areas (EPA, 2020). Roads, buildings, and other structures contribute to the warming effects of the earth's surface, as opposed to natural surfaces absorbing and dissipating the heat properly (EPA, 2020).

In collegiate association football, universities can play and practice on both natural and artificial grass. These surfaces are not standardized and can change from facility to facility. NCAA fields range in dimensions between 70-75 yards in width and 115-120 yards in length as shown in Figure 3.

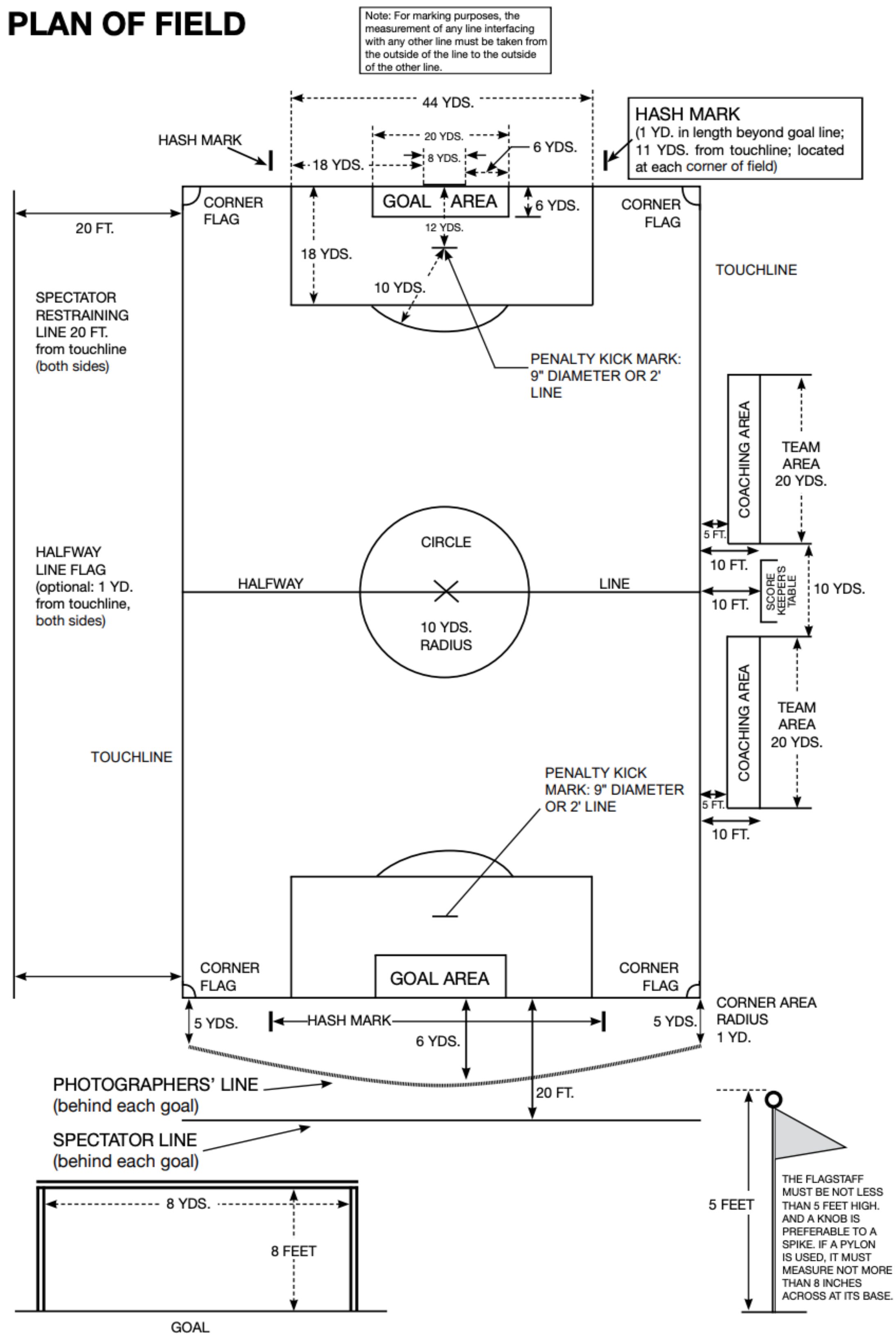


Fig. 3 Optimal Football Field Dimensions (NCAA, 2020)

This difference in dimensions can accommodate different playing styles, proper playing surfaces, and existing infrastructure (NCAA, 2020). For schools with artificial grass, the field is often shared with other sports such as American football, lacrosse, and field hockey and often contain the markings for these other sports.

Whether they are kicking around before a match or joining in a pick-up game, the environment for street football is rather informal. Traditionally, this game is played on any flat surface, wearing footwear closely resembles sneakers. Generally, the rubber used for the midsoles is denser, which enhances durability against the abrasive ground of asphalt (Parrish, 2018). Games can take place from school to the city plaza, focusing on quick touches, tricks, and speed of play.

Artificial Turf

Across the United States, synthetic turf fields are popping up more and more frequently. According to the Synthetic Turf Council, there are roughly 12,000-13,000 synthetic turf sports fields in the U.S., 1,200-1,500 added each year (Myrick, 2019). Because natural turf transpires water vapor into the atmosphere, it is rare to see a natural grass pitch reach over 100 degrees (Myrick, 2019). On the other hand, synthetic fields can easily rise to temperatures well over 100 degrees (Myrick, 2019). While the performance characteristics and health risks of synthetic surfaces are still being studied, it is well documented that synthetic ground heats the playing surface far more than the natural ground.

“Until temperatures can be reduced by at least twenty or thirty degrees for an extended period of time, surface temperature will remain a major issue on synthetic turf fields” (McNitt & Petrunak, 2010). Penn State University’s Center for Sports Surface Research conducted synthetic turf heat evaluation directly comparing the average temperatures of both natural and artificial surfaces. Both laboratory and outdoor tests were conducted on a variety of artificial surfaces, fibers, and fill. In the laboratory tests, each of the 11 samples was put under a 250-Watt infrared heat lamp and tested independently (McNitt & Petrunak, 2010). Although components including fibers and fill saw temperature change in some almost 20 degrees Fahrenheit, when implemented into turf systems the difference was only 12 degrees Fahrenheit after installation (McNitt & Petrunak, 2010). In the summer of 2011, outdoor testing was conducted using the only synthetic turf systems available at the time. With outdoor conditions reported as warm with clear skies, results recorded were similar to the laboratory tests (McNitt & Petrunak, 2010).

The use of synthetic pitches during peak hours may be unsafe for athletes and should be limited as much as possible (Myrick, 2019). Research has shown that when exposed to sunlight, synthetic turf playing surfaces can easily reach 40-70 degrees Fahrenheit higher than natural playing surfaces under the same conditions (Buskirk et al. 1971). On a day when outside temperatures were recorded at 98.6 degrees Fahrenheit, the synthetic turf surface temperature reached 199.4 degrees Fahrenheit (McNitt et al., 2007). Short-term solutions have also been evaluated such as painting the filled rubber a different color or watering the pitch before play. When the black rubber fill was painted white in attempts to reduce surface temperature, this resulted in only a few degrees difference (McNitt et al., 2007). With 30 minutes of irrigation, the synthetic surface temperature did drop to 84 degrees Fahrenheit (McNitt et al., 2007). However, within 5 minutes the temperature rose back to 120.2 degrees Fahrenheit, making it impractical for peak day performance (McNitt et al., 2007). Furthermore, the fill used in many synthetic turf surfaces is hydrophobic, making it more difficult to moisten the infill below, thus creating more water repellency than absorption (McNitt et al., 2007). With this in mind, footwear that helps alleviate this pain point is an area of innovation yet to be implemented in sports footwear.

Physiological & Biomechanical Needs of the Athlete

As mentioned above, college showcases are the most important step towards college and elite status. Over multiple days, athletes looking to impress scouts and coaches must perform to the best of their ability. Few players take into account the intense mental and physical stress their body is under when competing at the showcases (Deren, 2012). Injuries can compound quickly when the body is forced to perform at its peak from multiple games and skills tests that draw out every ounce of energy from the footballer. When tested, the heat transfer from the surface to the sole was reported as contributing a significant amount of psychological stress which may result in serious health-related injuries to the athlete (Abraham, 2019). Exercising in hot and humid climates makes it even more challenging when performing day in and day out. As the body tries to maintain homeostasis, repeated bouts of exercise especially in hot climates increase the rate of blood circulation from the core to the skin (Abraham, 2019). In this environment, dehydration and hyperthermia are great deals of concern (Abraham, 2019). By performing in these hot environments, thermoregulatory demands on the body pose a threat to peak intensity to maintain relative intensity and added stress on the cardiovascular system limits performance (Racinais et al., 2017). Adding fatigue into the mix, players may push their bodies to the limits when the thermal conditions created added barriers to performance.

The footwear in these environments is critical to their performance and overall comfort when competing. Thermal protection is critical when the body emits large amounts of heat in an environment that is already hotter than the footwear climate (Deren, 2012). Within the footwear, a fluctuation of heat occurs when blood flows through the foot's musculature. Accounting for roughly 7% of the body's surface, the feet undergo heat flux through the interacting surface's convection, which is accelerated during exercise (Covill et al., 2010). Heat transfer occurs when one environment is hotter than its surroundings. Homeostasis states that heat will transfer to level out and maintain a similar environment. When considering the temperatures of artificial surfaces in the heat, thermal radiation will gravitate towards the cooler climate of footwear as it makes direct contact with the surface (Deren, 2012). Analyzing the foot, sock, in-shoe air, ambient air, ground, and shoe materials are key to innovating around thermal comfort in these unique conditions (Covill et al., 2010). With this in mind, insulators such as the footwear midsole and insole have potential to slow the transfer of heat, though homeostasis is inevitable given enough time. What is more feasible is to slow this transfer of energy, giving the perception of thermal comfort within a short period of time. When exercising, the air is pumped in and around the internal climate of the shoe, involving the contact points of the foot and the materials that make it up (Covill et al., 2010). This pumping of air creates an increase in temperature, which can decrease thermal comfort if it has no escape (Covill et al., 2010). We must take into consideration the thermal conductivity of the sock and shoe materials, both the presence and restriction of airflow within the shoe, and the production and evaporation of sweat within the footwear microclimate that add to increasing footwear temperatures (Covill et al., 2010). In hot environments, the only way the skin can cool down is by producing sweat which will need to evaporate to have a cooling effect (Deren, 2012). Since heat conduction and convection are counterproductive in this case, thermoregulation is not possible which causes a decline in thermal comfort for the player (Covill et al., 2010).

Player Positions

Broken into 4 player positions, formations consist of a goalkeeper, defenders, midfielders, and forwards. The goalkeepers' role in the team is to keep the ball out of their own teams' net.

Sporting a different colored jersey than their team, this player is allowed to save a ball with any part of their body and handle the ball with their hands within their 18-yard box for up to 6 seconds. Most goalkeepers operate within their box though they are allowed to move anywhere on the field (United States National Soccer Team Players Association, n.d.). These players possess fast reflex skills and quick thinking. Defenders are the last line of defense before the goalkeeper (Dodd, 2020). In the traditional 4-3-3 formation, the defenders are divided into two categories: center back and full back. The center backs' territory is predominantly centered on the field and is responsible for preventing plays that run through their half of the field. Full backs are less limited on the pitch and share both attacking and defending duties. They operate along the outer touchlines on the field and supply runs and crosses to players in their opponents' 18-yard box (Bundesliga, 2020). Midfielders establish the tempo of the game and supply the ball to all positions around the field (United States National Soccer Team Players Association, n.d.). These midfield positions can be categorized by territory, much like defenders. Defending midfielders help the defense transition the ball from their half and into the feet of more attacking players. Central midfielders operate more centrally on the field and share attacking and defending responsibilities. Lastly, attacking midfielders join the forwards in creating scoring opportunities and taking shots on goal (Bundesliga, 2020). Finally, forwards play closest to their opponents' goal and are tasked with scoring. The two main categories of this position are center forwards and outside forwards. Outside forwards play mainly on the perimeter of the opponents' half and supply crosses and runs in and around the box. Center forwards stay close to the opponents' 18-yard box and connect with other attacking players to create chances on goal (Dodd, 2020).

Unlike association football, street football is a more casual form of the game. Teams are smaller and may even be uneven. These pick-up games are a gateway to start larger games and can be played with 5-7 players on each team, with or without designated goalkeepers (5-a-side.com, n.d.). As demonstrated in Figure 4, players of all ages join in and form teams.

Fig. 4 Street Football Around the World (Townsend, 2015)

For the general rules, many follow FIFA's futsal rules, the indoor version of football. Futsal allows for 5 players on the court at a time. The formation consists of a goalkeeper, a defender, 2 midfield players, and 1 forward. The outfield players can move more freely and play quicker for fast combinations and more opportunities on goal. (5-a-side.com, n.d.). With a condensed pitch, this allows for more touches on the ball and increased speed of play.

Keys to Success

Overall, success in this sport is simply scoring more goals than the opponent. Everywhere on the field are matchups that help the team achieve the common goal of putting the ball in the back of the net. Different from indoor football and full-field 11-a-side, street football focuses on a rapid speed of play along with many more touches in small spaces on the small pitch. Younger players are encouraged to play because it develops habits that can be translated into a larger field and helps build confidence due to its quick pace (Nagel, 2014).

Routes to Collegiate Football Within the United States

Regardless of the continent, becoming a professional footballer is merely a dream for millions of players around the world. To achieve a collegiate football career takes dedication and connections (Next College Student Athlete, n.d.). Opportunities are drastically different in the U.S. due to the link between teams and the education system (Ertheo Sports Programs, n.d.). Though there is no specific blueprint as to how to get into a varsity collegiate football team, it is recommended that kids begin the process at a young age just like European academies. From ages 5-9 years old, it is recommended that players join travel teams to experience a variety of competitions and form relationships with coaches (Ertheo Sports Programs, n.d.). This is different from recreational football, such as the American Youth Soccer Organization (AYSO), where competition is less emphasized. Between ages 9-17, it is suggested that the player joins a United States Soccer Development Academy (USSDA) program to strengthen their skills should they be qualified (Ertheo Sports Programs, n.d.). These travel clubs expose the player to stronger opponents and are one of the best ways to remain visible to scouts. In the later years, high school football should be included in the mix. From ages 15-18, players should be connecting with college coaches and attending trials and ID camps to gain recognition from college coaches (Ertheo Sports

Programs, n.d.). Furthermore, often competes with travel teams or a USSDA teams which offer stronger competition and greater exposure (Next College Student Athlete, n.d.).

Cleat Categories

As more pitches are installed across the country, specialized cleats and footwear have been created to provide players with optimal traction and performance when playing at their local field. On natural or artificial turf, cleat categorizations depend primarily on the stud configurations of the cleated soleplate. These categories fall under soft ground (SG), firm ground (FG), and artificial ground (AG) shown below in Figure 5.

Fig. 5 Stud Pattern Variations (Footy Headlines, 2018)

Firm-ground stud patterns are the most versatile and most common across all field environments (Footy Headlines, 2018). Since natural grass has substantial give, a more aggressive stud pattern is preferred as it allows for a quicker change of movement and quicker accelerations and decelerations. On AG sole plates, the synthetic turf is more abrasive and requires a less aggressive traction pattern (Footy Headlines, 2018). Having the proper stud pattern for the playing surface is essential to footwear performance as it was intended.

Competitor Analysis - Firm Ground/Artificial Ground Boots

These products were selected as they are the most similar products from the top football brands, and obtainable within the United States.

	***Nike Mercurial Superfly 7 Elite AG-PRO*** MSRP: $275 USD ● 360-degree Flyknit construction for a second-skin feel ● Nike Aerow Trac zone for increased responsiveness ● NikeGrip System reduces slippage within the boot ● New high-tenacity yarn & one-piece lining for a seamless fit ● Ultra-thin NikeSkin overlay for a barefoot feel ● Best for synthetic pitches (Pro: Direct Sport)
	***adidas Nemeziz .1 AG*** MSRP: $225 USD ● Laced closure ● Primeknit upper for 360-degree lockdown ● Mid-cut collar for support ● Optimized for artificial grass (Pro: Direct Sport)

Puma Ultra 1.1 FG/AG
MSRP: $200 USD

- Lightweight MATRYXEVO woven upper
- Constructed with reactive aramid & carbon fiber for support
- GripControl Pro coating for improved touch
- Removable sockliner with Nano Grip technology
- Pebax SpeedUnit outsole for lightweight traction
- Suitable for firm natural surfaces & artificial grass

(Pro: Direct Sport)

Competitor Analysis - Futsal/Indoor/Court Shoes

Nike React Gato IC
MSRP: $140 USD

- Flexible rubber pods for underfoot feel on the ball
- React cushioning for maximum control
- Lightweight Flyknit upper fused with compound for upper grip
- Reinforced toe band

(Pro: Direct Sport)

adidas X Ghosted .1 IN
MSRP: $120 USD

- Ultralight Fluroskin upper with a wireframe support system for stability
- Lightstrike cushioning for forwarding propulsion
- Low-cut collar for a range of motion
- Laced vacuum fit

(Pro: Direct Sport)

Puma 365 Ignite Fuse 1 IN
MSRP: $140 USD

- Fusefit knitted upper for customizable lacing to enhance support & fit
- Ignite foam midsole and heel cage supports & stabilizes
- Suitable for all types of hard ground
- Fully knitted upper
- Grip for quick movements & optimal cushioning

(Pro: Direct Sport)

S.W.O.T. Analysis of Firm Ground/Artificial Ground Boots

Product	Strength	Weakness	Opportunities	Threats
Nike Mercurial Superfly 7 Elite AG-PRO	+ Traction system designed specifically for an artificial surface (Vujovic, 2020)	- Added material that adds thickness and weight - Softer soleplate (Vujovic, 2020)	• Incorporate thermal material to create barrier between foot • Optimize for added heat within the soleplate	• Perception of traction using conical studs
adidas Nemeziz .1 AG	+ Less aggressive studs for artificial surfaces + Same upper material as premium boot + Same cost (Vujovic, 2020)	- Lack of split tooling - Extra width compared to FG boots (Vujovic, 2020)	• Hollow out studs to reduce weight • Create a unique outsole with more points of contact in the form of bumps	• Basic outsole • Different shoe completely when compared to a laceless model
Puma Ultra 1.1 FG/AG	+ Reactive Kevlar and carbon yarns for support + Grip coating provides control in rain + Comfortable ankle collar + Affordable (Byrne, 2020)	- MATRYXEVO upper doesn't offer a lot of give - Pressure in the heel - Traction geared towards firm ground (Byrne, 2020)	• Targeted grip coating placed in areas prone to sole separation • Metal thread variations could change thermal properties • Design around conical studs for easier rotation	• Upper material very different than previous Puma speed boots

S.W.O.T. Analysis of Futsal/Indoor/Court Shoes

Product	Strength	Weakness	Opportunities	Threats
Nike React Gato IC	+ Nike Touch360 + Nike Flyknit for lockdown + Nike React for energy return (Vujovic, 2020)	- Using Touch 360 pods may seem gimmicky (Vujovic, 2020)	● Lightweight upper that reflects light away from feet ● Integrated colling material within the midsole	● Too much technology that confuses the consumer ● Threatens the validity of design meant to help an athlete perform
adidas X Ghosted .1 IN	+ Same upper material as X .1 + Lightweight and responsive (Vujovic, 2020)	- Outsole made for indoor - Different fit than FG version - Glued in insoles on a premium shoe (Vujovic, 2020)	● Different material choice for better breathability and reflectivity of radiation	● May spike price that most are unwilling to pay
Puma 365 Ignite Fuse 1 IN	+ Unlimited lacing options + Variation and customization + Fits different shapes of feet (Vujovic, 2017)	- Inconstant feel on the ball - Lack of response due to custom lacing (Vujovic, 2017)	● Secure fit that enhances airflow within the footwear ● Abrasion resistant upper for asphalt surface	● Seamlessly incorporating lacing system without changing concept completely

Patent Landscape

Relevant patents that directly relate to the thermoregulation of soles & uppers.

A43B7/005 - Footwear with cooling arrangements:

- Shoe inserts used for cooling the foot (U.S. Patent No. 20080028637 A1, 2007)
- Flow Insole - generates air circulation (U.S. Patent No. 20200037696 A1, 2012)
- Method and apparatus for cooling footwear (U.S. Patent No. 20130019503 A1, 2012)
- Footwear article having a temperature regulation system (U.S. Patent No. 20140259790 A1, 2014)

Materials

The materials used in football boots today are most often synthetic. Uppers that replicate the feeling of real leather are possible, as well as knit uppers that can be precisely engineered. The synthetic knits are knitted together in one piece and can change density where more support is needed. In Puma's Ultra, their synthetic knit upper is blended with polyester and carbon yarns mixed with aramid fibers (Puma, 2020). Changing the density and material blend between the medial and lateral sides, the boot has built-in stability for quick directional changes. Today, knit uppers are constructed on a 4D knitting machine where there is little to no offcut. This knitting machine allows for the engineered knit to have added structure and density where it is instructed. In Nike's Mercurial Superfly 7 Elite, the high tenacity yarns are made from polyester yarns with a tensile strength of 6 grams-force per denier (U.S. Patent No. 2012138488A3 A1, 2011). Coatings and synthetic overlays also cover the upper which provides grip and an improved touch on the ball. Less conventional may be 3M Tegaderm, a lightweight yet breathable film dressing (Kaplan, (2018). While being very lightweight, this transparent dressing is also incredibly flexible, making it easy to mold to complex geometry and remain close to whatever it is adhered to (Kaplan, (2018). Although used in the medical industry, this upper layer can be added to fabrics to create a barrier between the footwear upper and the playing environment. Both 100% synthetic, Puma's (Puma, 2020) and Nike's coating, NikeSkin (McCole, 2019), allow for enhancing grip across their thin synthetic upper. For the midsole and studs, an injection mold is used, creating a firm yet snappy soleplate that later gets glued to the upper material. On Nike's current AG models, a Texon® shield is inserted to alleviate the feet from added heat on artificial turf (Nike, 2016).

Manufacturing

The process of manufacturing today's football boots is broken down into collecting and cutting out materials, printing graphics and logos, stitching the boot together, lasting and assembly, and then a final quality control check before it is packaged and distributed (Nunley, 2009).

Fig. 6 Cleat Construction (DICK'S Sporting Goods, n.d.)

Creating and cutting the upper material comes first as it takes the most steps in creation. Nowadays, these materials are often polyurethane textiles or knits that are then coated in with a polyurethane. Once the upper is patterned, it is then cut out using a large stamping machine. The second step is to apply the graphic elements to the upper before all the other components are stitched in place. This may include embossing logos or textures onto the upper material, while stitching combines all of the cut pieces into a seamless upper (Nunley, 2009). At this point, the lasting and assembly process can begin. According to Texon, both Strobel and non-woven insole inserts can be implemented into footwear (Texon, 2016). The non-women Texon insole is ideal for cement or board lasting whereas the Strobel insert can be directly sewn into the upper (Texon, 2016). This technology can Lasting allows the boot to form its shape, and by adding cement, the upper and midsole will stick together. While many different materials can be used for lasting, my new innovation takes aerogel technology to create the barrier between the upper and tooling. Insulating at both hot and cold conditions, silica aerogel is one of the best know insulators in existence (Aspen Aerogels Industrial Aerogel Insulation, n.d.). Starting as a solid of gel, the liquid component is then replaced with gas, making up 97% of the materials mass. This creates and extremely lightweight, yet powerful thermal insulator that can be manufactured into flexible sheets (Aspen Aerogels Industrial Aerogel Insulation, n.d.). Once the strobel of choice is selected, by using a UV light, the cement will turn to glue, allowing for full coverage between the two elements (Parrish, 2018). Using a hydraulic press, the two components are pressed together to form a bond. Finally, the studs are screwed or pressed into place (Parrish, 2018). After all these processes, it is time for quality control and packaging. This consists of checking for any imperfections in the upper and stitching, color matching, and size fitting (Nunley, 2009). Once approved the boot is ready to be wrapped and put into its respective box.

Graphics and Color

In material design, flashy colors can be in the DNA of the boot silo, and materials can play a large part in that process. Explored by NASA, space blankets were invented which contain body heat and slow down thermal radiation. Paper-thin, this technology has evolved into thin, metalized films that can be used in various ways of manufacturing products (Sigma Technologies, 2016). From astronauts to firefighters, aluminum foil laminates and metalized films can protect from environments normally hazardous to the human body. In this application, heat reflective fabric would not only shine bright on the pitch but create a thermo-protective layer between the boot and playing surface (Sigma Technologies, 2016). In cases of extreme heat, these reflective materials can not only withstand abnormally hot climates but provide a different type of color than what is most common in the football boot industry.

Strengths for Innovation

Within the United States, it can be more difficult to find elite products specific to these artificial playing surfaces. Up until now, players in the U.S. could not get their hands-on artificial ground cleats from Nike and would have to settle for a cheaper alternative, multi ground. As more artificial pitches are being installed, this playing surface may account for more than half of players' games, making this a better solution for traction, durability, and overall safety. Over the years, the regularity of artificial grass fields will create a need for thermoregulative football footwear. Reflective materials within footwear are also on the horizon as new material technologies are being introduced in a variety of uses. Furthermore, current patents do not account for this system, making it a unique environment to explore and design within.

Professional Development

This footwear project aligns best with my strengths as it provides opportunities to think critically about a sport I am so attached to, compete against the current product on the market, and ideate in a product space that is a different way of thinking than traditional cleats and footwear.

As an innovator, I plan to use my undergraduate background in multimedia production to design and create footwear solutions and display them in a professional manner that sells my idea. It has been my goal since high school to be a football designer at the highest level with brands such as Nike, adidas, and Puma. Thinking about future technologies and innovation that can change the sport in an impactful way, as this project will allow me the opportunity to dive deep into a sport that I know most and allow me to connect with experts in the design/footwear industry that can elevate my work to new heights.

Bibliography

Abraham, J. (2019, April 1). Heat risks associated with synthetic athletic fields. *International Journal of Hyperthermia*, *36*(1). Taylor & Francis. 10.1080/02656736.2019.1605096

Aspen Aerogels Industrial Aerogel Insulation. (n.d.). *About Aerogel and Aerogel Insulation*. Retrieved January 5, 2021, from https://www.aerogel.com/resources/about-aerogel/#:~:text=Invented%20in%201931%20by%20Dr,has%20been%20replaced%20with%20gas.&text=These%20characteristics%20make%20aerogels%20the,and%20most%20effective%20thermal%20insulator.

Bundesliga. (2020, October). *Soccer positions explained: names, numbers and what they do*. Bundesliga. Retrieved December 6, 2020, from https://www.bundesliga.com/en/bundesliga/news/soccer-positions-explained-names-numbers-what-they-do-2579-786

Buskirk, E. R., McLaughlin, E. R., & Loomis, J. L. (1971). Microclimate over Artificial Turf. *Journal of Health, Physical Education, Recreation*, *42*(9), 29-30. Taylor & Francis. 10.1080/00221473.1971.10617177

Byrne, B. (2020, September 7). *Puma ULTRA 1.1 Review*. Soccer Cleats 101. Retrieved November 23, 2020, from https://www.soccercleats101.com/2020/09/07/puma-ultra-1-1-review/

Byrne, B. (2020, September 9). *Nike Phantom GT Elite Boot Review*. Soccer Cleats 101. Retrieved November 23, 2020, from https://www.soccercleats101.com/2020/09/09/nike-phantom-gt-elite-boot-review/

Chua, J. (2020, May 12). *Review: Puma Future 5.1*. Boothype. Retrieved November 24, 2020, from https://boothype.com/2019/12/05/review-puma-future-5-1/#:~:text=The%20Future%20is%20bright&text=Overall%2C%20the%20Puma%20Future%205.1,it's%20also%20not%20too%20heavy.

Chua, J. (2020, November 12). *Review: adidas X Ghosted .1*. Boothype. Retrieved November 24, 2020, from https://boothype.com/2020/11/12/review-adidas-x-ghosted-1/

Covill, D., Guan, Z., Raval, H., & Bailey, M. (2010, August 2). Development of Thermal Models of Footwear Using Finite Element Analysis. Proceedings of the Institution of Mechanical. *Proceedings of the Institution of Mechanical Engineers.*, *225*(3), 268-281. 10.1243/09544119JEIM860

Crocombe, M. (2019, July 22). *The Origin, History, and Invention of Soccer*. liveaboutdotcom. Retrieved November 10, 2020, from https://www.liveabout.com/who-invented-soccer-3556873

Deren, T. (2012). An Analysis of Thermoregulatory Sweating and Heat Balance in American Football Linemen and Backs. *University of Ottawa*. Retrieved December 5, 2020, from https://ruor.uottawa.ca/handle/10393/20644

DICK'S Sporting Goods. (n.d.). *Five Tips for Buying Kids' Soccer Cleats*. Pro Tips. Retrieved December 1, 2020, from https://protips.dickssportinggoods.com/sports-and-activities/soccer/5-tips-for-buying-kids-soccer-cleats

Dodd, M. (2020, April 4). *Positions in Soccer and Their Roles*. How They Play. Retrieved December 6, 2020, from https://howtheyplay.com/team-sports/Positions-in-Soccer-and-Their-Roles

EPA. (2020, August 24). *Heat Island Effect*. United States Environmental Protection Agency.

Retrieved November 17, 2020, from https://www.epa.gov/heatislands#:~:text=Heat%20islands%20are%20urbanized%20areas,as%20forests%20and%20water%20bodies.

Ertheo Sports Programs. (n.d.). *How to become a professional soccer player*. Ertheo. Retrieved November 15, 2020, from https://www.ertheo.com/blog/en/becoming-professional-footballer/#:~:text=to%20the%20top-,Steps%20to%20becoming%20a%20pro%20soccer%20player%20in%20the%20US,your%20knowledge%20of%20the%20game.

The FA. (n.d.). *THE HISTORY OF THE FA*. The FA. Retrieved November 10, 2020, from https://www.thefa.com/about-football-association/what-we-do/history

FIFA. (2007, January 23). *The History of Football*. FIFA.com. Retrieved November 10, 2020, from https://www.fifa.com/news/the-history-football-425

5-a-side.com. (n.d.). *Positions for 5-A-Side*. 5-a-side positions: Find Your Best Spot. Retrieved November 16, 2020, from http://www.5-a-side.com/tactics/5-a-side-positions/

Footy Headlines. (2018, August 8). *Compare All Nike Phantom Vision Boots Sole Types - FG vs AG vs SG-Pro Anti-Clog vs Indoor vs Turf Versions*. Footy Headlines. Retrieved November 30, 2020, from https://www.footyheadlines.com/2018/08/compare-all-nike-phantom-vision-boots-sole-types.html

Kaplan, M. (2018, February 12). *From Tegaderm sizes to shapes - Everything to know about it*. Save Rite Medical. Retrieved April 15, 2021, from https://www.saveritemedical.com/blogs/news/from-tegaderm-sizes-to-shapes-everything-to-know-about-it-3m-tegaderm-film-1626w

Khodaee, M., Currie, D. W., Asif, I. M., & Comstock, D. R. (2017, January 18). Nine-year study of US high school soccer injuries: data from a national sports injury surveillance programme. *British Journal of Sports Medicine*, 51(3). https://bjsm.bmj.com/content/51/3/185

Lange, D. (2020, November 26). *Number of participants in U.S. high school soccer 2018/19*. Statista. Retrieved November 30, 2020, from https://www.statista.com/statistics/267963/participation-in-us-high-school-soccer/

Litterer, D. (2010, May 31). *An Overview of American Soccer History*. The American Soccer History Archives. Retrieved November 15, 2020, from https://soccerhistoryusa.org/ASHA/overview.html

McCole, A. (2019, August 19). *Deep Dive Instep Review: Nike Mercurial SuperFly VII*. SoccerPro.com. Retrieved November 23, 2020, from https://www.soccerpro.com/theinstep/deep-dive-instep-review-nike-mercurial-superfly-vii/

McNitt, A. S., & Petrunak, D. M. (2010). Evaluation of playing surface characteristics of various infilled systems. *University Park, PA: Center for Sports Surface Research, Pennsylvania State University.* Retrieved November 17, 2020, from http://www.groundsmartrubbermulch.com/docs/resources/Evaluation-of-Playing-Surface-Characteristics-of-Various-In-Filled-Systems.pdf

McNitt, A. S., Petrunak, D. M., & Serensits, T. J. (2007, June). Temperature amelioration of synthetic turf surfaces through irrigation. *II International Conference on Turfgrass Science and Management for Sports Fields,* 783 (pp. 573-582). 10.17660/ActaHortic.2008.783.59

Myrick, S. (2019, May 18). Synthetic Sports Fields and the Heat Island Effect. *National*

Recreation and Park Association. Retrieved November 17, 2020, from https://www.nrpa.org/parks-recreation-magazine/2019/may/synthetic-sports-fields-and-the-heat-island effect/#:~:text=Another%20study%20conducted%20at%20Brigham,skin%20contact%20in%20two%20seconds.%E2%80%9D

Nagel, A. (2014, May 24). *The Benefits of Pick Up Soccer.* Skyline Soccer. Retrieved December 10, 2020, from http://www.skylinesoccer.org/benefits-pick-up-soccer/

NCAA. (2020, August 26). *2020 and 2021 NCAA Men's and Women's Soccer Rules*. National Collegiate Athletic Association. Retrieved November 30, 2020, from http://www.ncaapublications.com/productdownloads/SO21.pdf

Next College Student Athlete. (n.d.). *How to Find the Right Men's Soccer Tournaments, Camps and Showcases*. NCSA. Retrieved November 15, 2020, from https://www.ncsasports.org/mens-soccer/tournaments-camps-showcases#:~:text=College%20men's%20soccer%20camps%20and%20clinics&text=In%20general%2C%20an%20ID%20camp,lasting%20one%20or%20two%20days.

Nike. (2016, October 3). *Nike Football's Traction Revolution.* Nike News. Retrieved December 13, 2020, from https://news.nike.com/news/nike-football-s-traction-revolution

Nunley, K. (2009, October 22). *How Are Soccer Cleats Made?* SportsRec. Retrieved December 6, 2020, from https://www.sportsrec.com/soccer-cleats-made-5557014.html

Parrish, R. (2018, November 16). *The Advantage of Indoor Soccer Shoes*. SportsRec. Retrieved December 6, 2020, from https://www.sportsrec.com/1007854-fix-toe-shoe-rubber-sole.html

Puma. (2020, August 12). *PUMA UNLEASHES UNCATCHABLE SPEED WITH THE NEW*

ULTRA. Puma. Retrieved December 6, 2020, from https://about.puma.com/en/newsroom/brand-and-product-news/2020/2020-08-12-ultra_1_1

Racinais, S., Cocking, S., & Périard, J. D. (2017, August 4). Sports and environmental temperature: From warming-up to heating-up. *US National Library of Medicine National Institutes of Health*, *4*(3), 227–257. US National Library of Medicine National Institutes of Health. 10.1080/23328940.2017.1356427

Scholarship Stats.com. (2020). *Odds of a High School Soccer Player competing in College 2020*. Scholarship Stats.com. Retrieved November 17, 2020, from https://scholarshipstats.com/soccer

Sigma Technologies. (2016). *6 Applications for Heat Reflective Fabric*. Sigma Technologies. Retrieved December 6, 2020, from https://www.sigmalabs.com/blog/6-applications-for-heat-reflective-fabric

Stockdale, C. (2019, June 22). *The 50 hottest cities in America: Phoenix tops the list*. USA Today. Retrieved December 7, 2020, from https://www.usatoday.com/story/money/2019/06/22/50-hottest-cities-in-america/39599939/

Texon. (2016). *Materials User Guide.* Texon Material User Guide. Retrieved December 13, 2020, from https://www.texon.com/wp-content/uploads/2018/01/Texon-Material-User-Guide4.3-WEB.pdf

Townsend, J. (2015, February 18). *The Culture Wars of American Soccer*. Far Post Footy. Retrieved November 30, 2020, from https://farpostfooty.com/2015/02/18/articles-the-culture-wars-of-american-soccer/

United States National Soccer Team Players Association. (n.d.). *Beginners Guide to Soccer*. United States National Soccer Team Players. Retrieved November 15, 2020, from https://ussoccerplayers.com/beginners-guide-to-soccer

U.S. Soccer. (n.d.). *Timeline*. US Soccer Timeline. Retrieved November 15, 2020, from https://www.ussoccer.com/history/timeline

Vujovic, J. (2020, February 12). CREATE YOUR OWN LACING SYSTEM! - Puma 365 Ignite NETFIT Indoor - Review + On Feet [Video]. YouTube. https://www.youtube.com/watch?v=qzL2fYvzzoI&t=672s

Vujovic, J. (2020, July 6). IT'S ABOUT TIME THEY DID THIS! [Video]. YouTube. https://www.youtube.com/watch?v=NdwvJ_d3vas

Vujovic, J. (2020, April 26). NEW BOOTS FOR RONALDO & MBAPPÉ FOR WHEN FOOTBALL COMES BACK! [Video]. YouTube. https://www.youtube.com/watch?v=9soakDtyBrI&t=475s

Vujovic, J. (2017, October 21). THE MOST HIGH-TECH INDOOR FOOTBALL BOOTS EVER! [Video]. YouTube. https://www.youtube.com/watch?v=OdOSSnGJFPo

Vujovic, J. (2020, November 23). We waited 10 years for Adidas to make these! [Video]. YouTube. https://www.youtube.com/watch?v=FH9DAX95nIk

White, P., Golden, J. S., Biligiri, K. P., & Kaloush, K. (2010, September). Modeling climate change impacts of pavement production and construction. *ScienceDirect*, *54*(11), 776-782. Retrieved November 30, 2020, from https://www.sciencedirect.com/science/article/pii/S0921344909002869?casa_token=85CMwDTza_wAAAAA:KqunUjEs4pWwkNOZKx4iNDfungCxOkjJAuqits3H-NjTWgxlsgZG1vgJQ7S5AoIelE5wfjtBIg

REFRACT

FOOTBALL

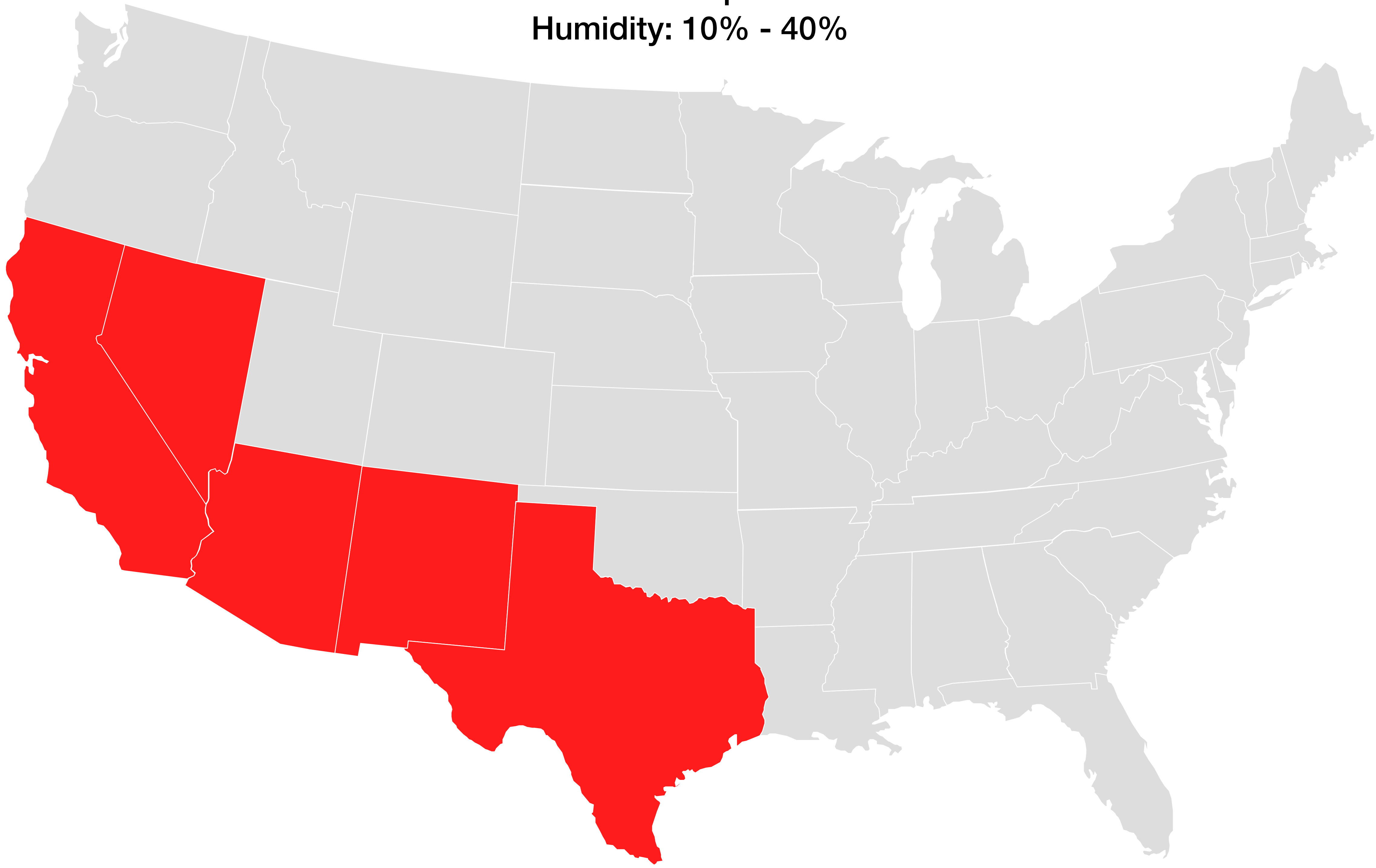
PLAYING

SURFACE

When the air is 94°F

Southwest Sun Belt

Summer temp: 90°F+
Humidity: 10% - 40%



ATHLETE

PAIN POINTS

Heat-Related Injuries

- Blisters
- Foot Swelling

Decreased Activity

- Reduced time to be active
- Decrease peak performance

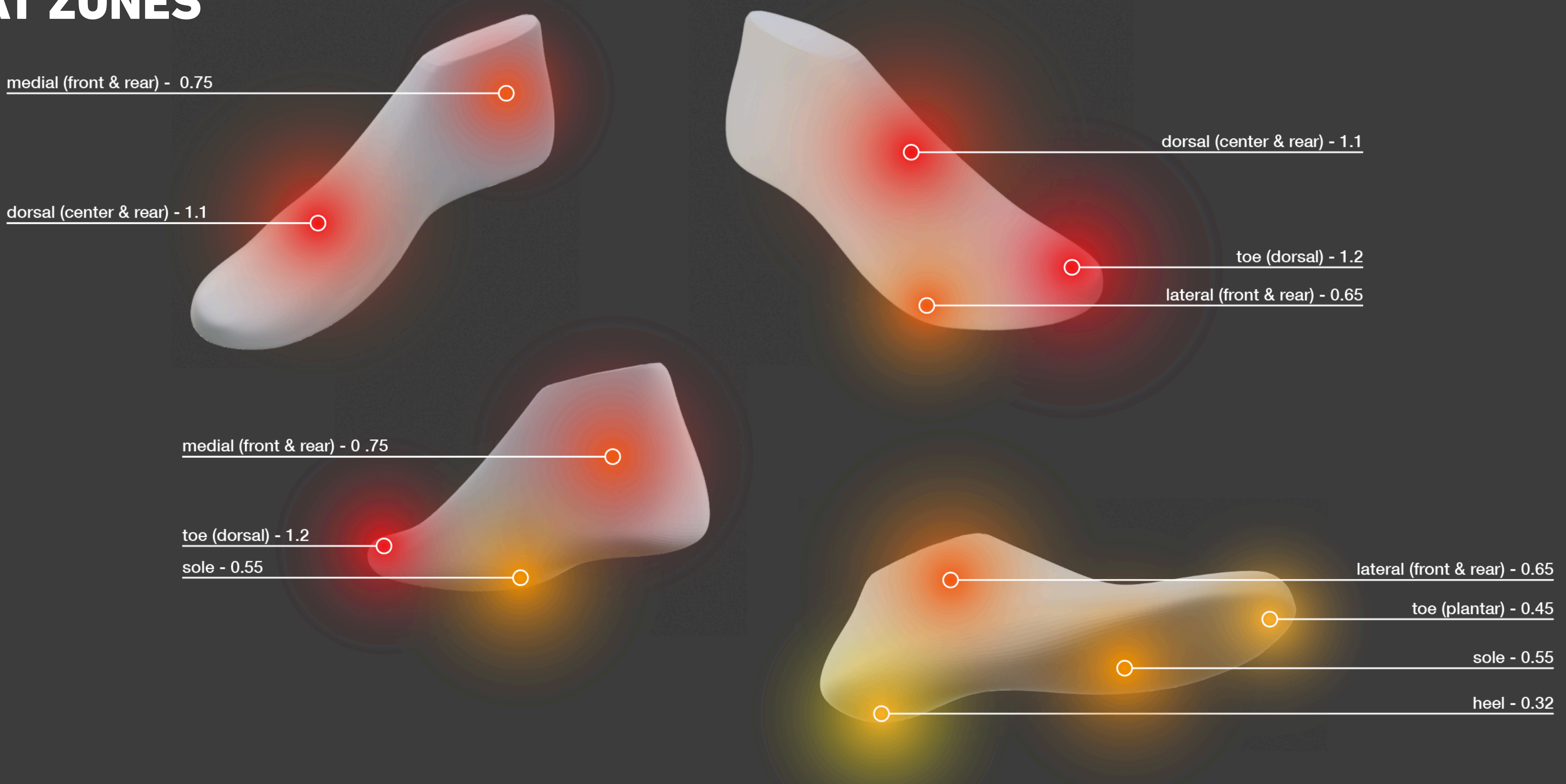
Artificial Grass is the Industry Standard

- 1,200 - 1,500 fields added each year
- Calls for optimized footwear

MALE SWEAT DISTRIBUTION ON THE HUMAN FOOT POST EXERCISE

FOOT

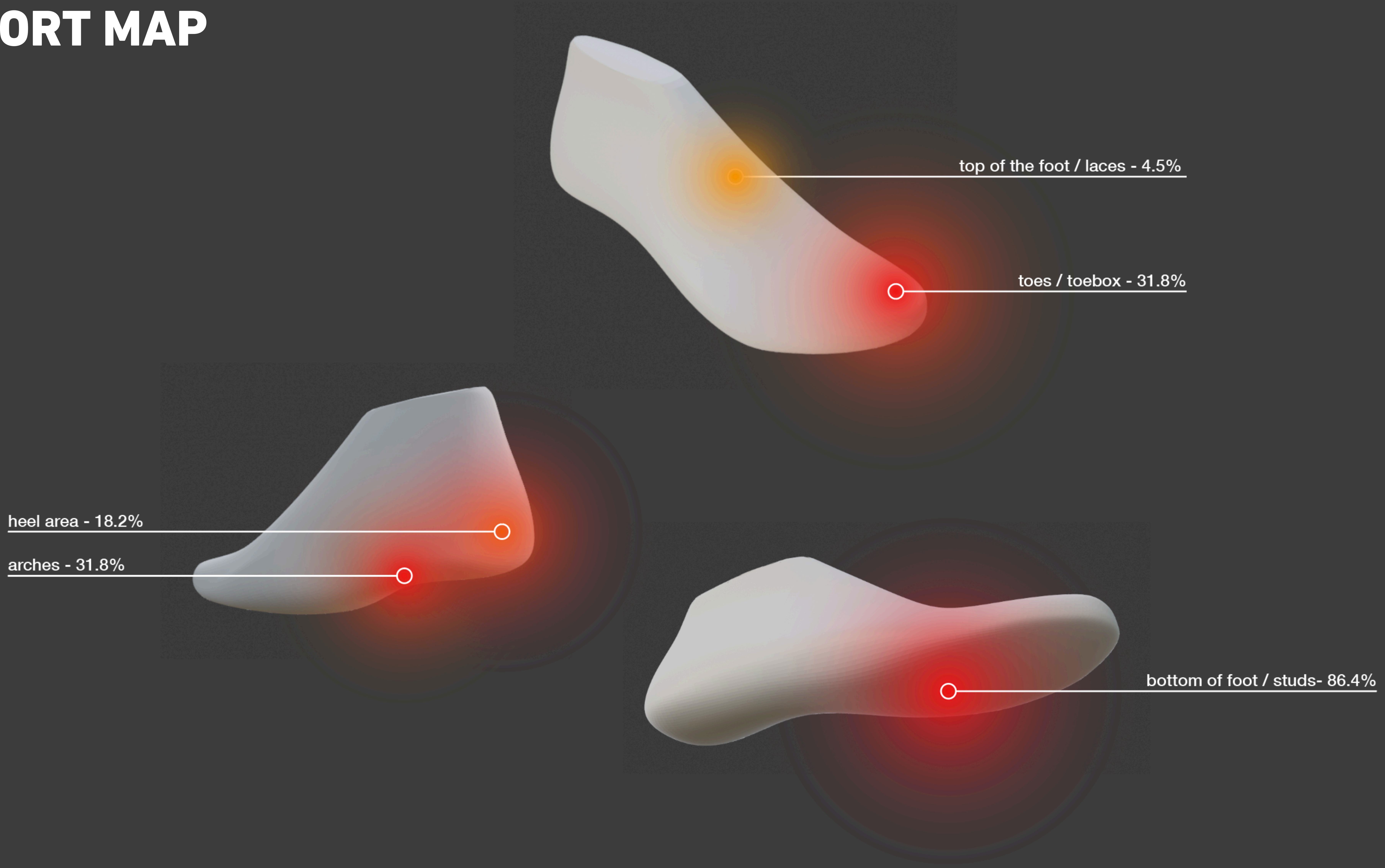
SWEAT ZONES



High-Intensity Exercise Sweat Rate (mg.cm^{-2}.min^{-1})

FOOT DISCOMFORT AFTER PLAYING ON TURF

FOOT
DISCOMFORT MAP



*Results from 22 Responces (multiple choice)

CONSUMER RESEARCH - 22 RESPONSES

FOOTWEAR NEEDS

What are the most important components of an artificial grass football cleat?

1. Thermal Comfort
2. Touch
3. Weight

What are the most important components of a street football shoe?

1. Thermal Comfort
2. Traction
3. Stability

Do you have any remedies for thermal comfort when playing on hot artificial turf or asphalt (insoles, double sock, water, etc.)?

“Walk on different parts of your feet.”

“Sometimes double sock.”

“Spray water for temporary relief, but often it makes it worse.”

“No.”

“Keep moving or stay off them during breaks.”

How would you improve your thermal comfort when playing on hot artificial surfaces?

“Anything with a thick sole.”

“I genuinely do not know.”

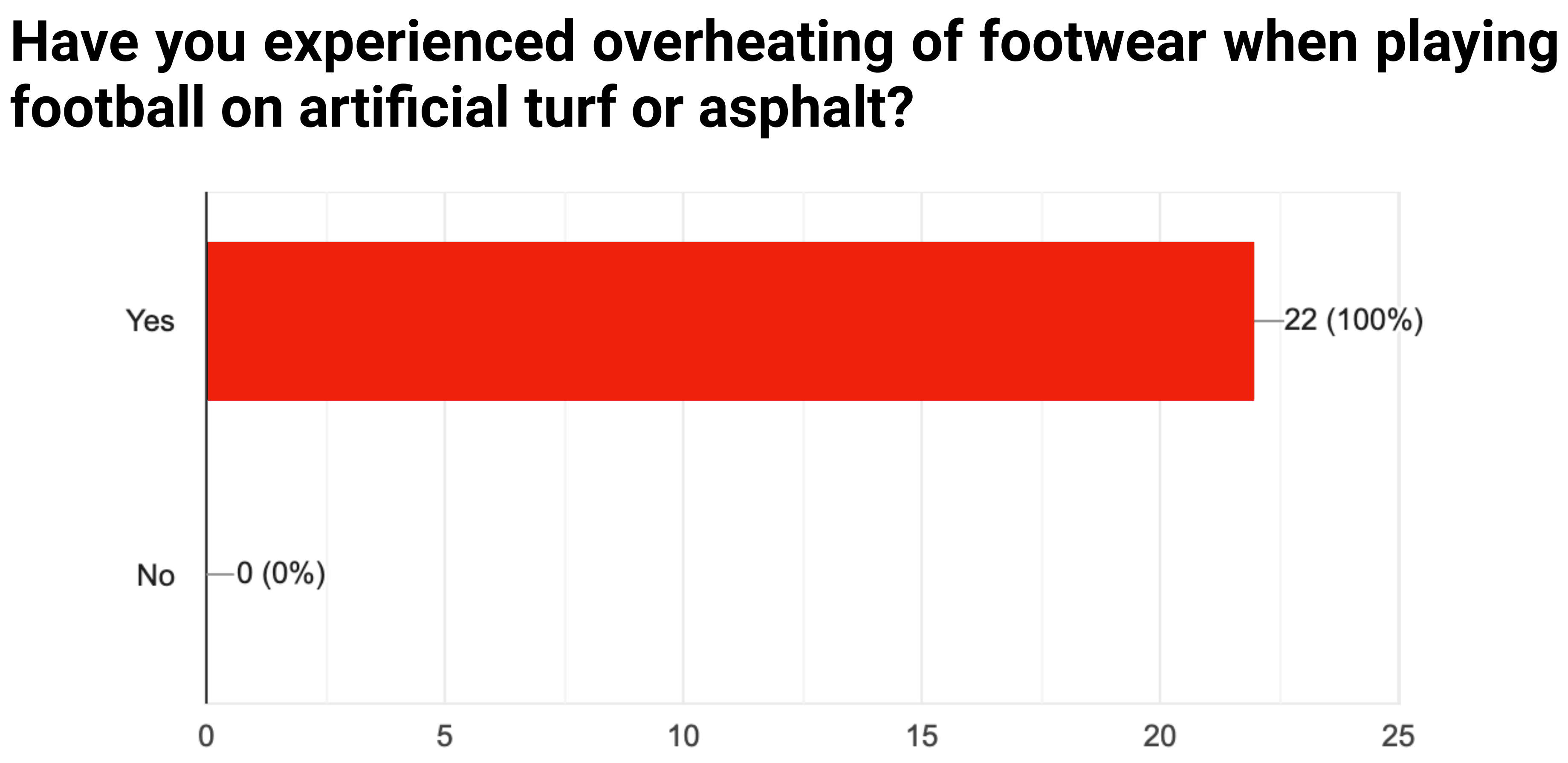
“More cushion I’m sure is better.”

“Cleats with a white sole.”

“Lighter colored cleats.”

CONSUMER RESEARCH

FINAL TAKEAWAY



“Stepping onto the field is like stepping onto a battlefield, anything can happen and you have to do whatever it takes to win. Every moment matters, and the heat doesn’t care if you’re tired, it is relentless and won’t let up on you. At the end of the day, the game is just 11 individual battles and your job is to do everything you can to win yours.” - ***Quanah Brayboy | D1 Midfielder at Yale University***

PROJECT

PROBLEMS TO SOLVE

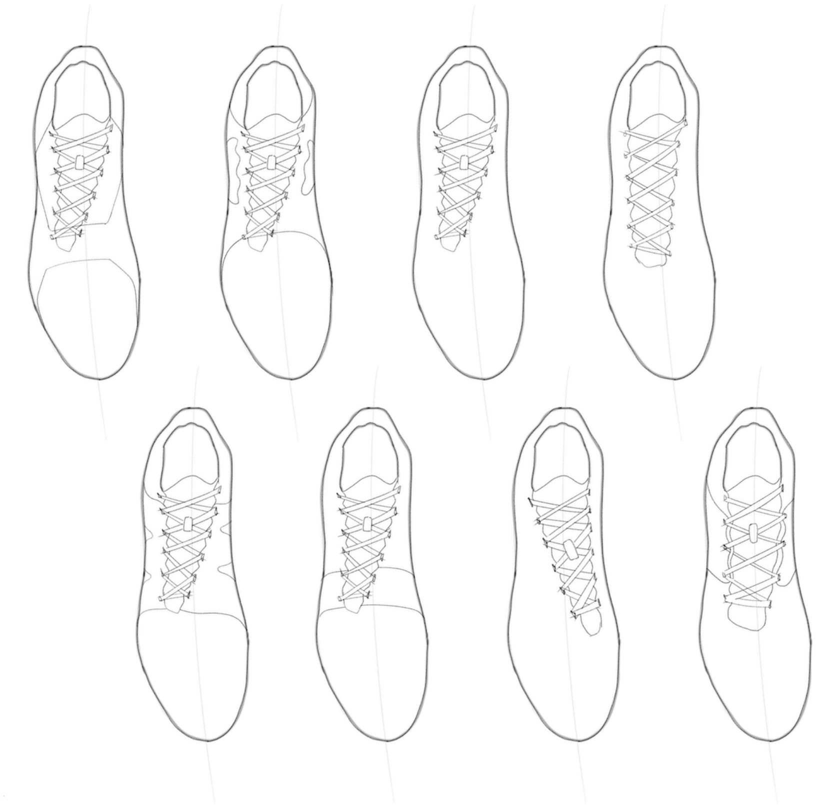
Asphalt

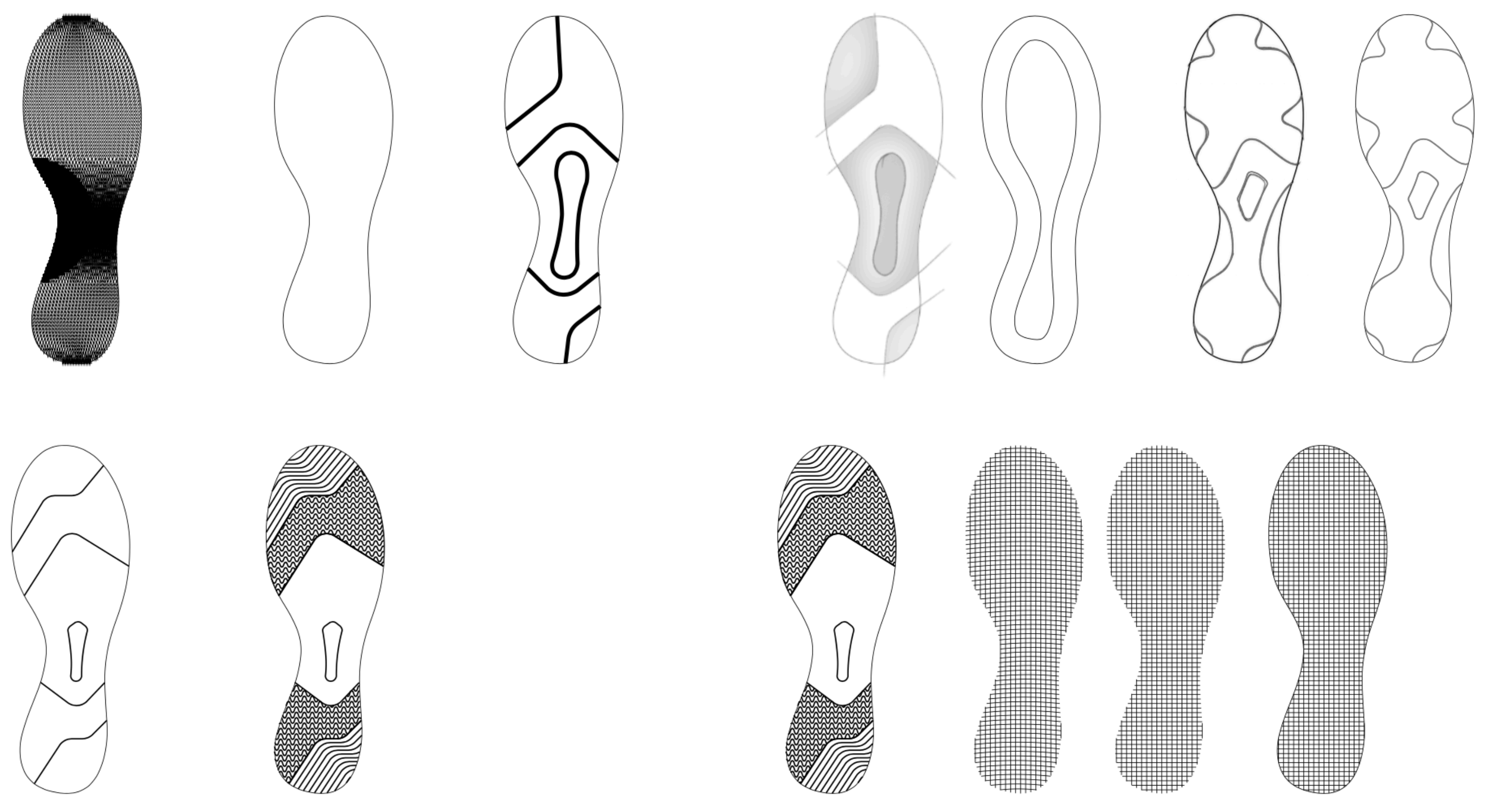
Artificial Grass

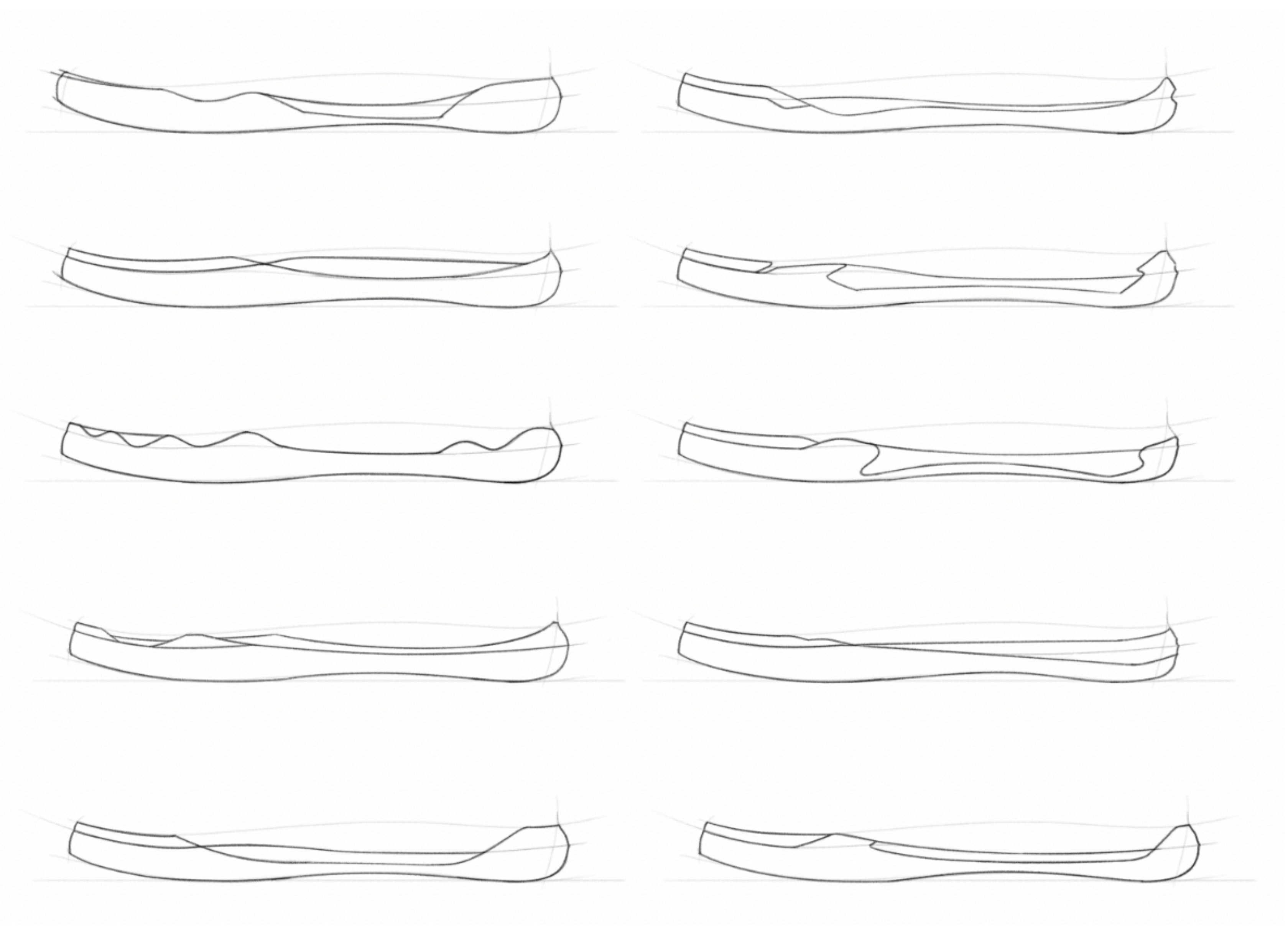
Thermal Comfort + **Lightweight Construction**

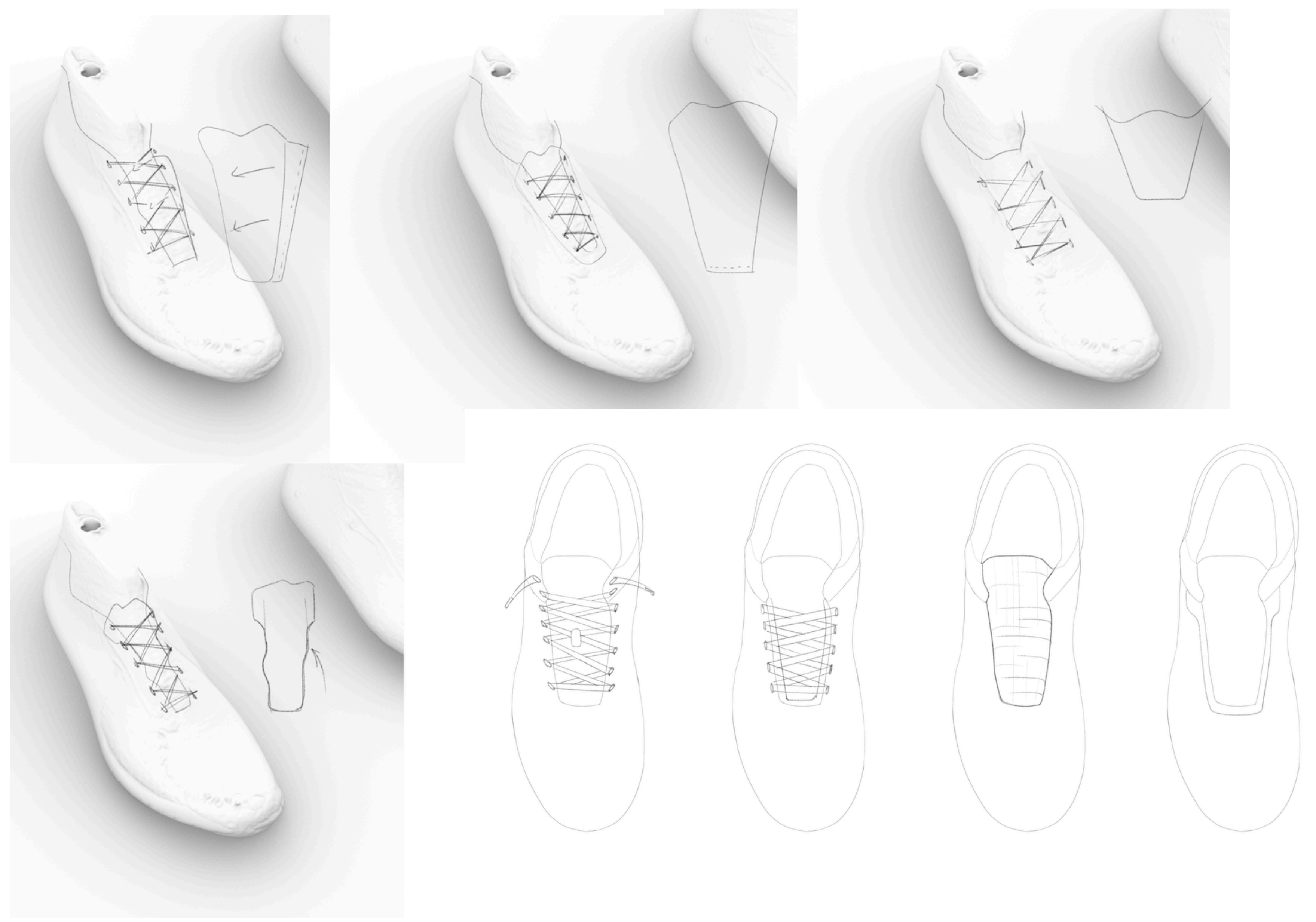
IDEATION

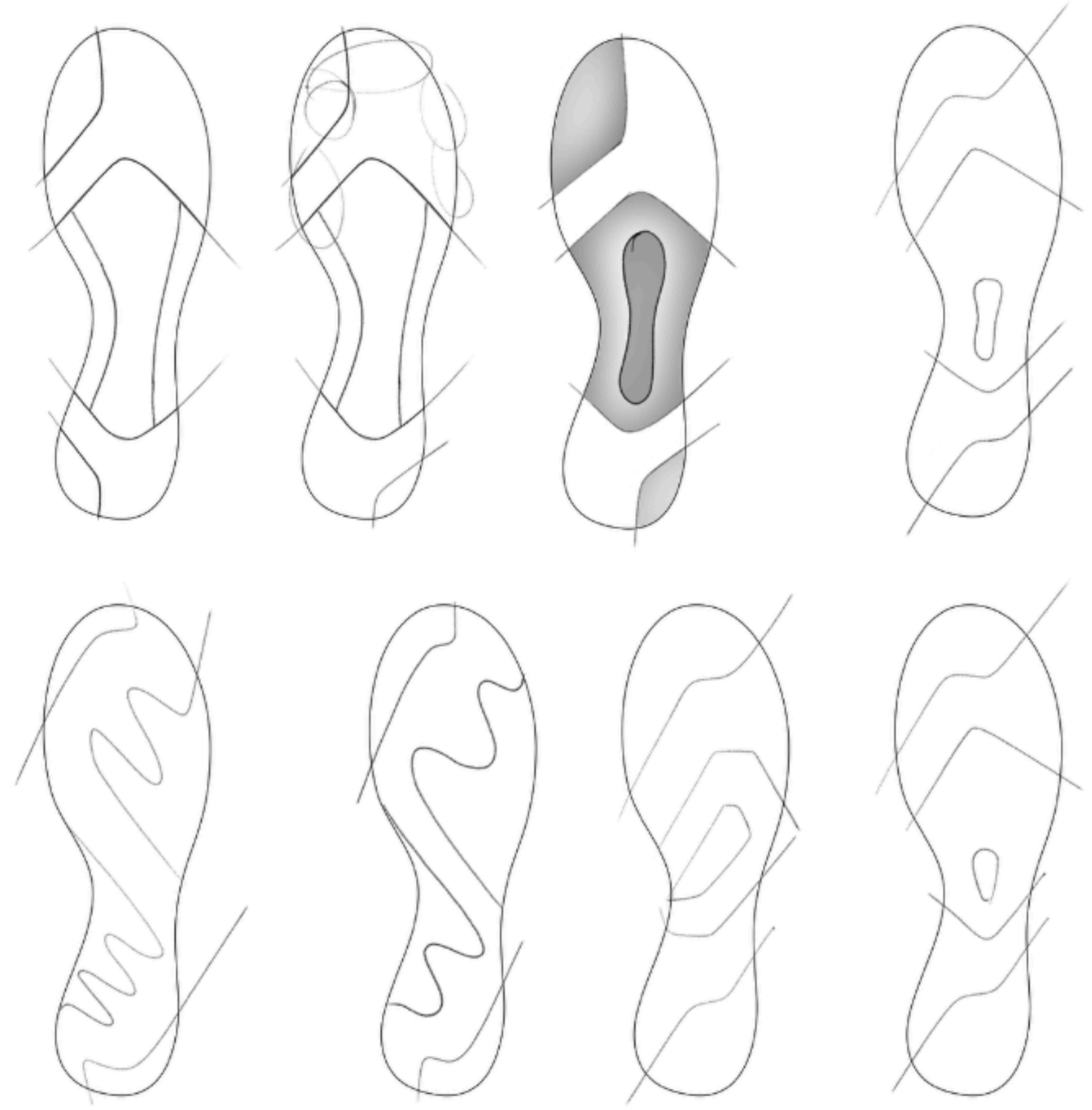
STREET





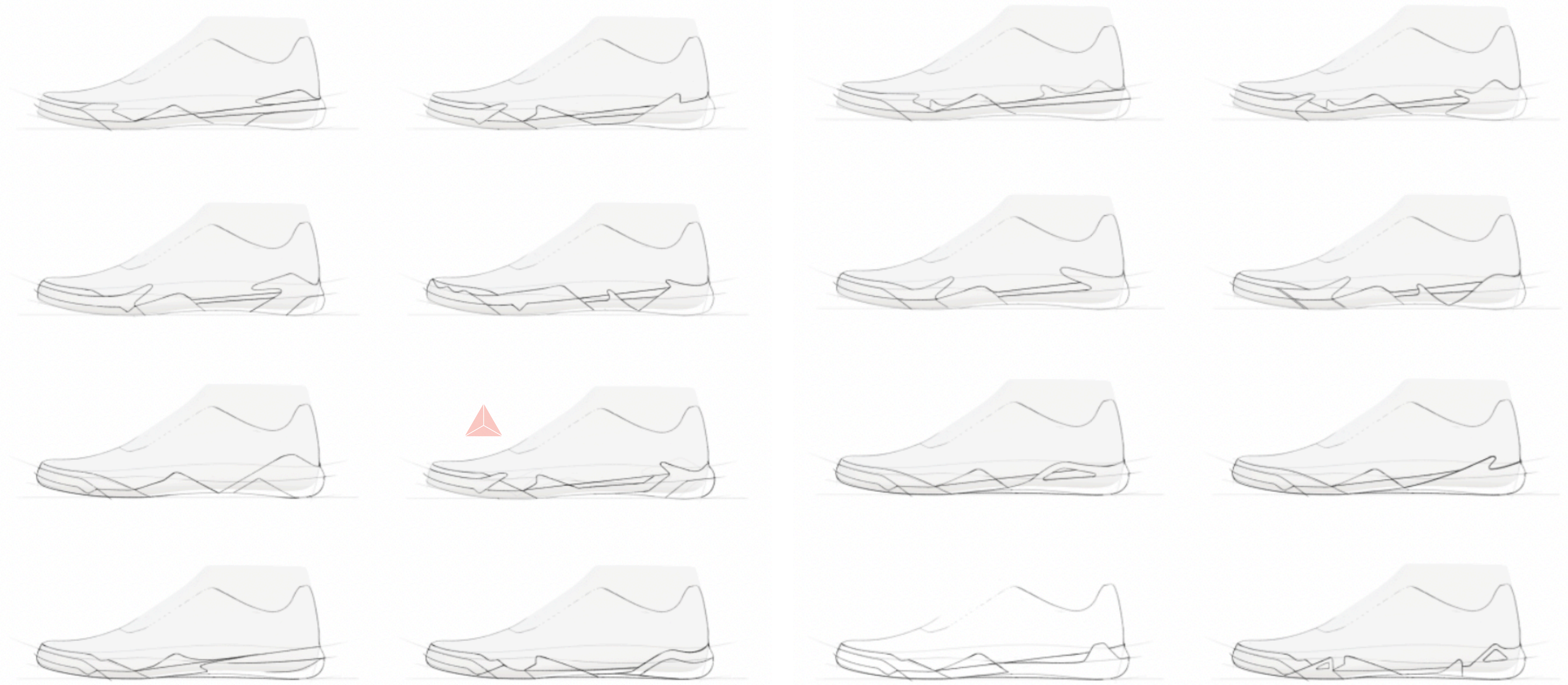






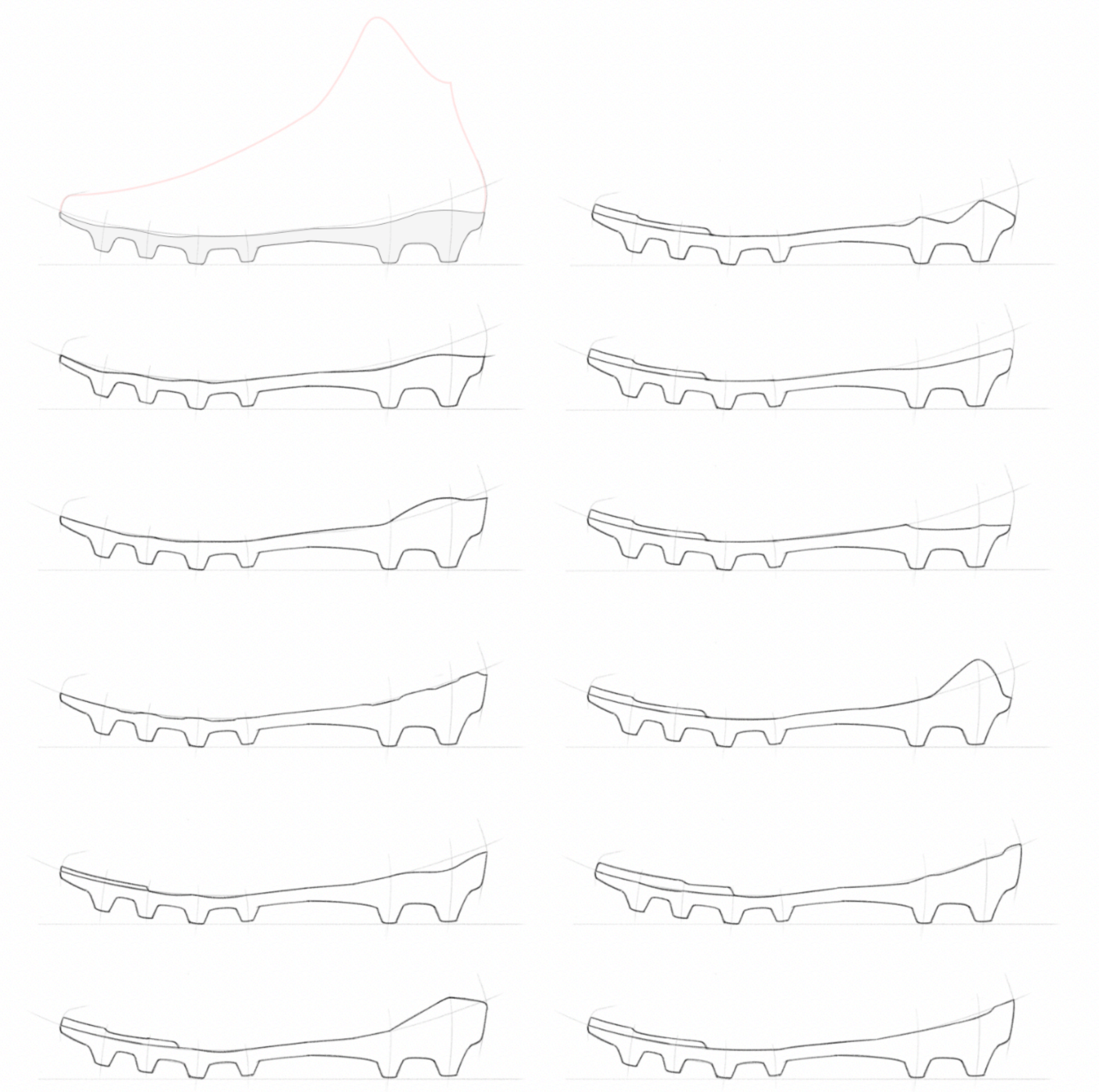
IDEATION

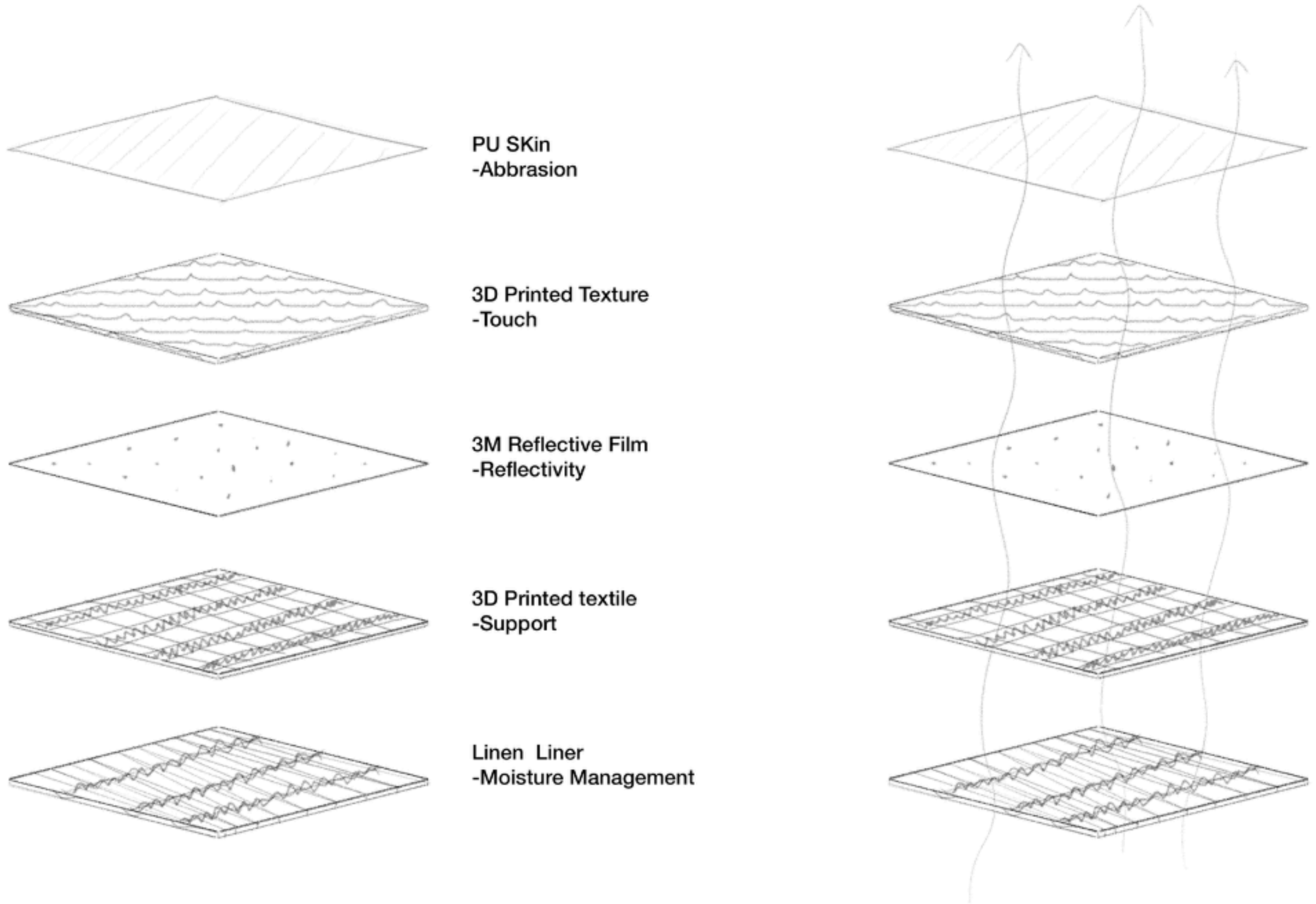
STREET

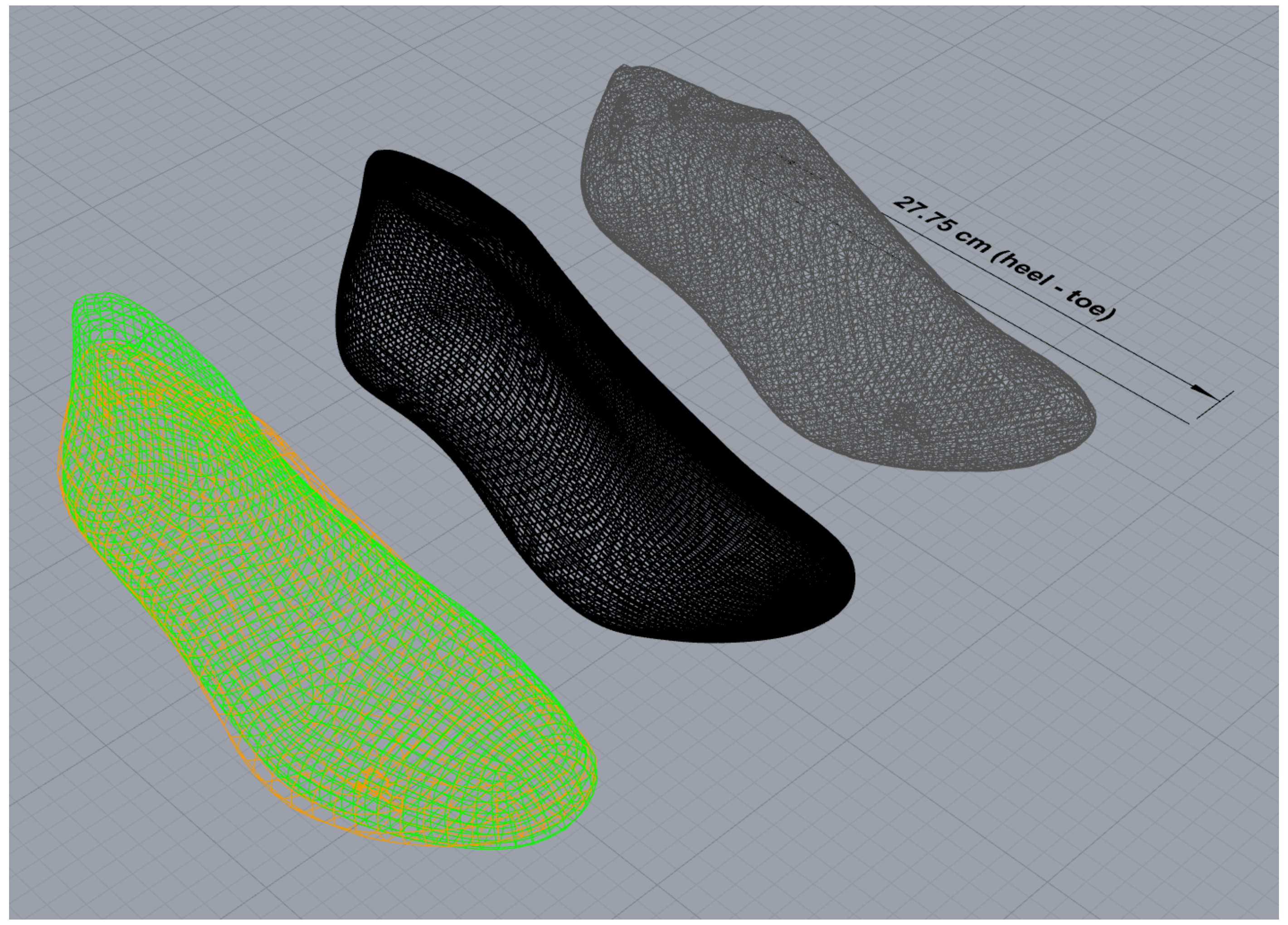


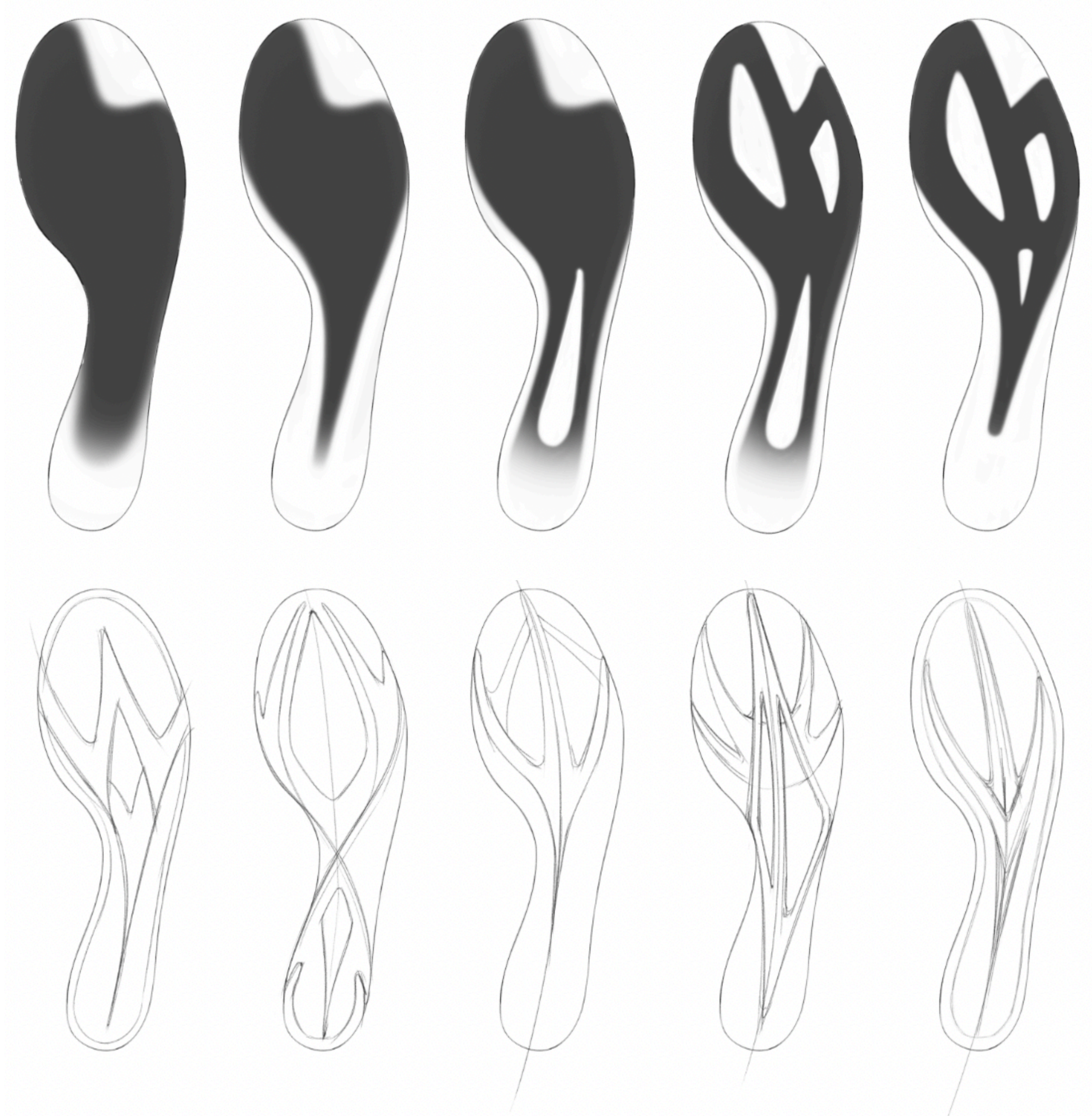
IDEATION

CLEAT



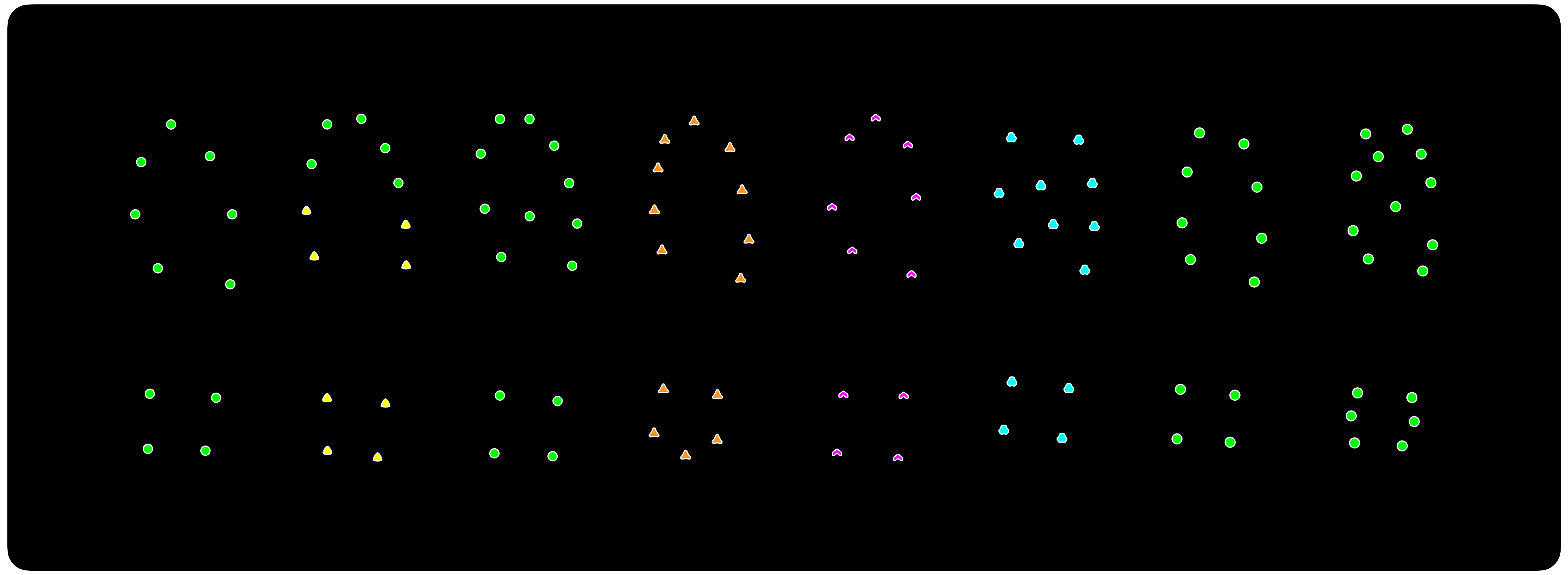


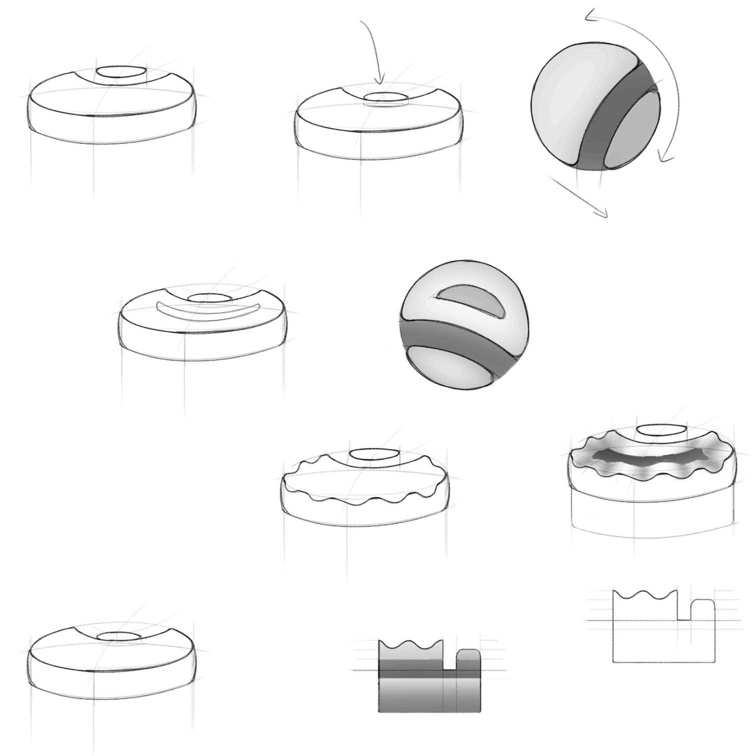


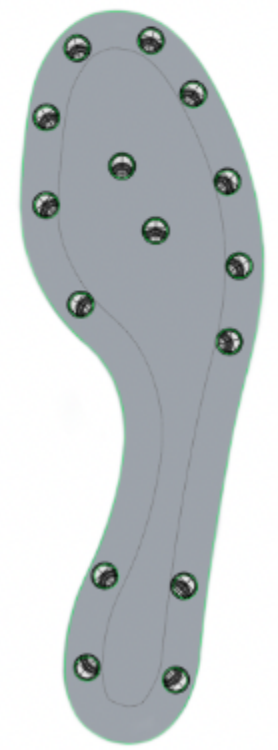


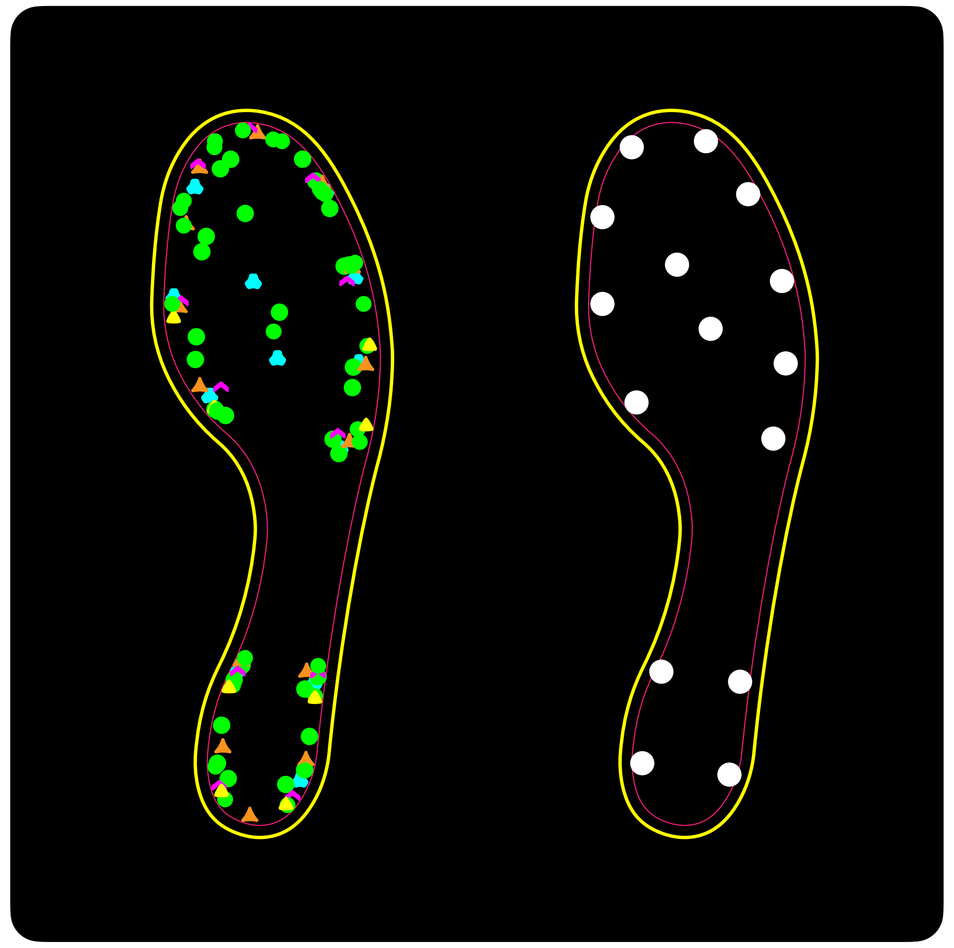
IDEATION

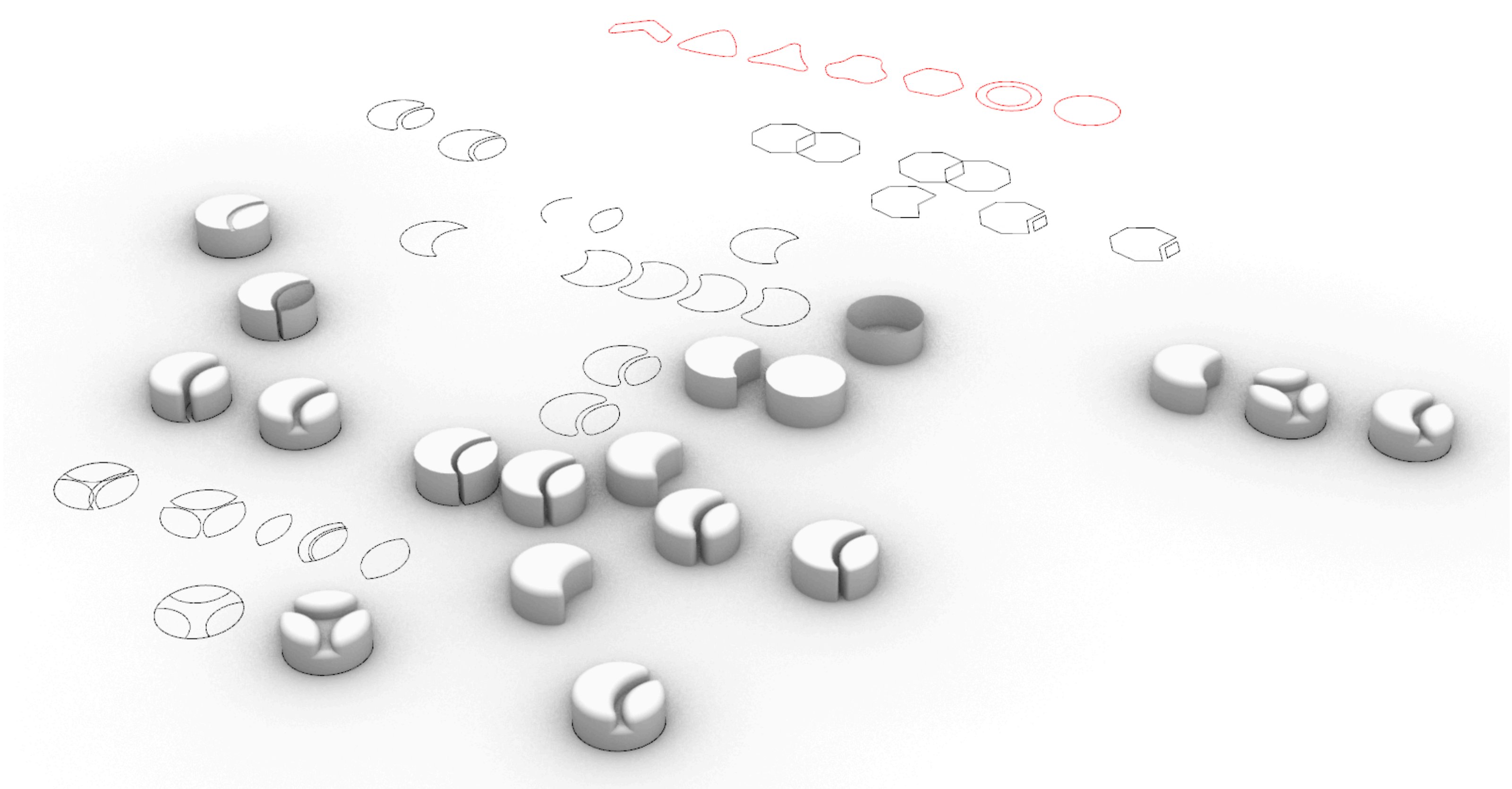
CLEAT

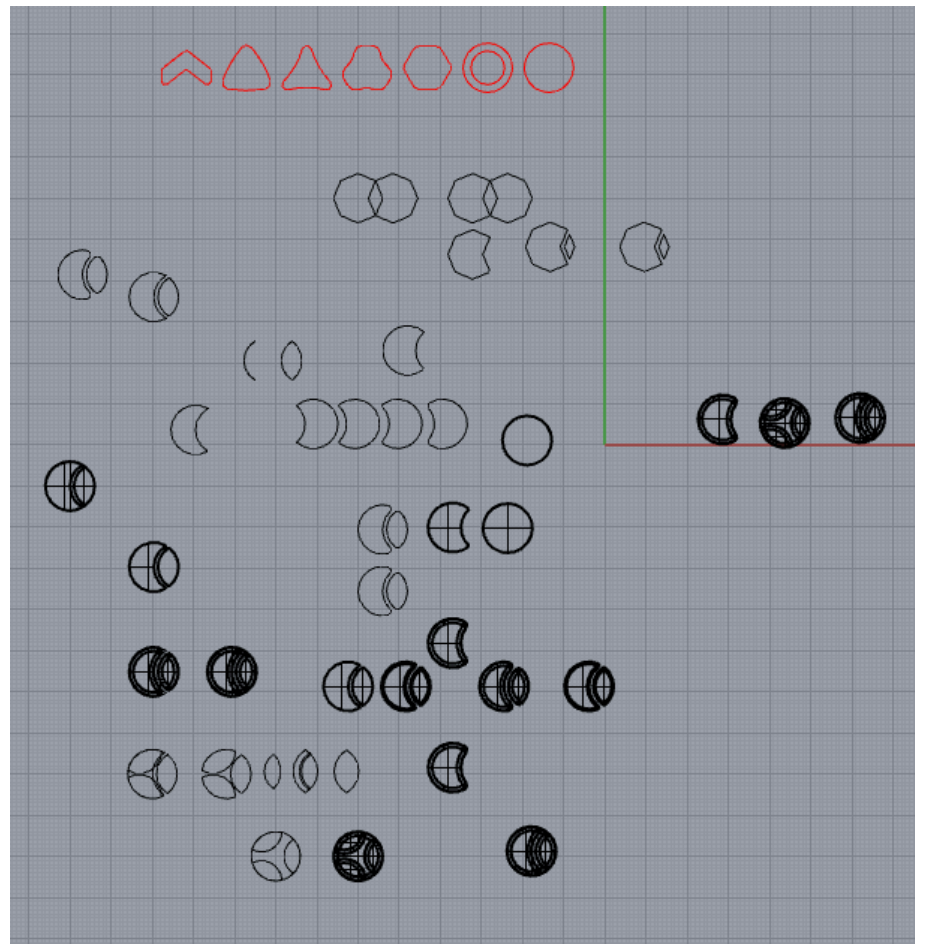






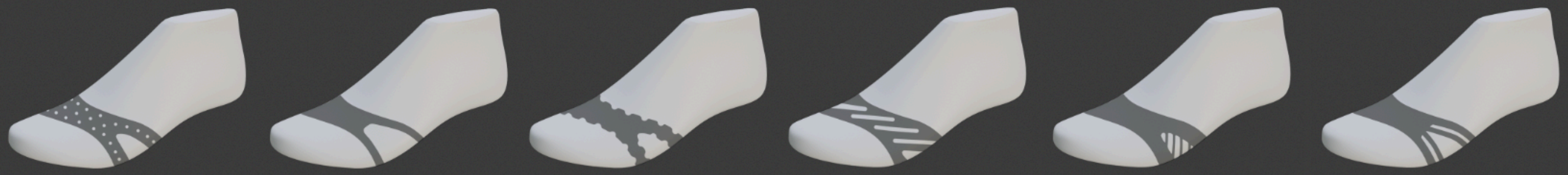


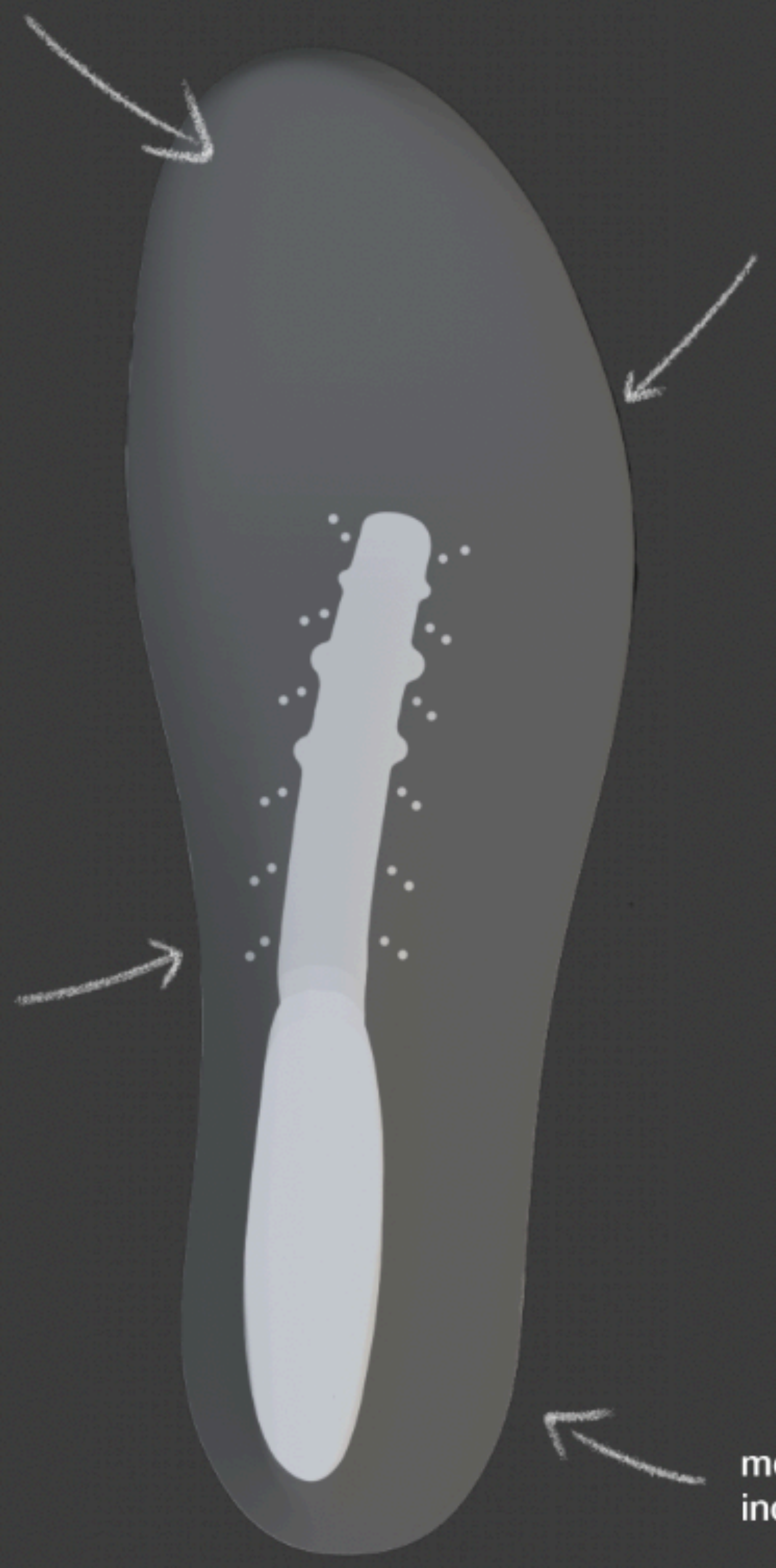


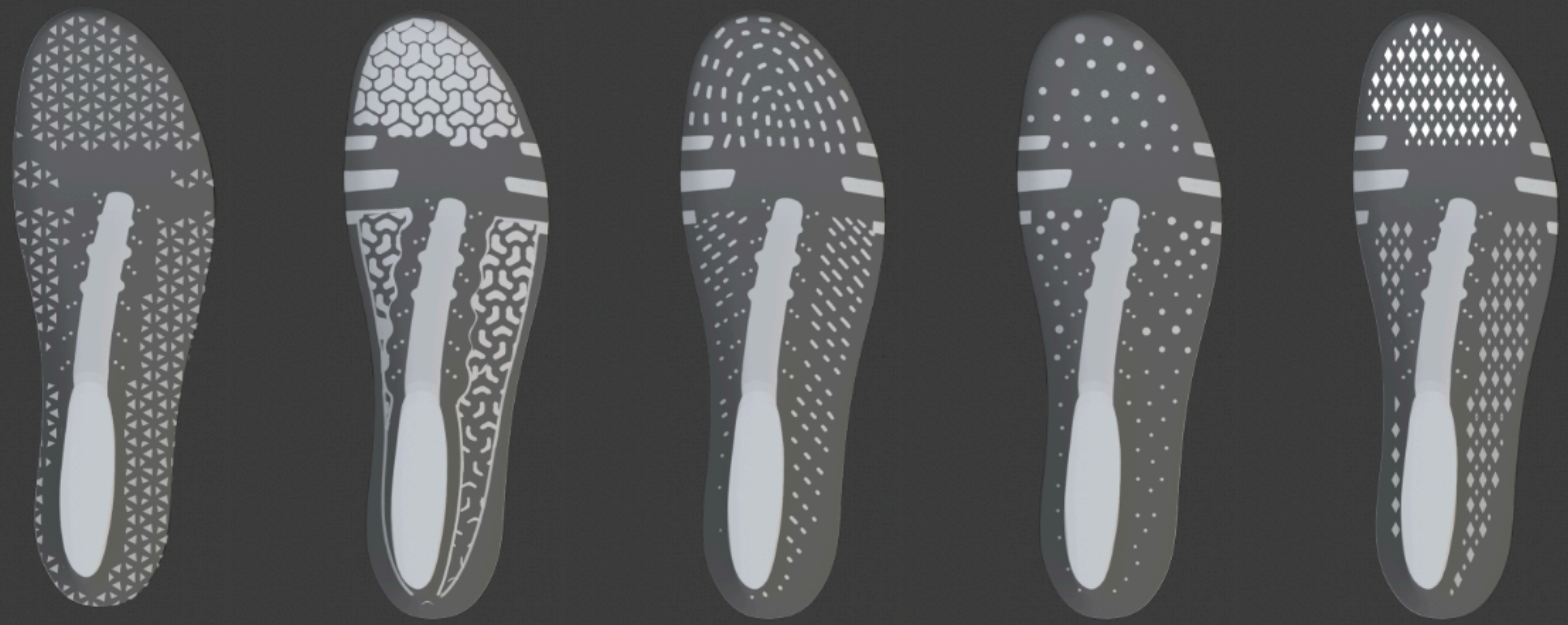


ADHESIVE

IDEATION

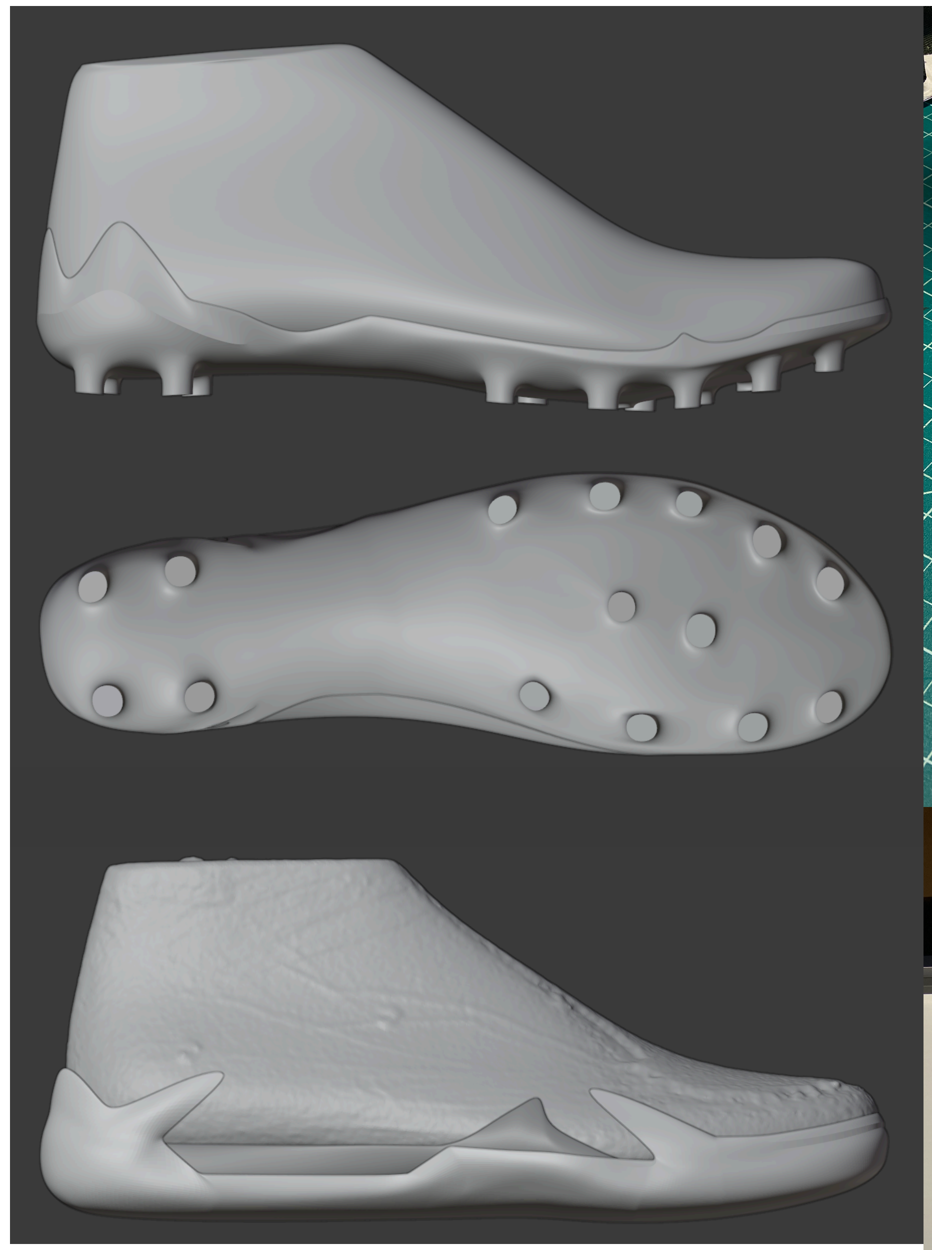


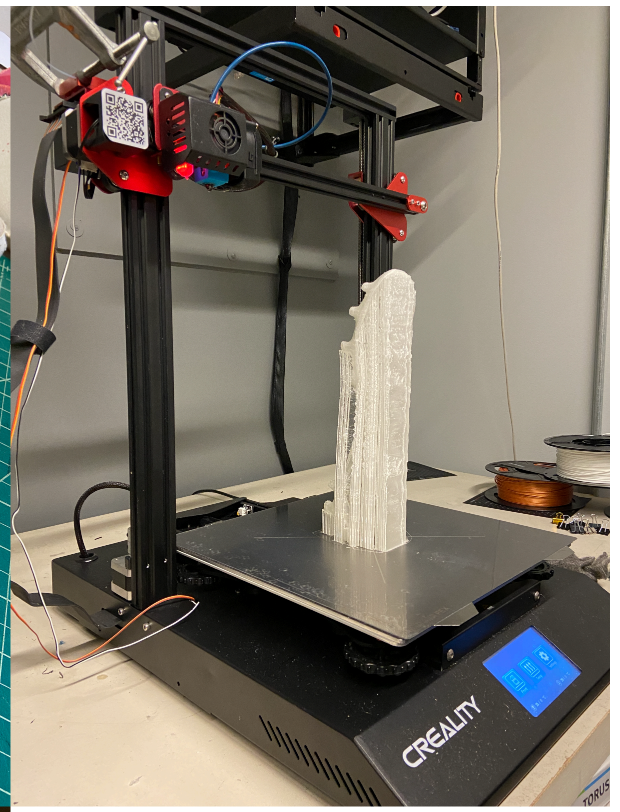


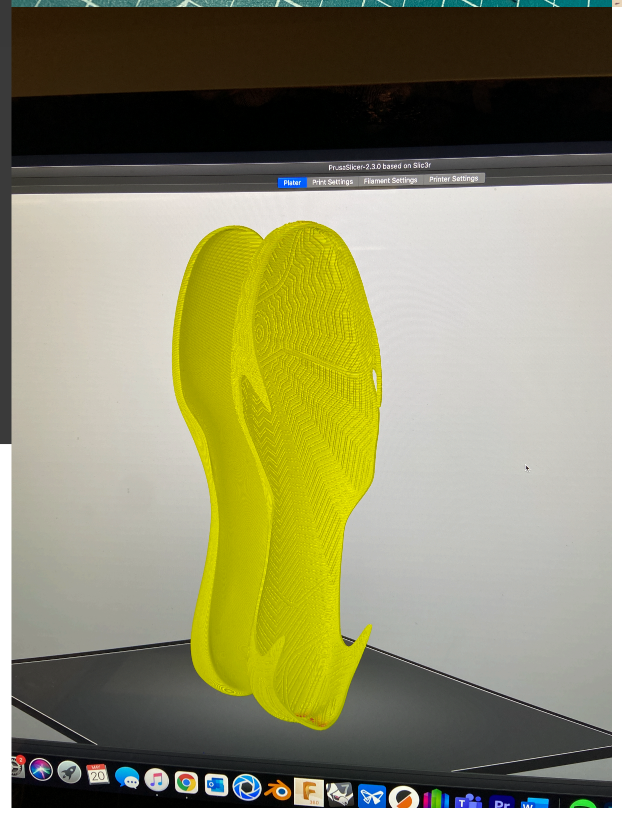


FOOTWEAR

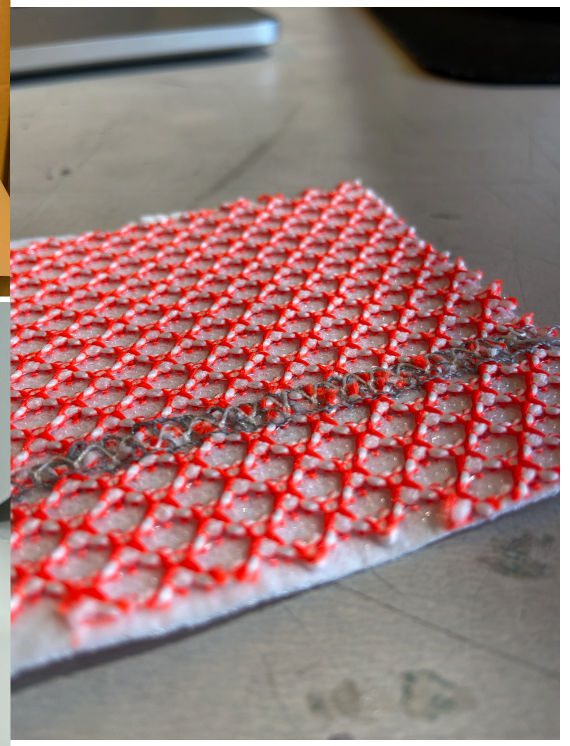
PROTOTYPING













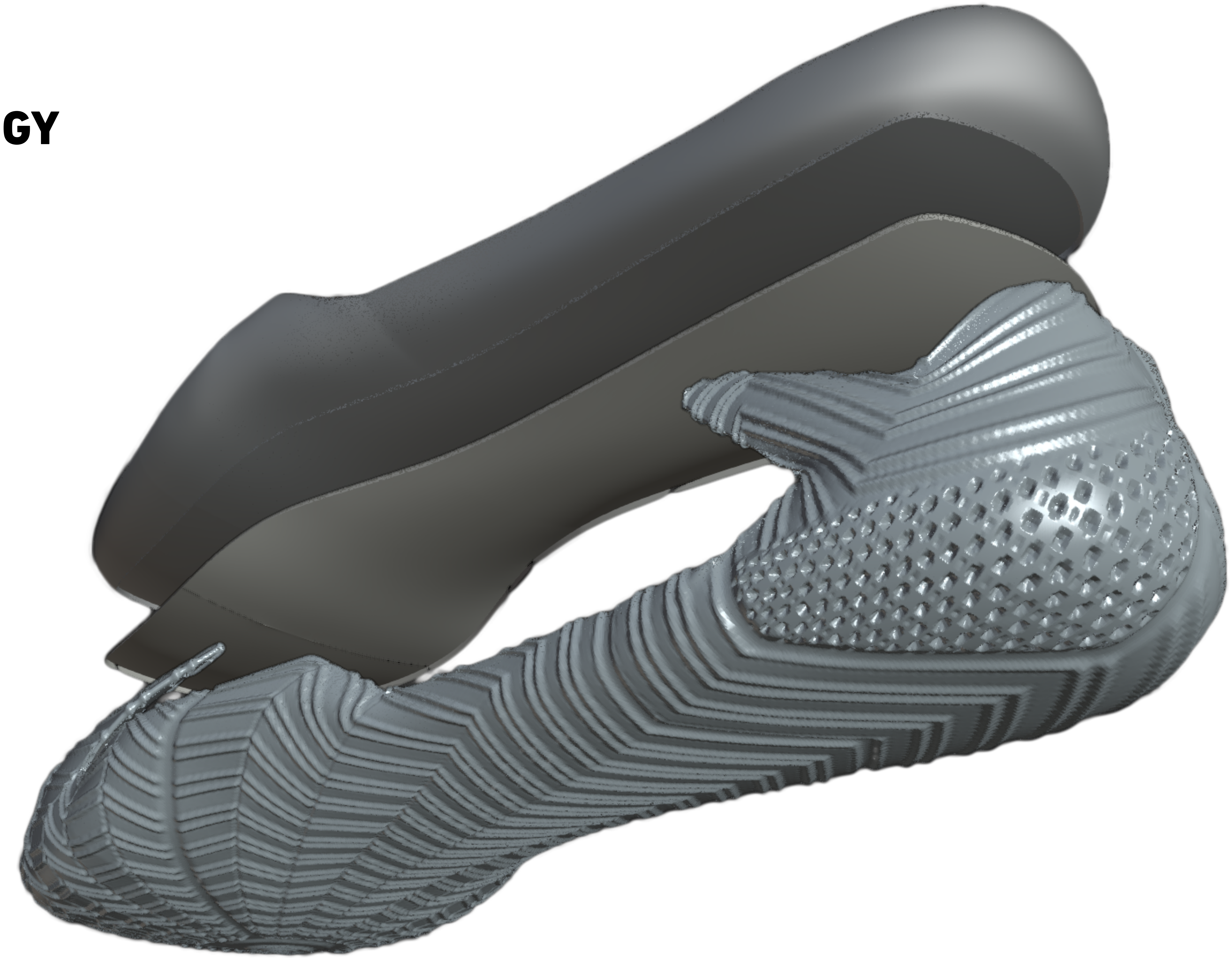
REFRACT
STREET SHOE

STREET SHOE

PARTS & PURPOSE

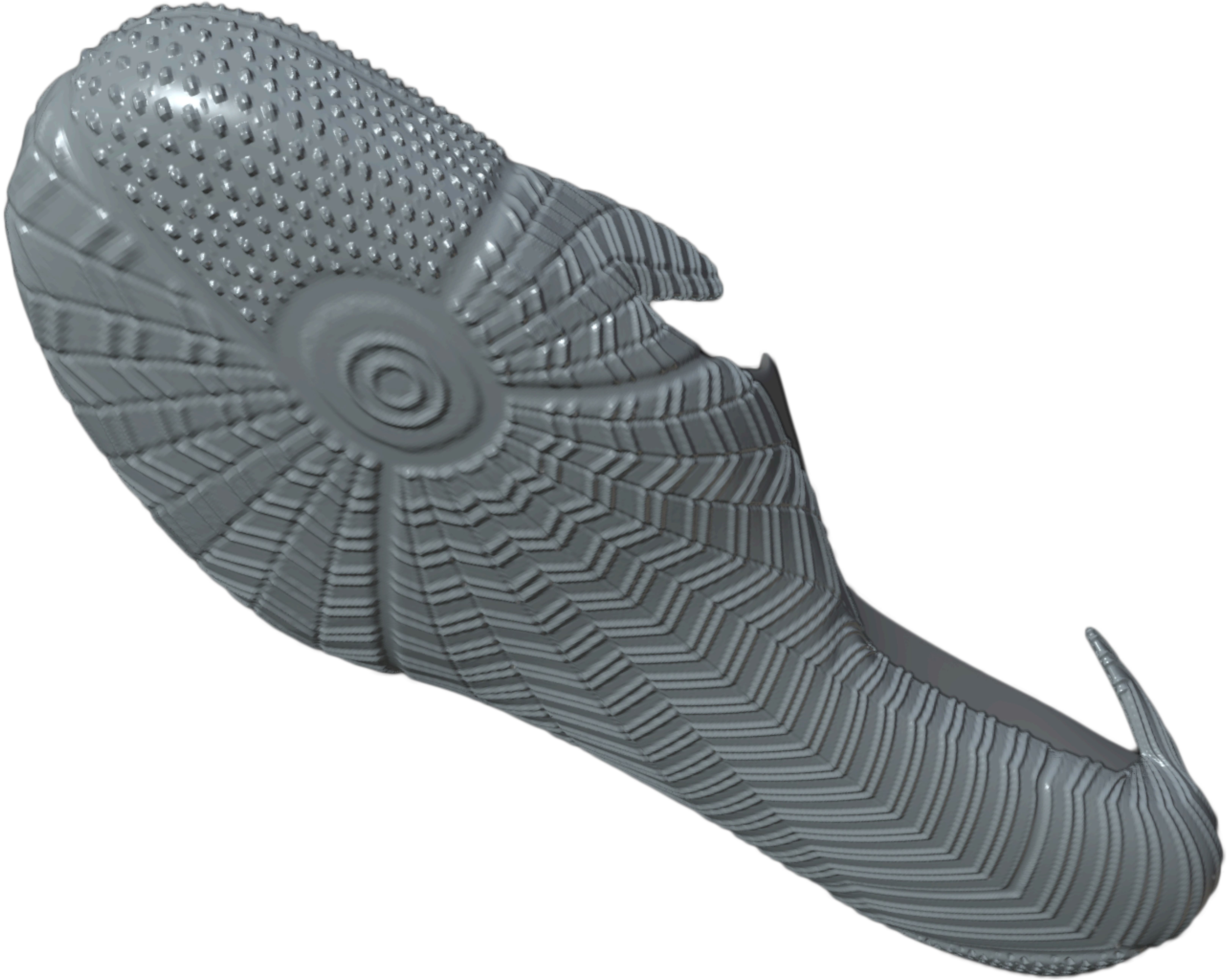
STREET SHOE

TECHNOLOGY



STREET SHOE

TECHNOLOGY



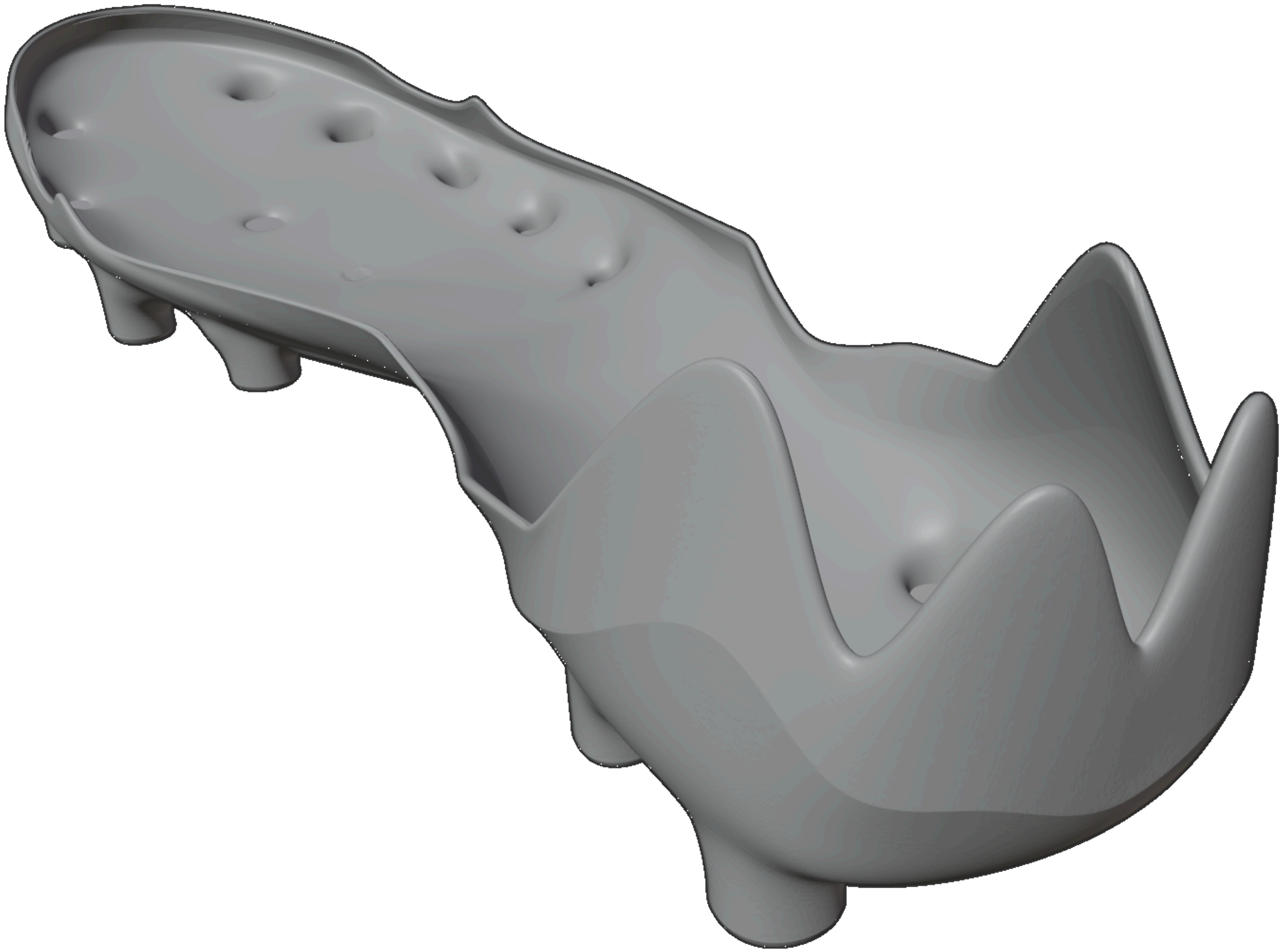

REFRACT
ARTIFICIAL GRASS CLEAT
adidas

ARTIFICIAL GRASS CLEAT

PARTS & PURPOSE

ARTIFICIAL GRASS CLEAT

TECHNOLOGY



ARTIFICIAL GRASS CLEAT

TECHNOLOGY


adidas


adidas

MATERIAL

TESTING

THERMAL RESISTANCE - 20 MIN HOT PLATE

Nike Mercurial 7 AG Pro (Cleat) - 5 mins
Nike React Gato (Street) - 8 mins

Refract AG Cleat - 9 mins (20% increase)
Refract Street Shoe - 14 mins (30% increase)

OVERALL WEIGHT - US 9M

Nike Mercurial 7 AG Pro (Cleat) - 188 grams
Nike React Gato (Street) - 273 grams

Refract AG Cleat - 151 grams (19.7% lighter)
Refract Street Shoe - 266 grams (2.6% lighter)

FOOTWEAR

VALIDATION

Bryant Jimenez

Former UO Men's Club Team Player
Position: Striker/ Right-Wing
Class: 2020

STREET SHOE

"The streets shoe had quite a bit of support on the arch of my foot where most other shoes normally are pretty flat, especially supportive with the cork insole adding a bit of rigidity."

"The shoes are a nice design with the wings as well as a outsole design that you don't really find it in court shoes."

ARTIFICAL GRASS CLEAT

"By incorporating texture into the actual material of the upper I felt like I had more grip on the ball. Also, the external heel counter felt very secure and supportive"

"The upper was a more breathable than expected compared to other soccer cleats I've tried, and this one felt as if my foot could really heat up and not cause too much of an issue."

COLLECTION

IMPACT