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).

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

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.
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).

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.

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