Effect of material of the 3D printed foot on ankle kinematics/kinetics and toe joint bending during prosthetic walking

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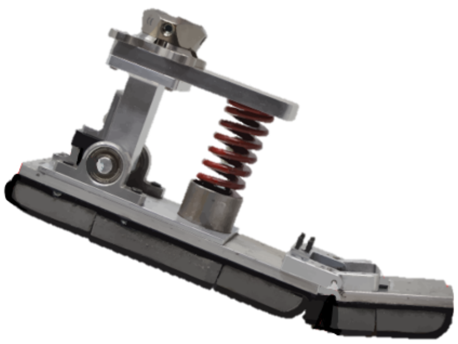
Introduction

Powered toe joint[1]



Toe joint with interchangeable springs[2]

3D printed prosthetic foot[3]

[1] J. Zhu, et al., 2014
[2] E.C. Honert, et al., 2018
[3] H. Kim, et al., 2020

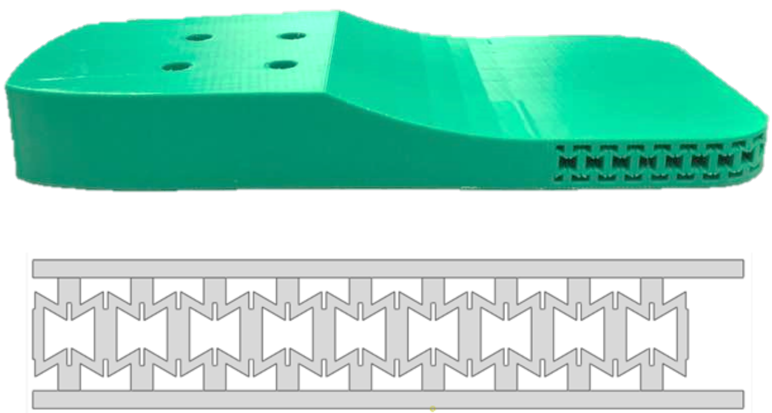
Research focus

- How the material of 3D printed foot affects the ankle kinematics/kinetic during a prosthetic walking

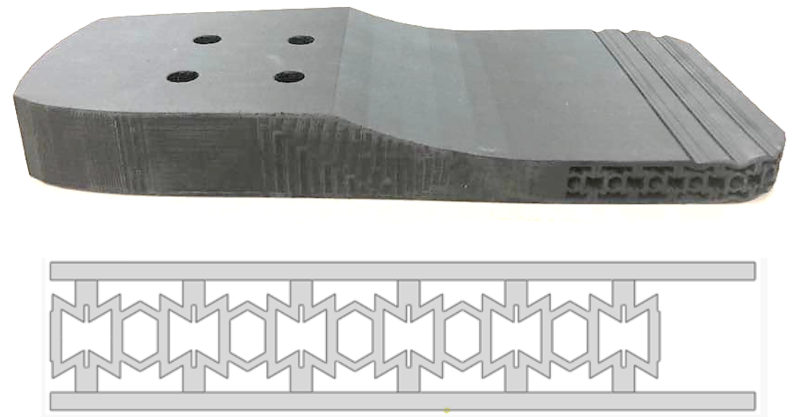
- How the material of 3D printed foot affects the toe joint bending during a prosthetic walking

Foot structure and material proposal

A



B



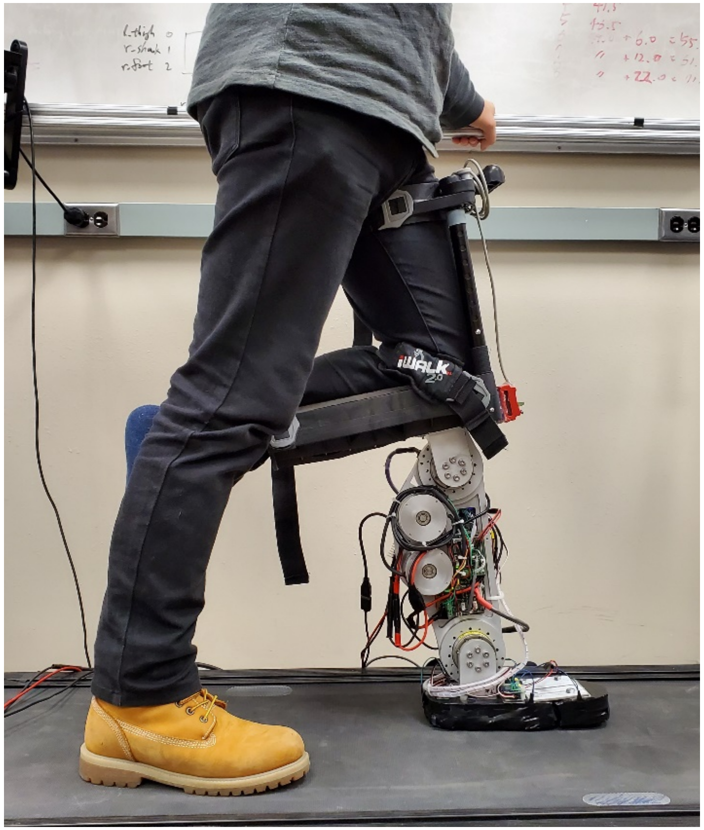
Foot structure and material combination[3]

	Structure	Material	Weight
Green foot (A)	Re-entrant structure	ABS	510 g
Black foot (B)	Re-entrant honeycomb structure with BZ	Onyx	540 g

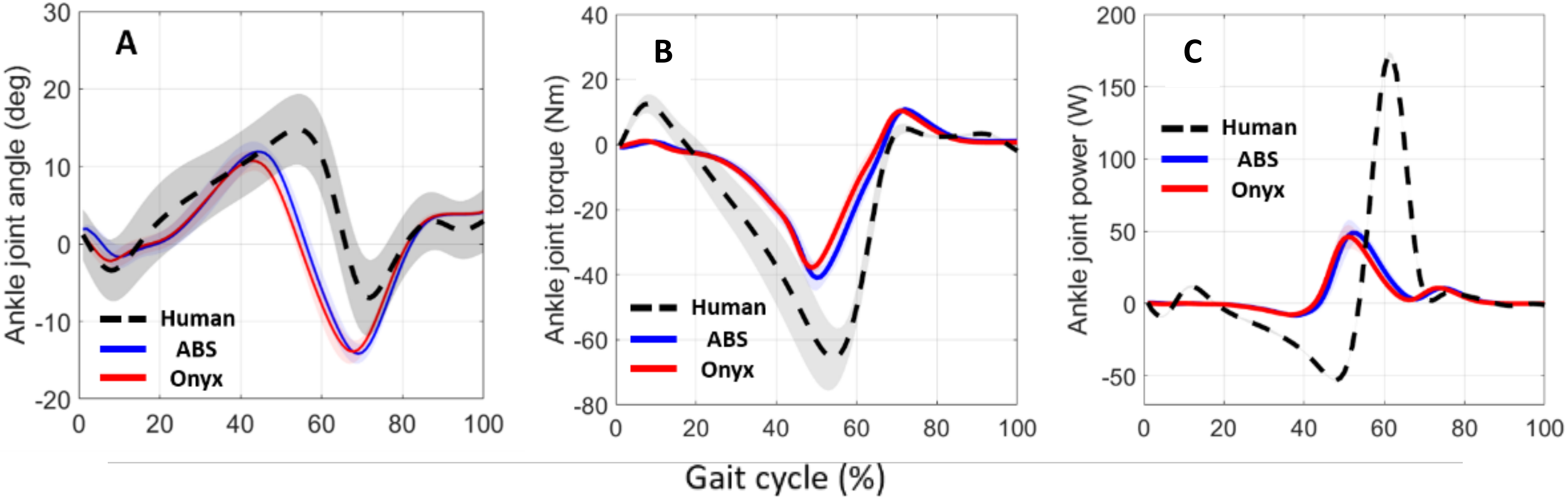
[3] H. Kim, et al., 2020

Experimental protocol

- A treadmill walking test at subject's preferred speed (0.60 m/s)
- A healthy young subject (male, 31 yrs., 1.70 m, 70 kg)
- Two different feet (ABS Vs. Onyx) are used for the comparison.
- Control framework
  - Ankle: Impedance control
  - Knee: Impedance control (stance)
    PD control (swing)

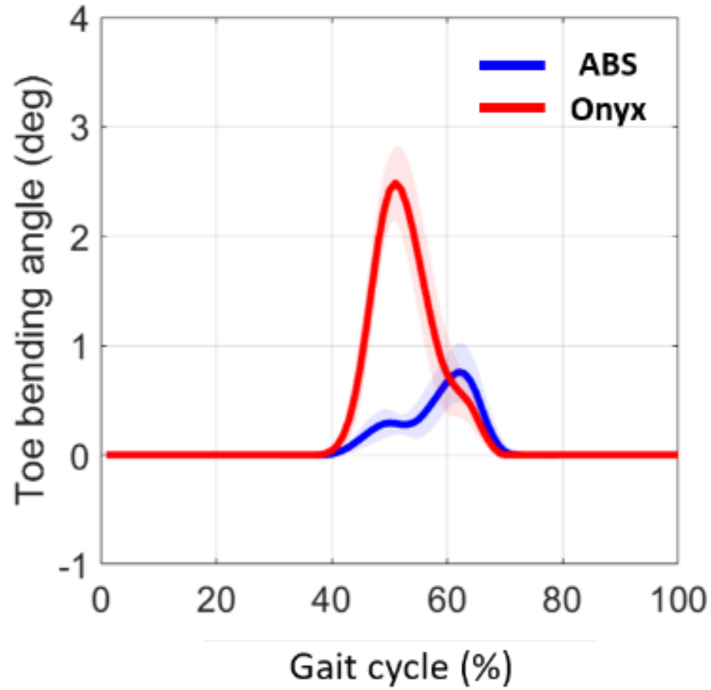


Results: ankle joint kinematics/kinetics



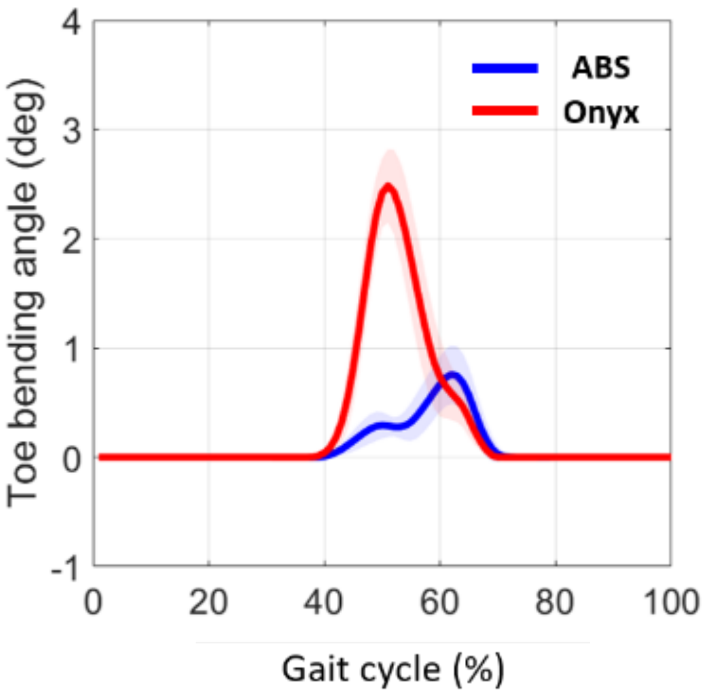
- Dorsiflexion (Fig. A): onyx foot < ABS foot
- Joint torque (Fig. B), power (Fig. C): onyx foot < ABS foot

Results: toe flexion/extension



- Toe flexion: onyx foot (2.46°) > ABS foot (0.74°)
- Both flexions are still too small compared to the simulation result (15°)[3].

Results: toe flexion/extension



Toe stiffness ?

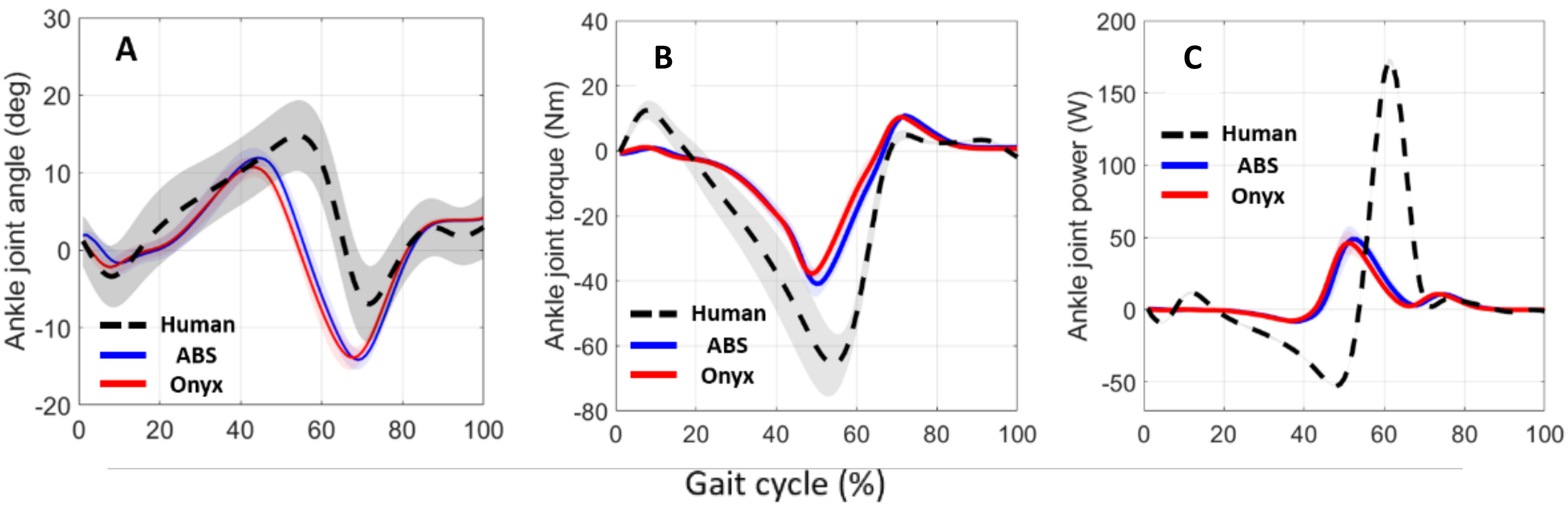
ABS foot > Onyx foot

stiffer

- According to the results, the ABS foot has larger dorsiflexion, torque, and power.
- As the toe joint stiffness is increased, the ankle dorsiflexion, torque, and power are increased[2].

[2] E. C. Honert, et al., 2018

Results: ankle joint kinematics/kinetics



- Human data is from a faster walking speed (0.80 m/s)[4].
- Both feet show smaller dorsiflexion and earlier push-off.
- The ankle torque and power are smaller due to the restricted torque limit of the actuator on the prosthesis.

[4] K. R. Embry, et al., 2018

Conclusion

- The onyx foot showed relatively significant compliance on the toe joint.
- The proposed foot is substantially lighter (540 g) compared to the previous feet (1.23~1.47 kg)[1,2].
- Using the new material (e.g., onyx) can be a good starting point for the new prosthetic foot design.

[1] J. Zhu, et al., 2014
[2] E. C. Honert, et al., 2018

Limitations

- Compared to the human, a toe bending of the onyx foot is still small.
- Due to the small toe bending, the effect of the proposed foot under the large toe deformation is not investigated.

Future works

- More compliant toe joints should be tested to investigate the effect of the toe joint.
- Maximize the biomechanical benefits of 3D printed foot with a realistic loading condition

References

[1] J. Zhu, Q. Wang, and L. Wang, *IEEE Transactions on Industrial Electronics,* Vol.61, No.9, p.4797-4807, 2014

[2] E. C. Honert, G. Bastas, and K. E. Zelik, *Bioinspiration & Biomimetics,* Vol.13, No.6, p.066007, 2018

[3] H. Kim, H. Um, W. Hong, H. Kim, and P. Hur, *American Society of Biomechanics (ASB), 2020*

[4] K. R. Embry, D. J. Villarreal, R. L. Macaluso, and R. D. Gregg, *IEEE Transactions on neural systems and rehabilitation engineering*, Vol.26, No.12, p.2342-2350, 2018

Thank you for watching!

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