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

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Introduction

1. Powered toe joint
2. Toe joint with interchangeable springs
3. 3D printed prosthetic foot

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

<table>
<thead>
<tr>
<th></th>
<th>Structure</th>
<th>Material</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Re-entrant structure</td>
<td>ABS</td>
<td>510 g</td>
</tr>
<tr>
<td>B</td>
<td>Re-entrant honeycomb structure with BZ</td>
<td>Onyx</td>
<td>540 g</td>
</tr>
</tbody>
</table>

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

K. R. Embry, et al., 2018
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

- 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\(^2\).

References:
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.
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.

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


Thank you for watching!