Fitstation by hp

The 3D-printing advantage for foot orthotics

By: Dr. Bruce Williams, DPM

3D-printing, or additive manufacturing, is now disrupting the entire manufacturing industry (ref. 1), and the custom-foot-orthotic industry is no exception. 3D-printing techniques and materials present a significant opportunity to improve on the functional abilities and traditional manufacturing processes of custom-foot orthotics.

The Fitstation by HP biometrics-capture system, combined with HP's revolutionary Multi Jet 3D printers, provide access to 3D-printed orthotics that are uniquely thin and lightweight. The lattice structure of these custom orthotic devices allows for precise control of the stiffness and torsion within very specific segmental regions of the foot orthotic (ref. 2–5). The HP Multi Jet 3D-printing process uses a material that has equivalent strength and flexibility to polipropilene, is more sustainable, and creates much less waste than traditional CNC manufacturing (ref. 6).

What is 3D-printing?

Whereas manufacturing by milling, grinding, and cutting removes material from a workpiece, additive manufacturing—"3D-printing"—is a digital technology that creates objects by selective material addition. This allows each 3D-printed part to be unique in the same way that each page printed by an inkjet or laser printer can have unique content. Digital technologies enable 2D and 3D-printing with the ability to create 100% customized content, page-to-page and part-to-part.

Segmental stiffness means a more unique prescription

In 3D-printing, because the building material is deposited selectively in space, complex lattice structures with mechanical properties can be built, giving the ability to design orthotics differently from the ground up. Lattice structures can be engineered to be extremely strong, but also flexible, as necessary (ref. 2).

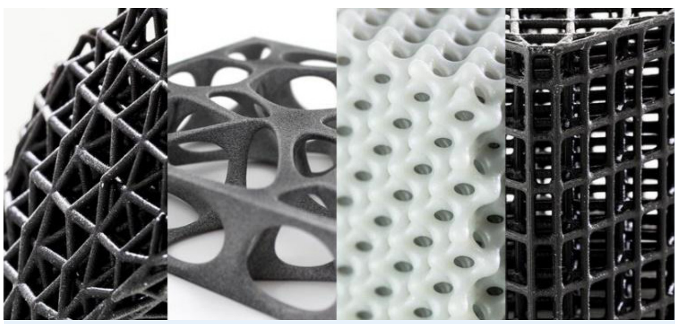


Exhibit 1: Different lattice structures.
Source: HP

For example, the GO4D custom foot orthotic has five segmental stiffness zones built into the device. Each of these zones can be made to be more flexible, or stiff, as the practitioner deems best for the patient (see exhibit 2). Altering stiffness in regions, such as the medial arch, may allow the orthotic to control pronation forces while potentially decreasing the need for extremes in varus posting of the device. In higher-arch feet, traditional casting techniques and materials often force practitioners to use increased arch fill to "decrease" the medial arch height of the custom foot orthotic in comparison to the patient's actual arch height. This process lowers the medial arch of the orthotic to keep the foot from flattening or pronating into an orthotic with an arch that is too high.

By being able to lower the stiffness, or make the medial arch more flexible, 3D-printing allows for a much more conforming device, with minimal to no need for the use of arch fill, while allowing the foot to still flatten or pronate as much as necessary. The ability to decrease plantar heel stiffness in the foot orthotic can also alleviate the need for a plantar accommodation for patients with "true" plantar, as opposed to "medial" heel pain.

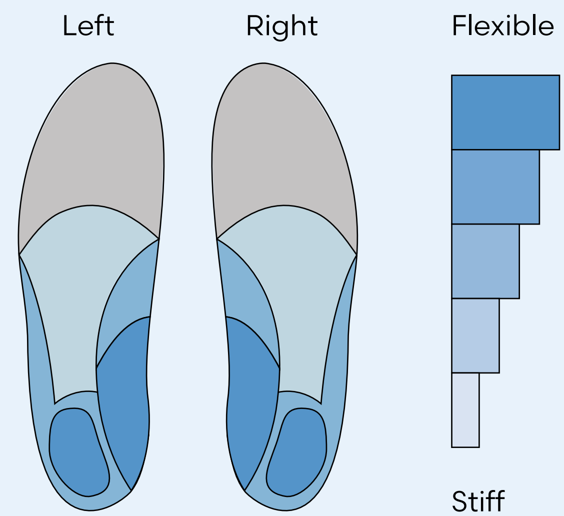


Exhibit 2: Segmental stiffness prescription on RSScan footscan 9 software. Source: Author

Personalized, lighter, and more wearable orthotics maximize the chances for patient compliance

When using lattice structures, significantly less material is needed for the creation of the foot orthotic vs. traditional CNC milling. Therefore, the custom orthotics are lighter than traditional foot-orthotic devices (ref. 2). 3D-printing also allows for the construction of extremely thin devices, allowing a minimum thickness of 1mm, in certain regions of the foot orthotic. The plantar lattice structure of 3D-printed devices also allows for a better grip of the plantar aspect of the inside of the shoe, leading to less opportunity for slippage of the orthotic.

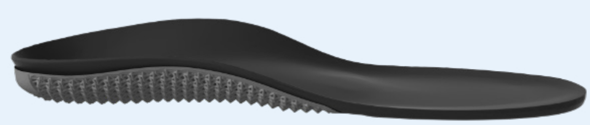


Exhibit 3: GO4D 3D-printed orthotic.
Source: GO4D

Different types of orthotics can be made for patients ranging from daily use, sports, and safety devices. Orthotics, like the one on exhibit 3, can also be made in widths from normal to thin and wide. There are also six different sporting-type devices available for our patients; they include running, soccer, golf, cycling, and both alpine and Nordic skiing.

Finally, because of the additive-manufacturing process, names and messages can be engraved on the device, adding opportunities for patient engagement.

Material properties with similar or superior performance to existing alternatives

PA 11 has been tested directly against polypropylene in a study from the Institute of Biomechanics of Valencia, Spain (ref. 13). In this head-to-head study, PA11 showed a close comparison between CNC milled polypropylene. The dynamic stiffness of the material, PA11, the deformation energy recovery, and the maximum permanent deformation mimicked the behavior of the most common CNC milled polypropylene currently used on the market (ref. 8, 9).

PA 11 elongation allows for strong flexion of the insole without breaking or producing minimal deformations, which means the insole will recover its original shape when flexed repeatedly (ref. 8, 9).

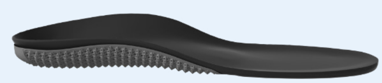
In addition, tests for heat-forming adjustments with thicknesses of 2mm, 3mm, and 4mm have been performed with a heat gun, allowing clinicians to make last-minute adjustments in-office when necessary (ref. 13).

Finally, the use of 3D-printing allows for many, if not most, of the usual foot-orthotic modifications that foot and ankle practitioners use daily. This includes modifications like varus and valgus heel wedging, heel lifts, also known as heel offsets, Morton's extensions, reverse Morton's extensions, metatarsal pads, metatarsal bars, and extra deep "UCBL" type of devices.

A radical reduction in waste and environmental impact

Sustainability is a key concern for modern consumers and industry players, and the orthotics industry has the opportunity to make a relevant contribution through more conscious production practices. Current machining processes for foot orthotics are inefficient, as 97% of the material is waste, implying an enormous environmental footprint. Also, HP Multi Jet 3D-printing utilizes PA11, a renewable raw material made from castor oil, for orthotics manufacturing (ref. 7, 8).

Each HP Multi Jet 3D printer is able to produce up to 21,000 foot-orthotic pairs per year. This means that every HP Multi Jet 3D printer installed will save approximately 40 tons of material waste per year vs. traditional CNC polypropylene milling. Although traditional CNC waste may be recycled, it requires a high amount of energy, labor, and transportation resources to do so (ref. 7, 12).



77gr/pair

CNC

Chips waste: 1,222gr/pair
Borders waste: 923gr/pair
Total waste: **2,145gr/pair**

vs.

HP Multijet

Powder degradation waste: **212gr/pair**

=

~90% waste reduction

Exhibit 4: Waste from CNC vs. HP Multi Jet in orthotics production. Source: HP

About the Author

Dr. Bruce Williams is a practicing podiatrist with 27 years of clinical experience specializing in sports medicine, biomechanics, orthotics, athletic shoes, and gait and movement analysis. He has 18 years of experience using pressure mapping technology for gait analysis of athletes and general patient care.

He is a former President and Fellow of the American Academy of Podiatric Sports Medicine, and he provides team consulting and education for professional sports teams and university programs.

Dr. Bruce Williams is a paid consultant for Fitstation by HP.

References:

1. 3D-printing: Disrupting the $12 Trillion Manufacturing Sector. With 3D-printing fueling the Fourth Industrial Revolution, an array of countries are poised to capture a competitive edge by investing in this rapidly advancing technology. Ben T. Smith IV, Bharat Kapoor, and Rafael Angelo. https://www.atkearney.com/operations-performance-transformation/article?/a/3d-printing-disrupting-the-12-trillion-manufacturing-sector
2. DESIGN OF GENERAL LATTICE STRUCTURES FOR LIGHTWEIGHT AND COMPLIANCE APPLICATIONS. Dr. David Rosen, Dr. Scott Johnston, Marques Reed, Dr. Hongqing Wang. Rapid Manufacturing Conference, Loughborough University, July 5-6, 2006.
3. Embracing additive manufacture: implications for foot and ankle orthosis design. BMC Musculoskeletal Disorders 2012, 13:84. Scott Telfer, Jari Pallari , Javier Munguia, Kenny Dalgarno, Martin McGeough and Jim Woodburn
4. DESIGN AND ADDITIVE FABRICATION OF FOOT AND ANKLE-FOOT ORTHOSES J. H. P. Pallari, K. W. Dalgarno, J. Munguia, L. Muraru, L. Peeraer, S. Telfer, and J. Woodburn.
5. Schrank ES, Stanhope SJ: Dimensional accuracy of ankle-foot orthoses constructed by rapid customization and manufacturing framework. J Rehabil Res Dev 2011, 48:31–42.
6. HP 3D High Reusability PA 11 powder is made with 100% renewable carbon content derived from castor plants grown without GMOs in arid areas that do not compete with food crops. HP 3D High Reusability PA 11 is made using renewable sources, and may be made together with certain non-renewable sources. A renewable resource is a natural organic resource that can be renewed at the same speed in which it is consumed. Renewable stands for the number of carbon atoms in the chain coming from renewable sources (in this case, castor seeds) according to ASTM D6866.
7. According to HP customer research, an average pair of 77-gram insoles can produce 2145 grams of waste material using manual-production methods. An equivalent pair of insoles produced with HP MJF can produce 212 grams of waste, resulting in a 90% waste reduction.
8. Testing according to ASTM D638, ASTM D256, and ASTM D648 using HDT at different loads with a 3D scanner for dimensional accuracy. Testing monitored using statistical process controls.
9. Compared to selective laser sintering (SLS) technology. Providing an elongation at break XY of 50% with up to 70% post-production surplus power reusability according to the ASTM D638 test method. For testing, material is aged in real printing conditions and powder is tracked by generations (worst case for reusability). Parts are then made from each generation and tested for mechanical properties and accuracy.
10. The HP powder and agents do not meet the criteria for classification as hazardous according to Regulation (EC) 1272/2008 as amended.
11. HP 3D agents were tested for Hazardous Air Pollutants, as defined in the Clean Air Act, per U.S. Environmental Protection Agency Method 311 (testing conducted in 2016) and none were detected.
12. Compared to selective laser sintering (SLS) and fused deposition modeling (FDM) technologies, HP Multi Jet Fusion technology can reduce the overall energy requirements needed to attain full fusing and reduce the system requirements for large, vacuum-sealed ovens. In addition, HP Multi Jet Fusion technology uses less heating power than SLS systems for better material properties and material reuse rates, minimizing waste.
13. According to HP's "Manufacturing Insoles with HP Multi Jet Fusion Technology" report.