

# Design of 3D printable prosthetic foot to implement nonlinear stiffness behavior of human toe joint based on finite element analysis

FEA를 통한 인간 발가락의 비선형 강성 거동을  
모방한 3D 프린팅가능한 의족 발 디자인



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# Design of 3D printable prosthetic foot

## ► Research necessity

자연스러운 보행을 위한 발목 관절을 모방한 의족에 대한 연구는 많이 이루어지나,  
인간의 발가락 관절을 모방한 의족에 대한 연구가 부족함

## Design of 3D printable prosthetic foot to implement nonlinear stiffness behavior of human toe joint



발가락 관절은 의족 설계시 중요한 요소 중 하나

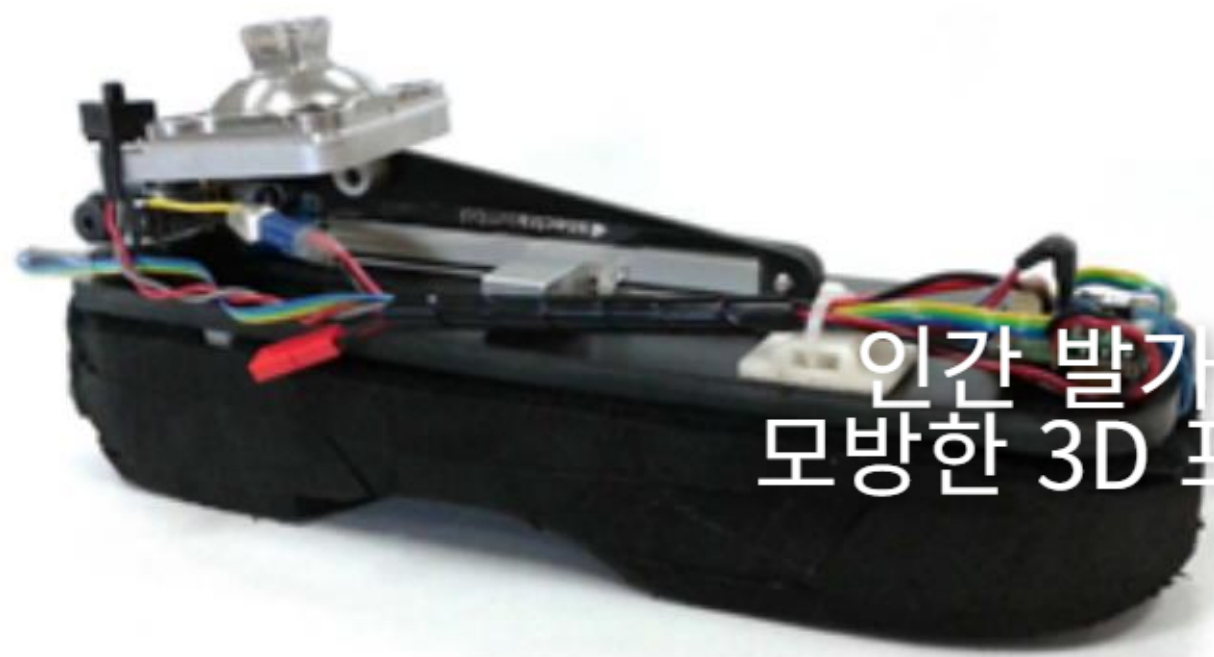
발가락 관절의 강성은 발목 kinetics에 영향을 끼치며, toe-off(보행중 발가락이 떨어지는 시기)동안 일반적인 탄력감을 제공



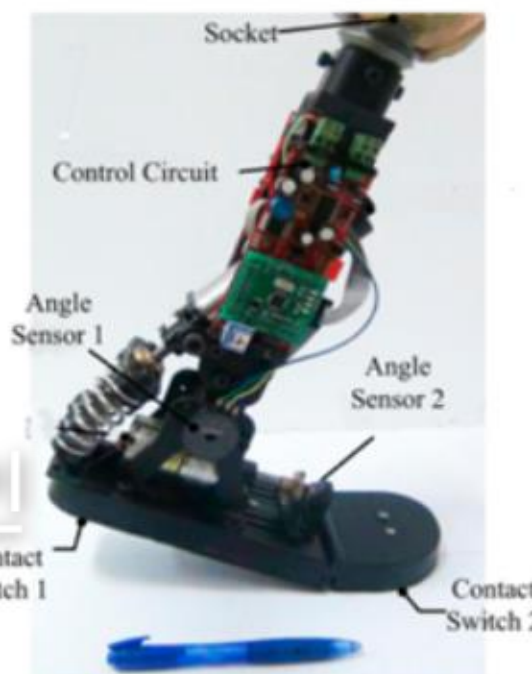
# Design of 3D printable prosthetic foot

## ► Research necessity

### 선행 연구



인간 발가락의 비선형 탄성 거동을 모방한 3D 프린팅 가능한 의족 발 디자인



Glanzer, E. M. & Adamczyk, P. G.

'Design and validation of a semi-active variable stiffness foot prosthesis'

Zhu, J., Wang, Q. & Wang, L.

'Effects of toe stiffness on ankle kinetics in a robotic transtibial prosthesis during level-ground walking'

### 한계점

복잡한  
제작과정

비선형 탄성 거동  
수행 불가

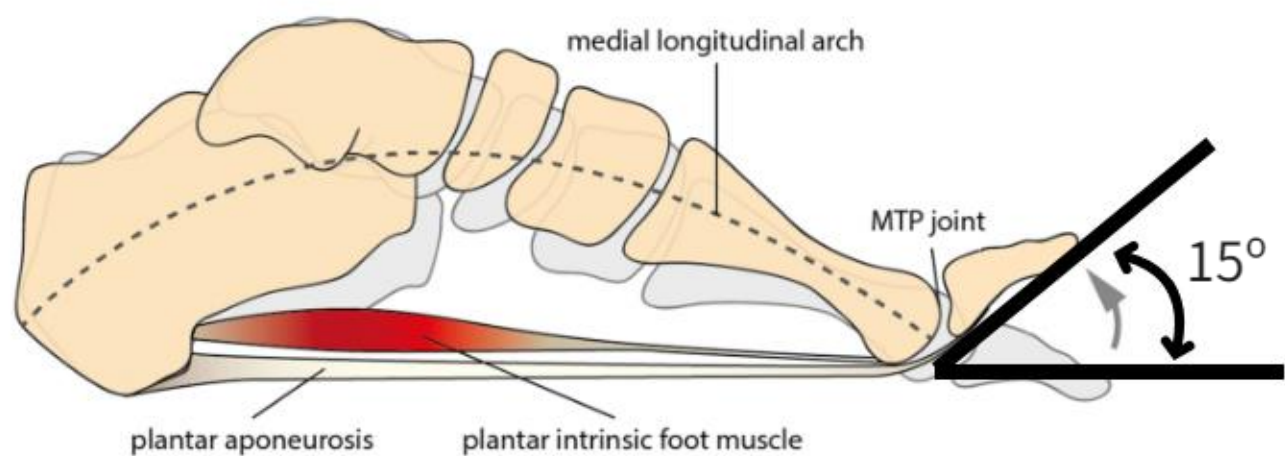
무거움

전동장치가 필요없고 인간 발가락 관절의 비선형 탄성 특성을  
가지는 가벼운 3d printing 가능한 foot 디자인 필요

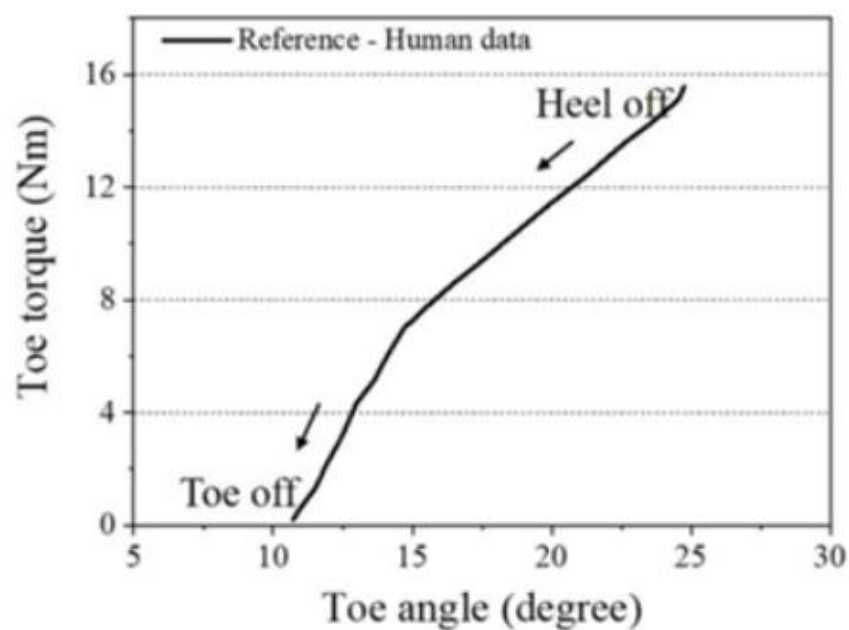
# Design of 3D printable prosthetic foot

## ► Method

### Design 고려사항



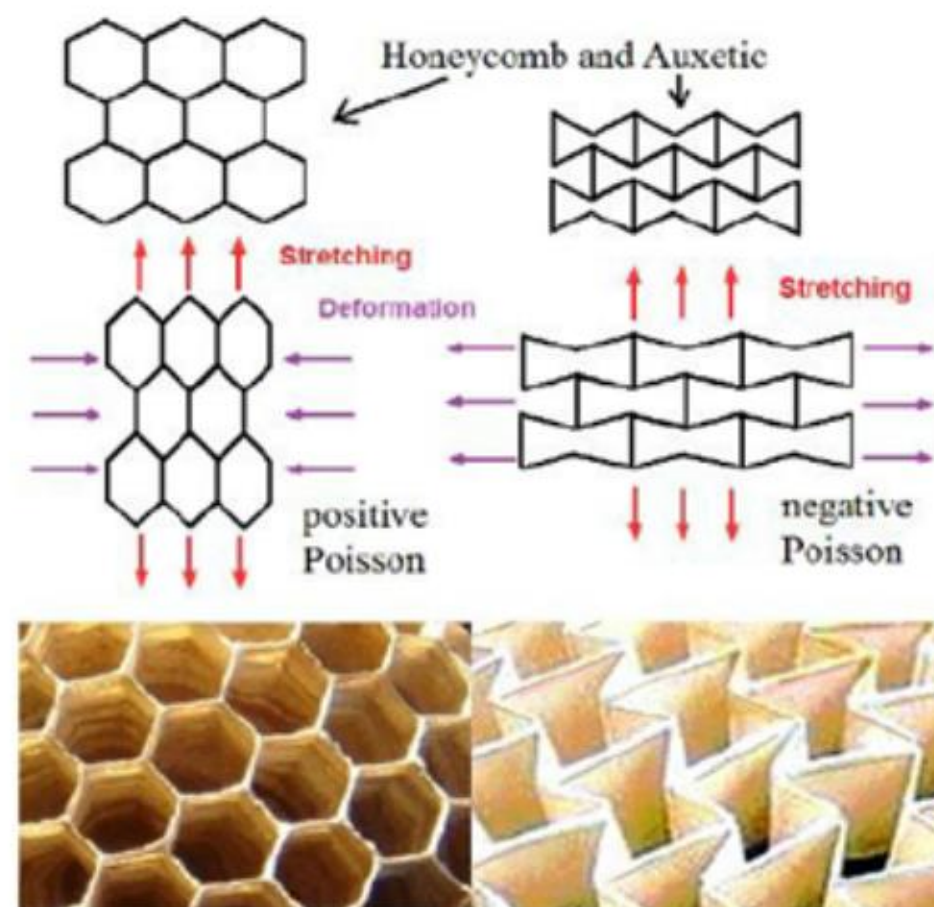
굽힘에 대한 안정성



비선형 탄성 거동



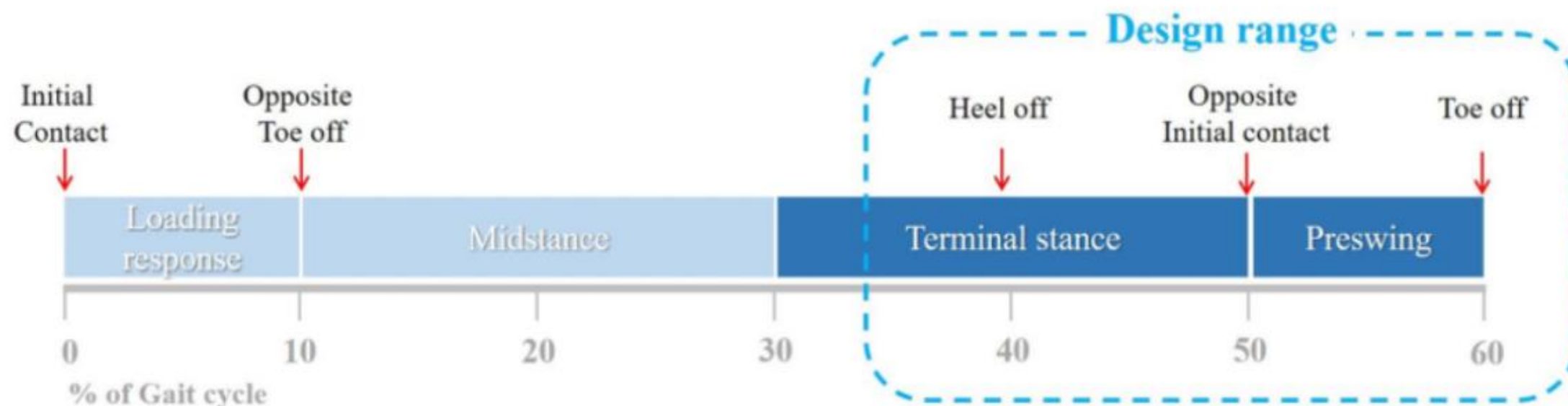
## Auxetic structure



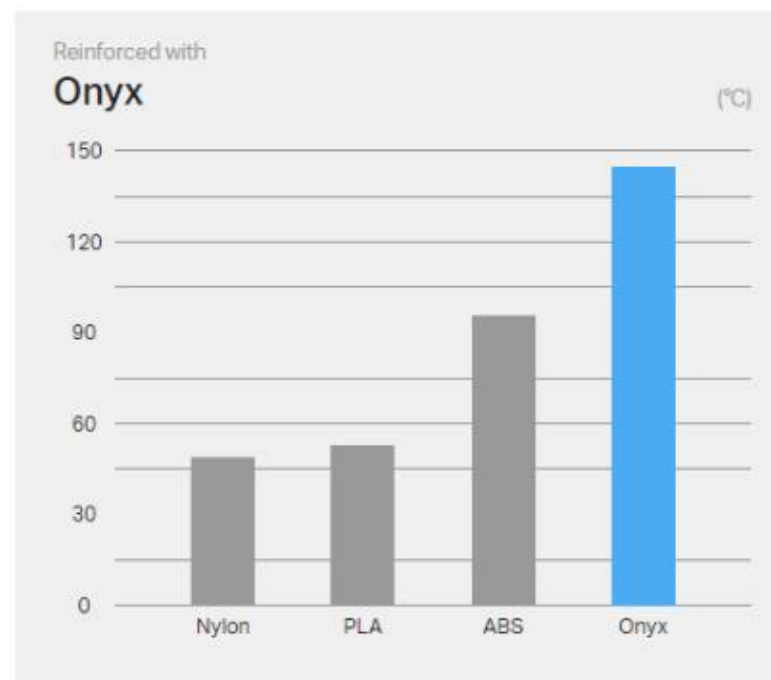
# Design of 3D printable prosthetic foot

## ► Method

### Design 고려사항



보행주기의 목표 디자인 범위

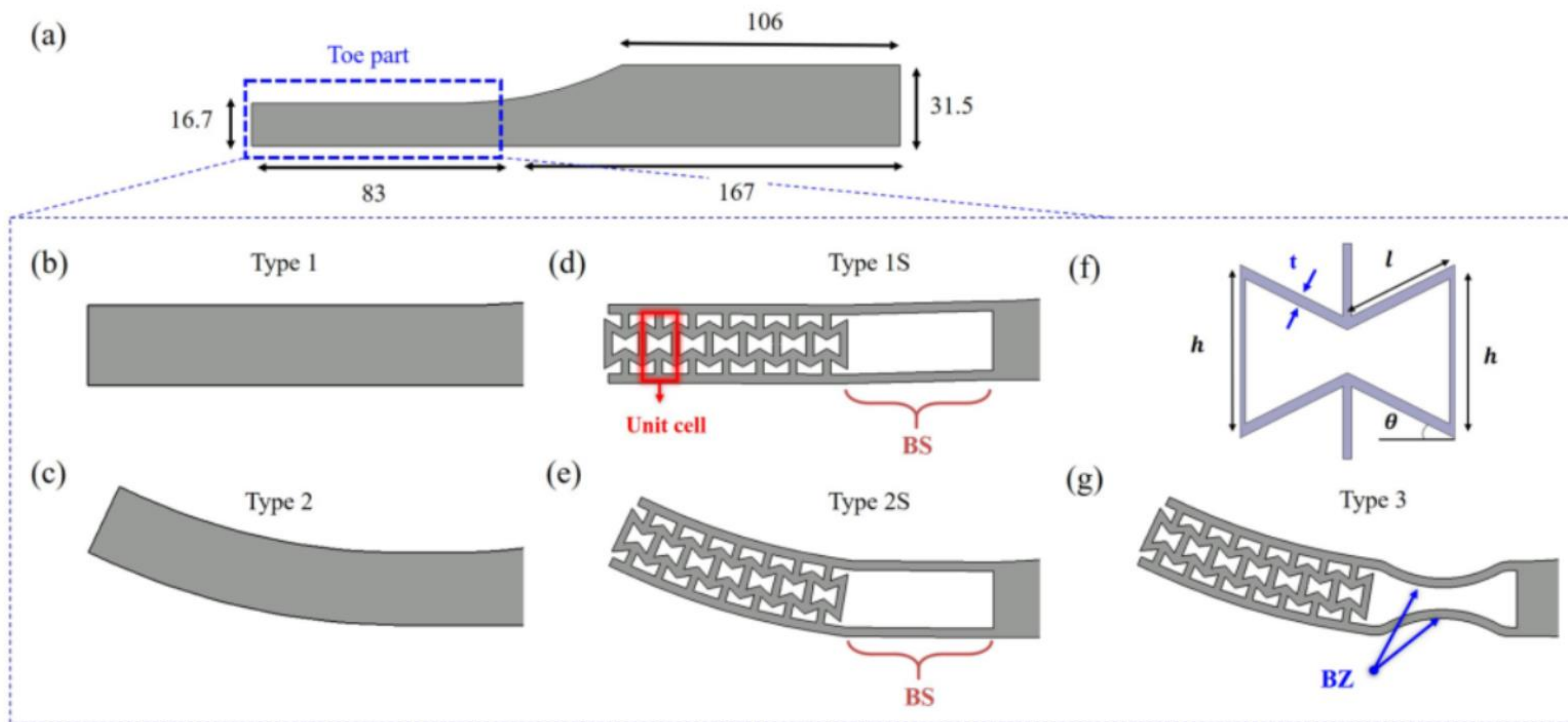


재료 : onyx filament



# Design of 3D printable prosthetic foot

## ► Method shape design

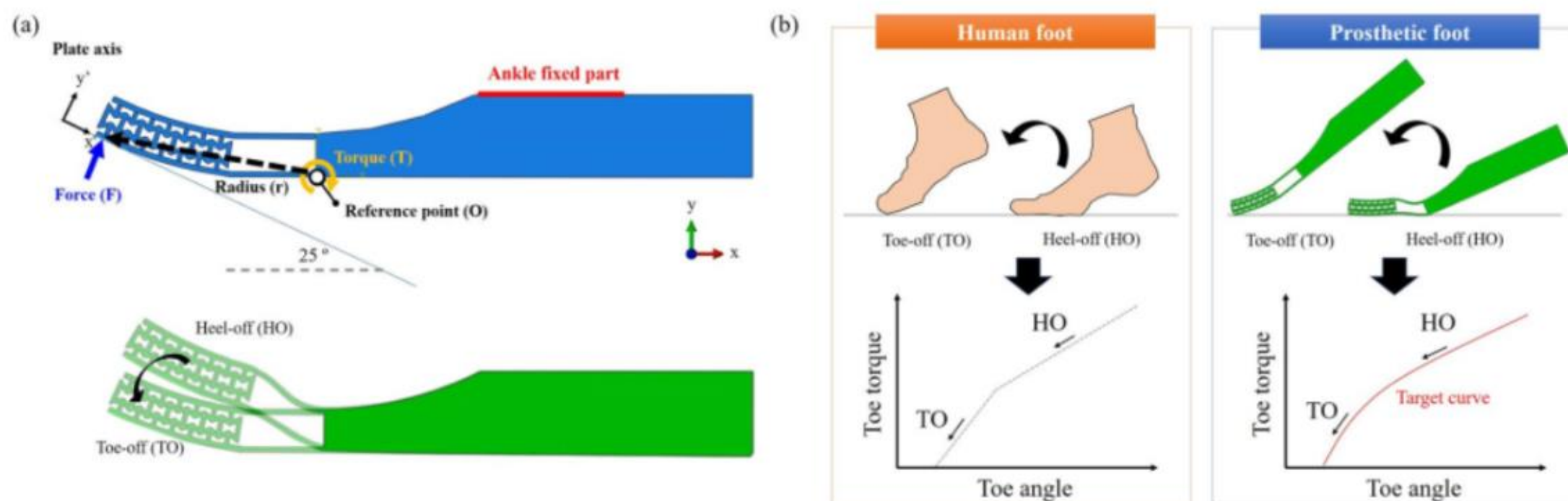


\* BS : Bending Space BZ : Bending Zone

# Design of 3D printable prosthetic foot

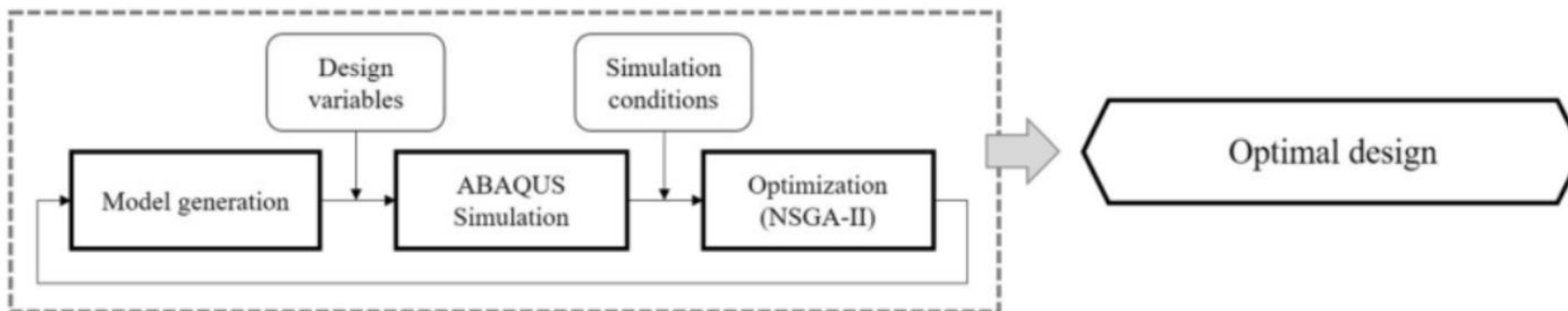
## ► Method

FEA



## Optimization

- Automation code flow chart

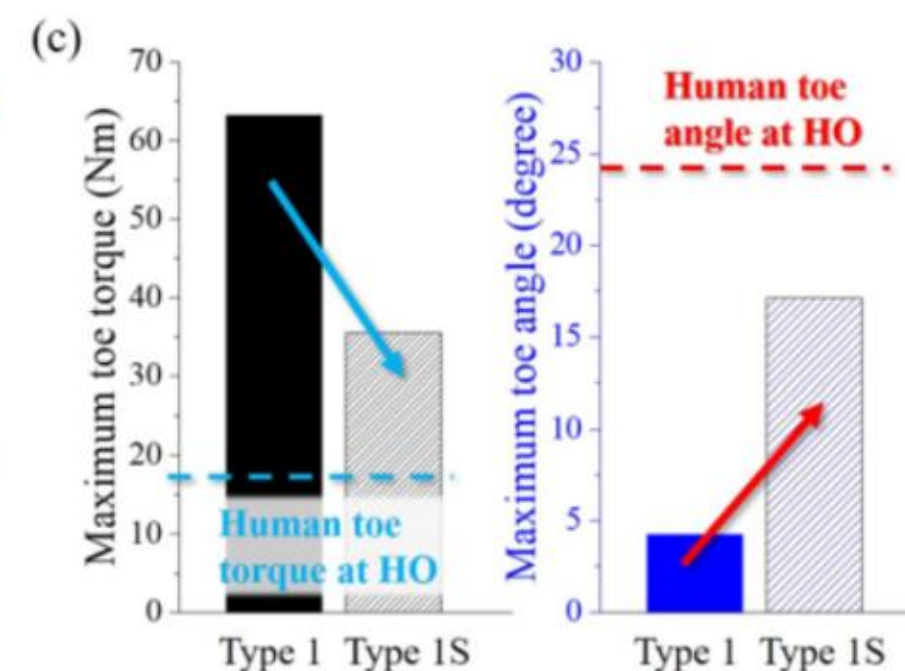
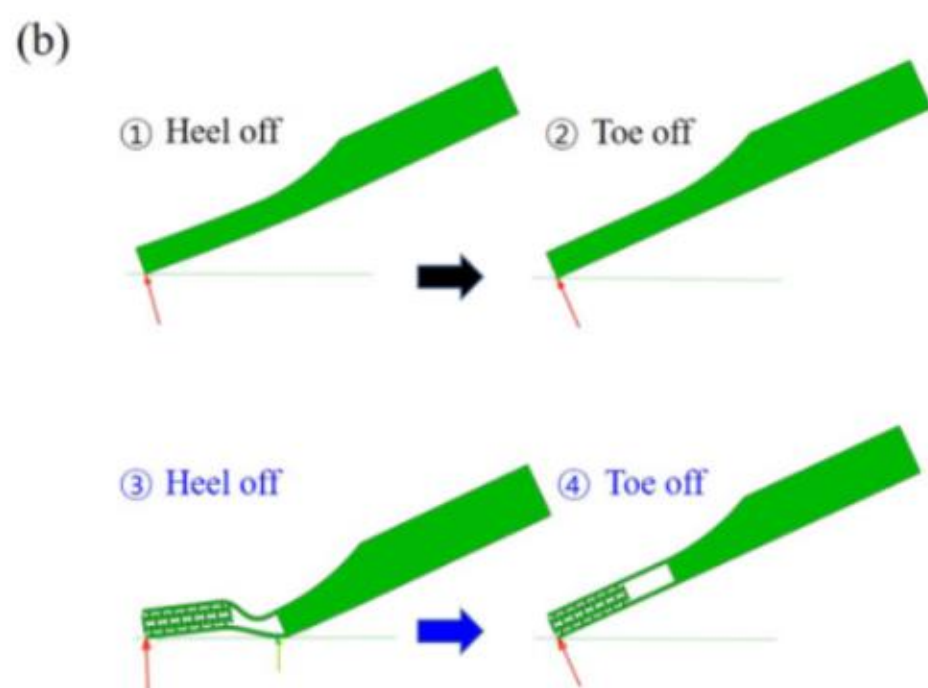
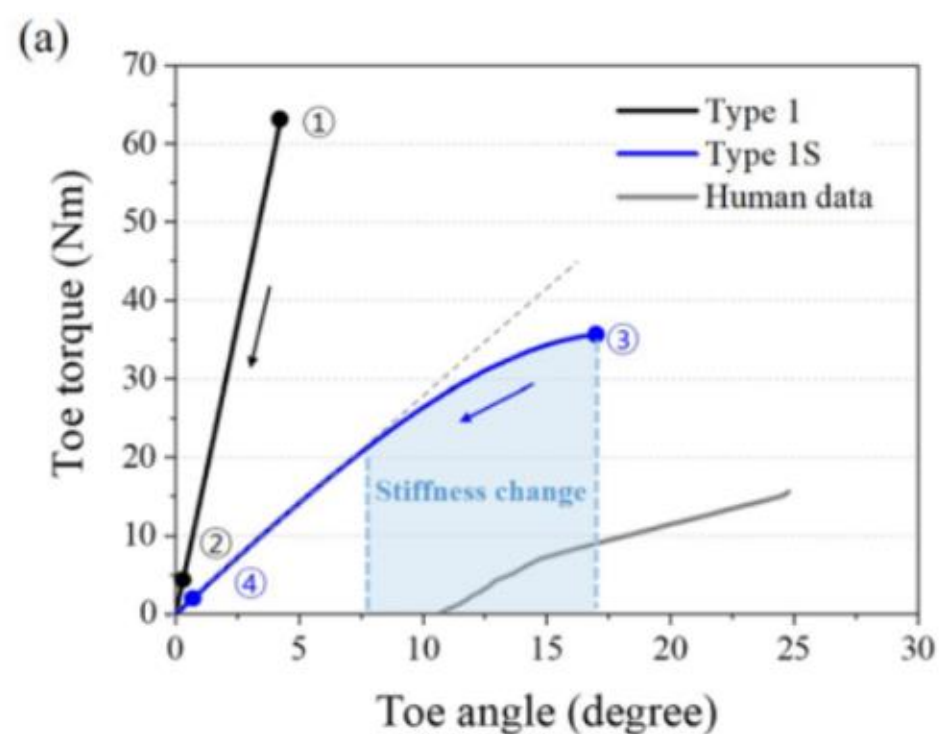




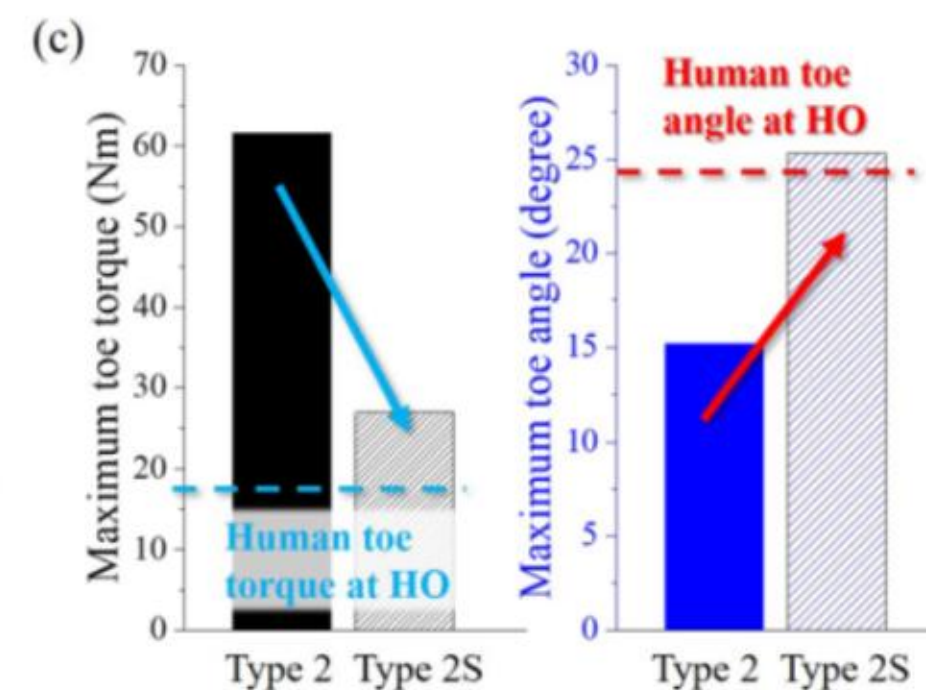
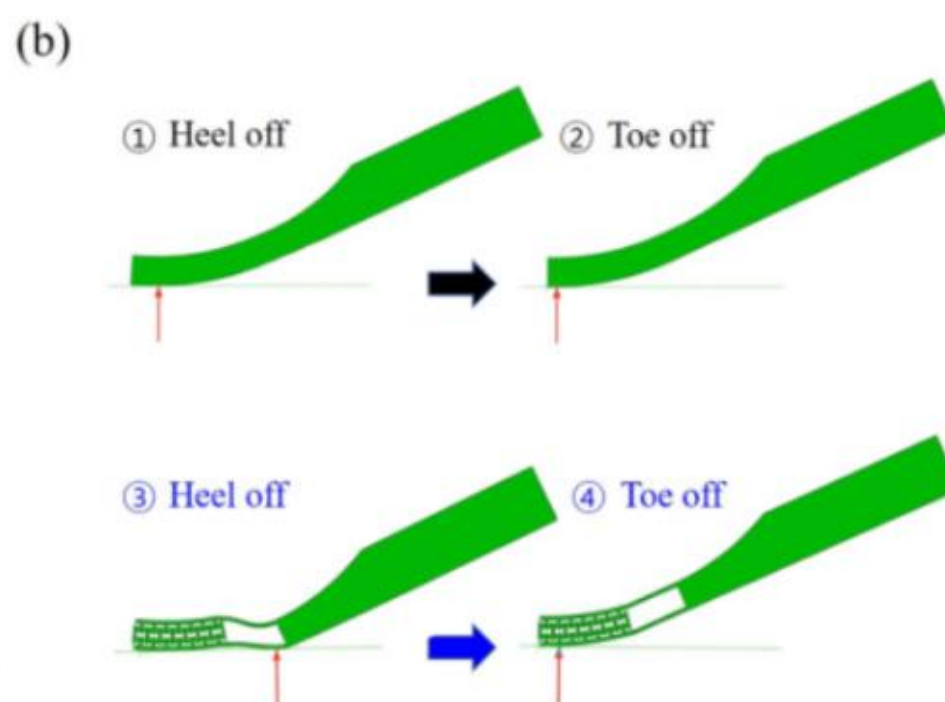
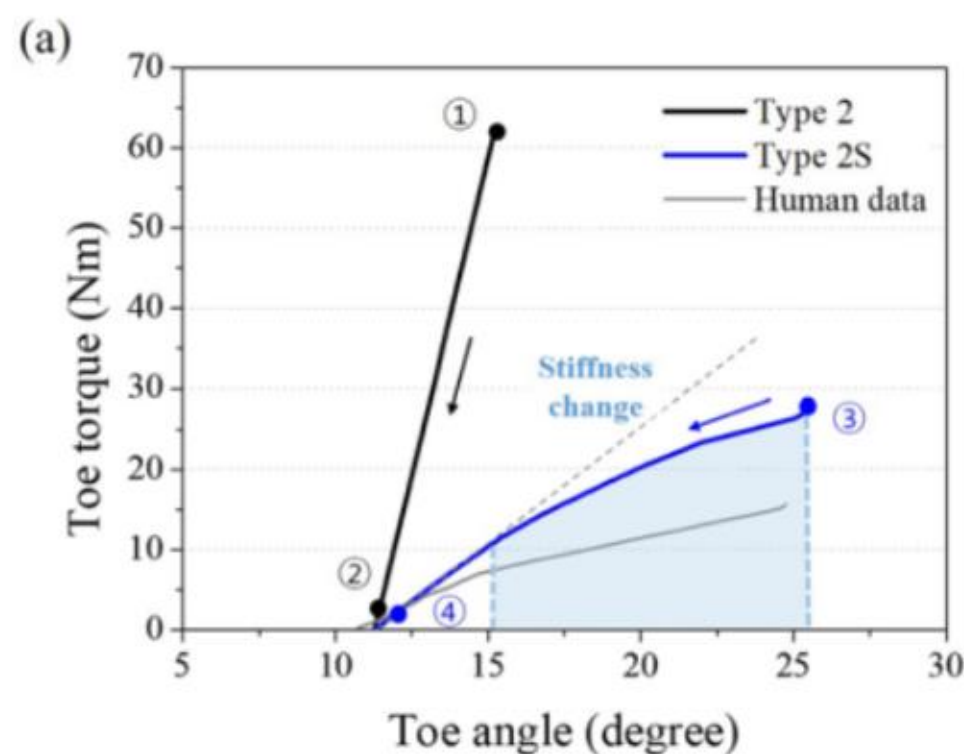
# Design of 3D printable prosthetic foot

## ► Results

### Type 1, 1S



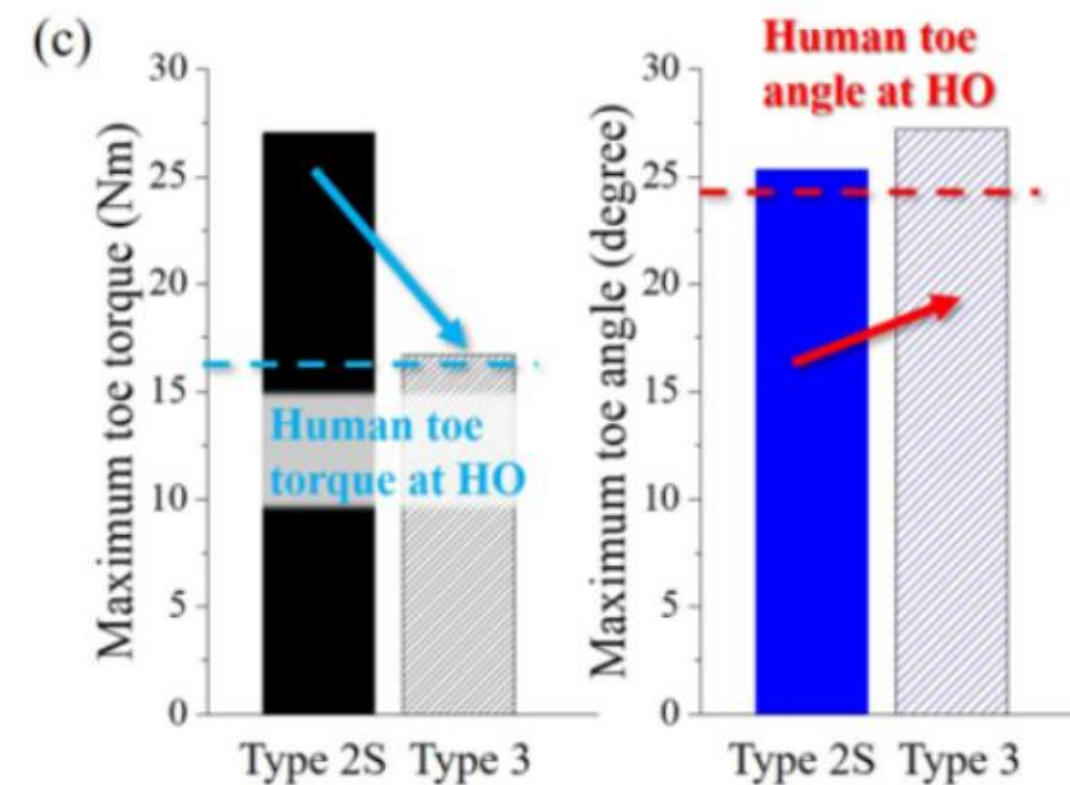
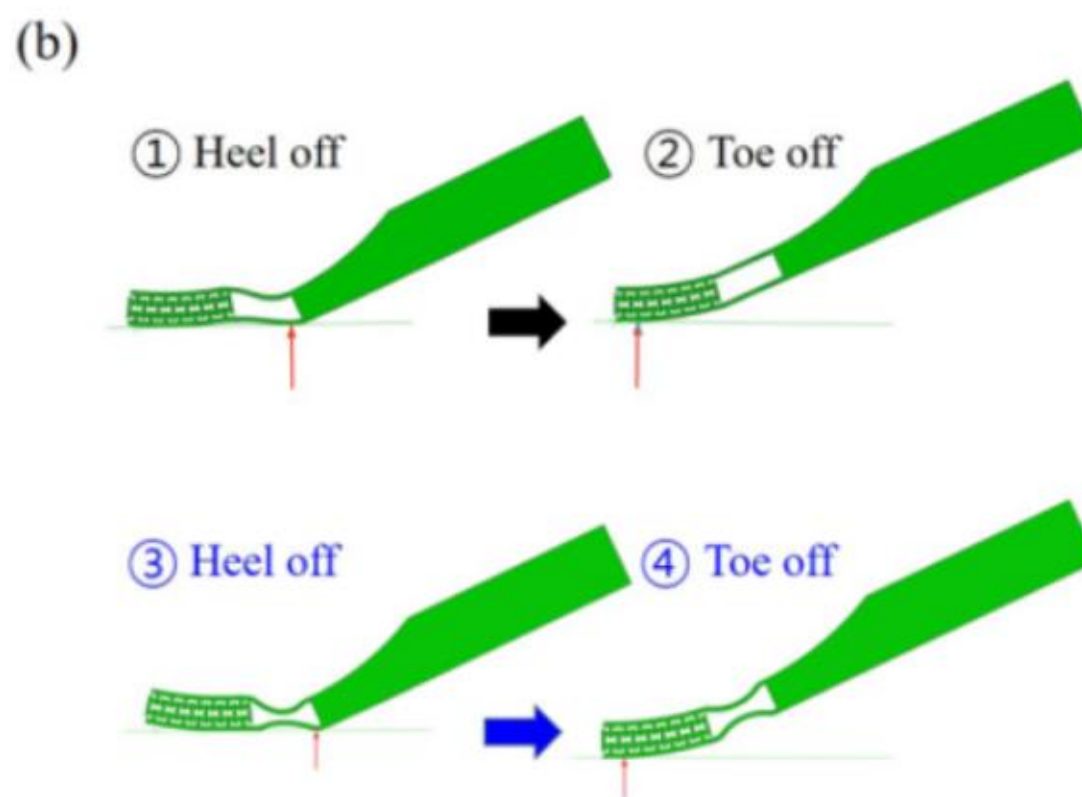
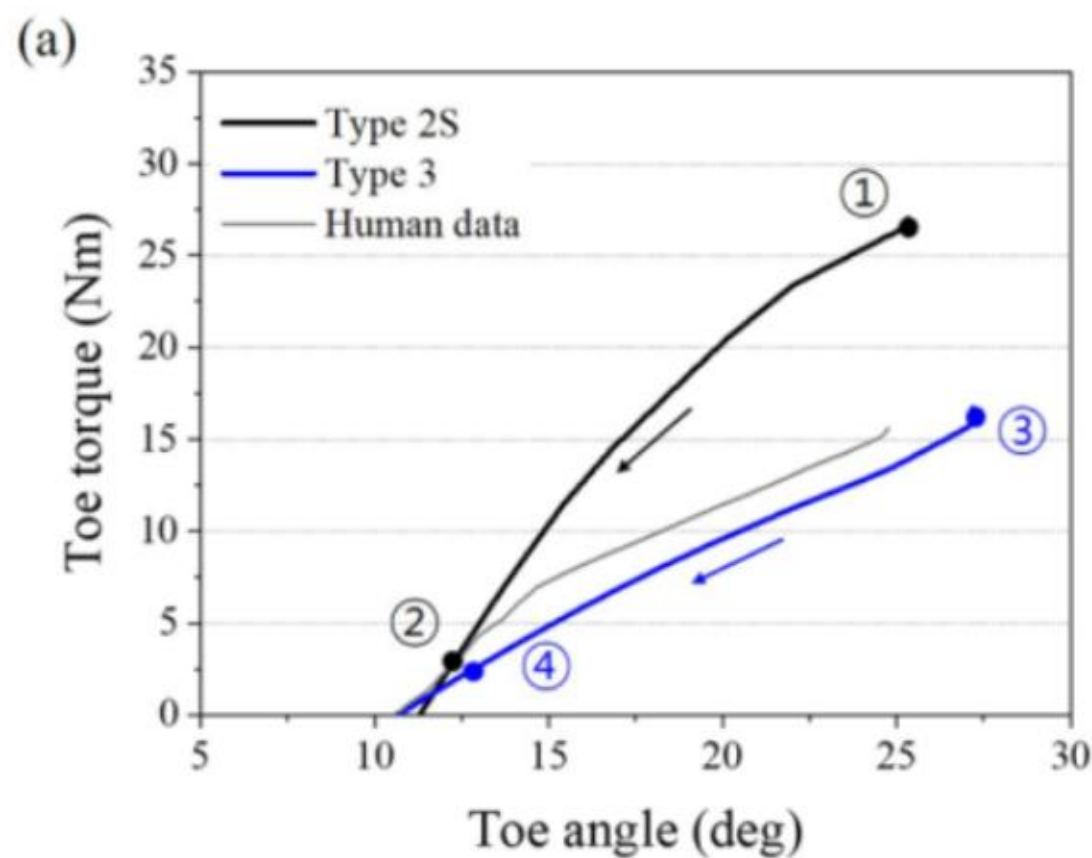
### Type 2, 2S



# Design of 3D printable prosthetic foot

## ► Results

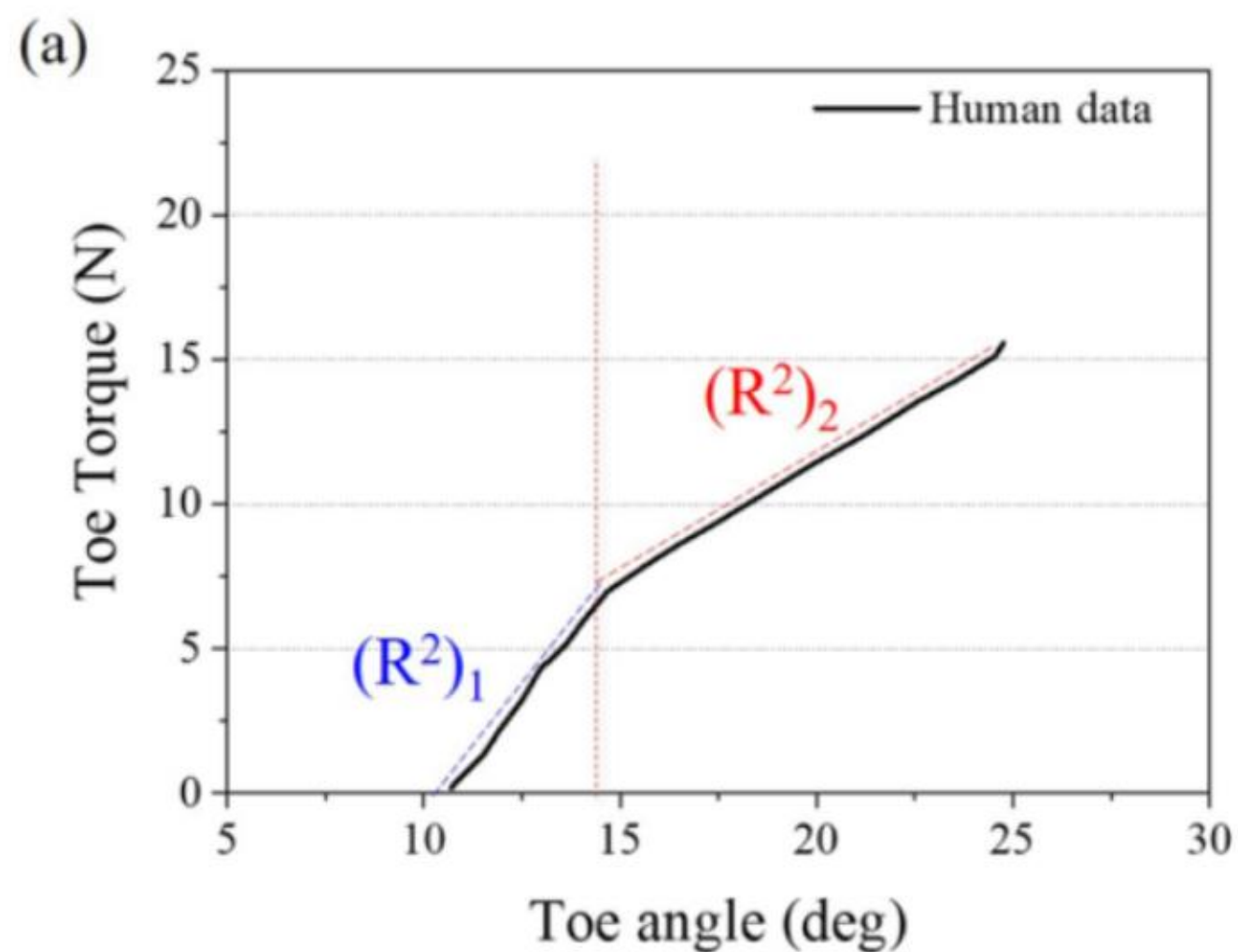
Type 2S, 3



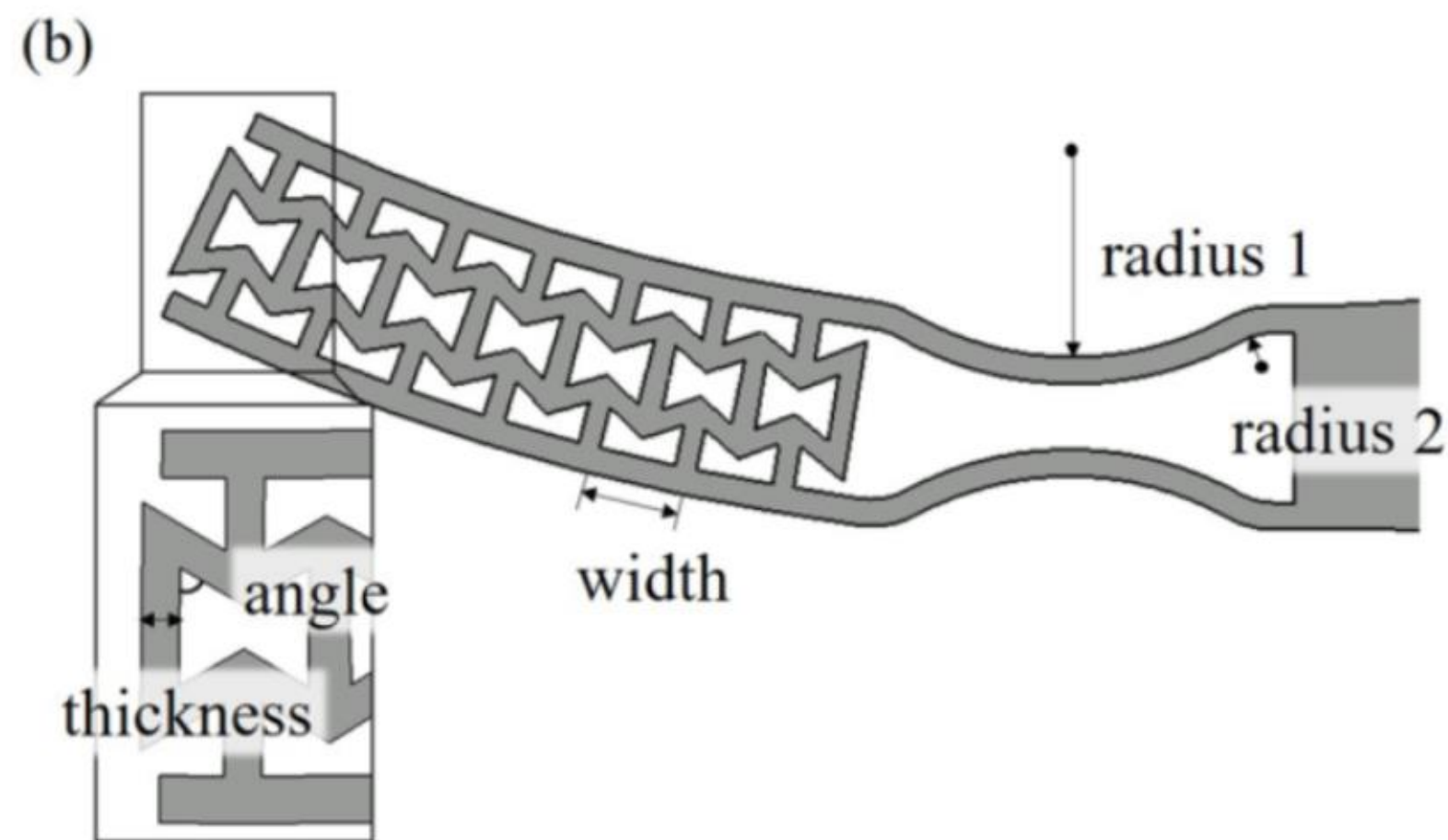
# Design of 3D printable prosthetic foot

## ► Results

### Optimization



결정계수의 계산영역



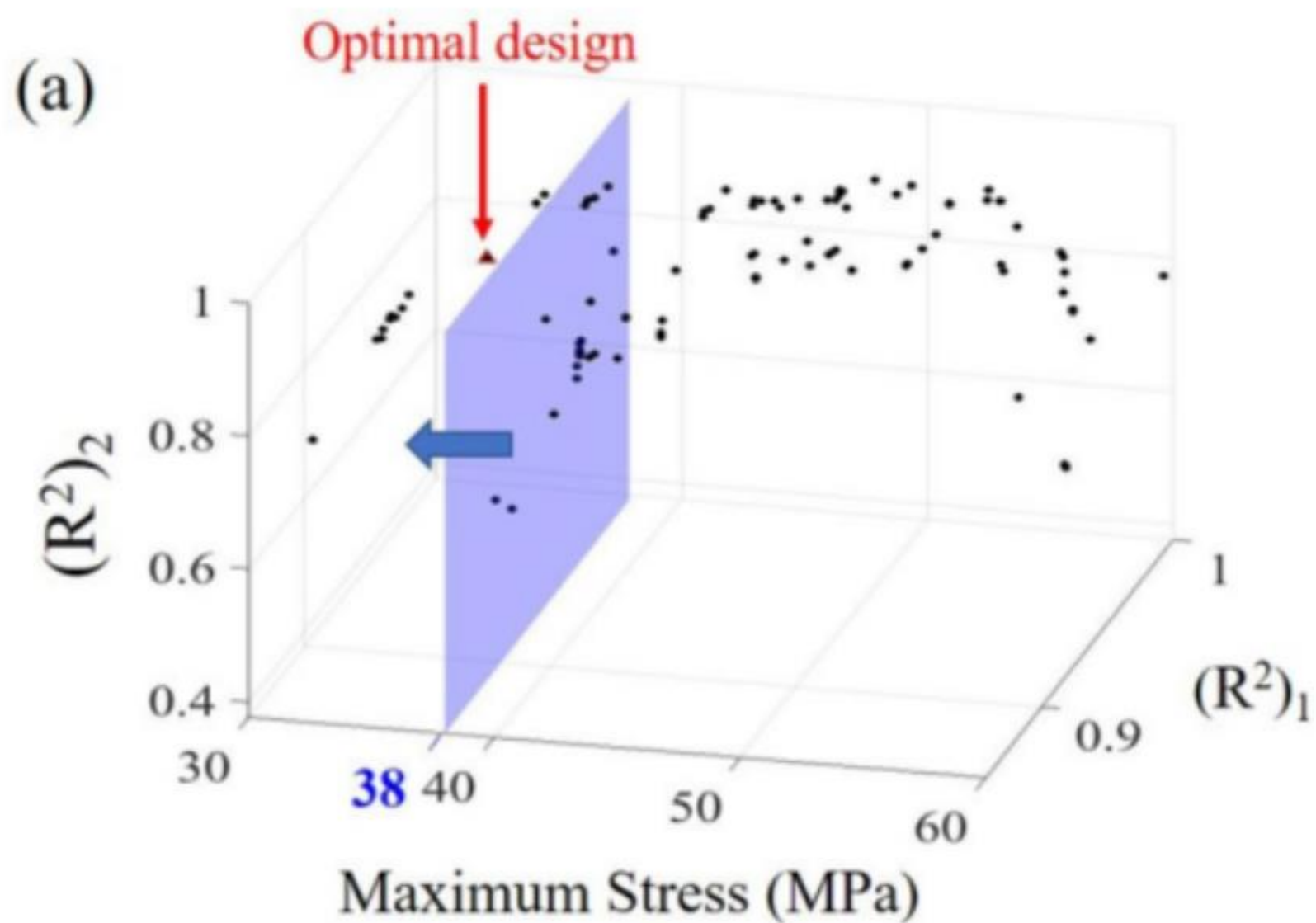
Type 3의 디자인 변수



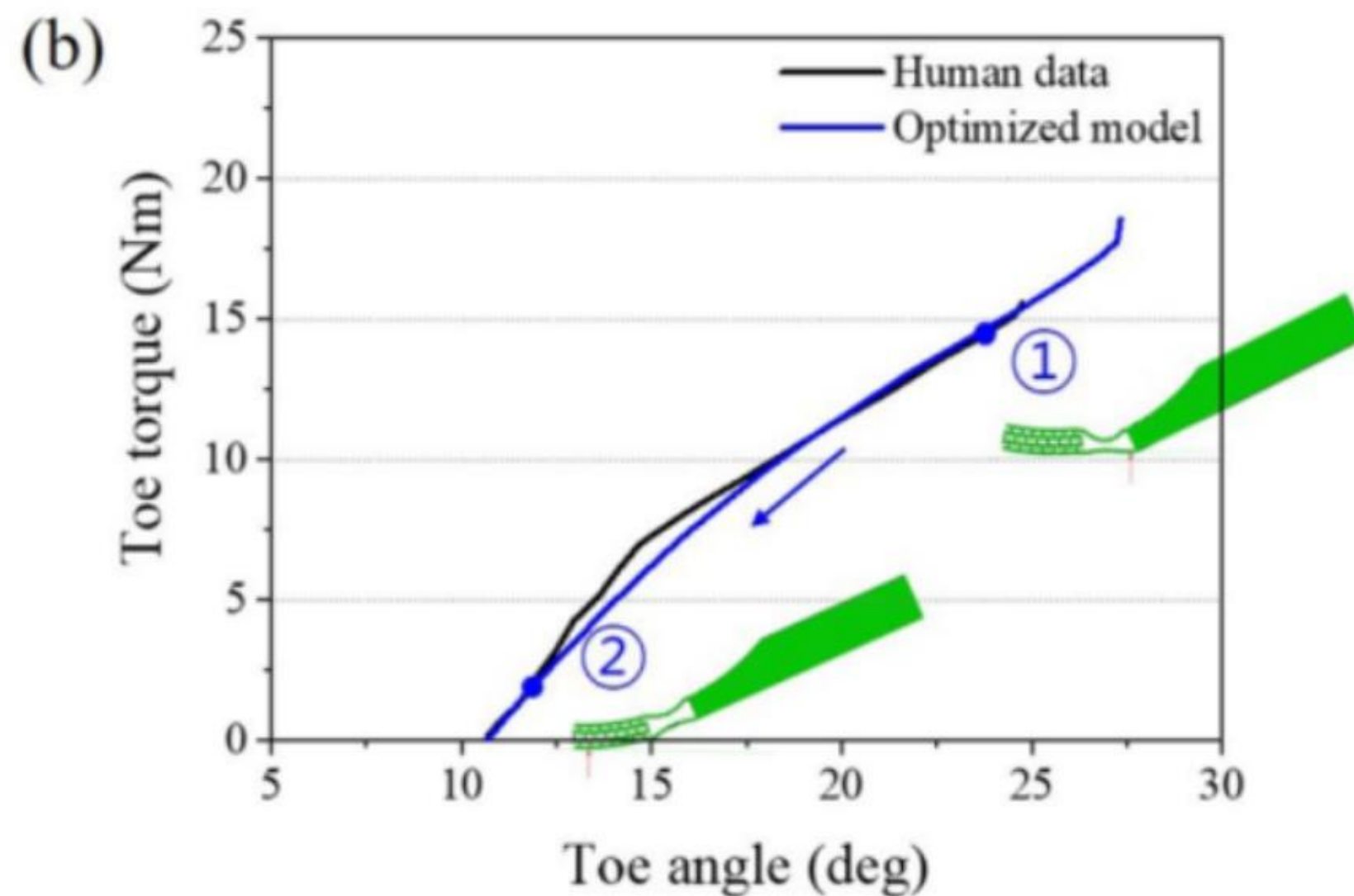
# Design of 3D printable prosthetic foot

## ► Results

### Optimization



optimization 결과

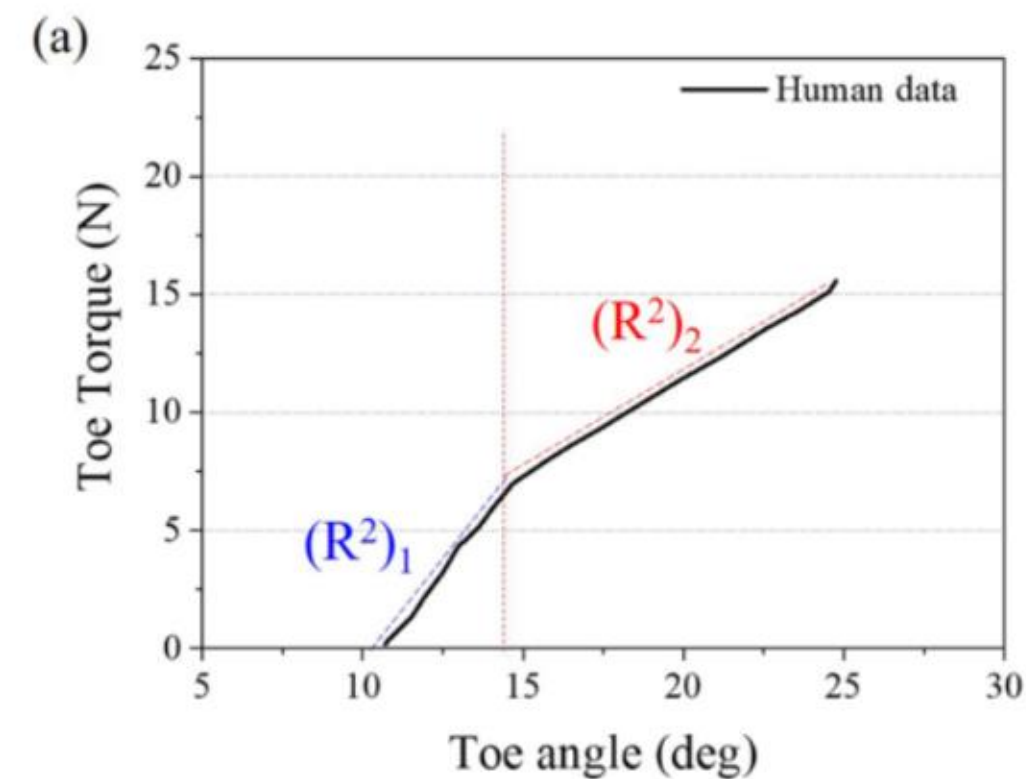
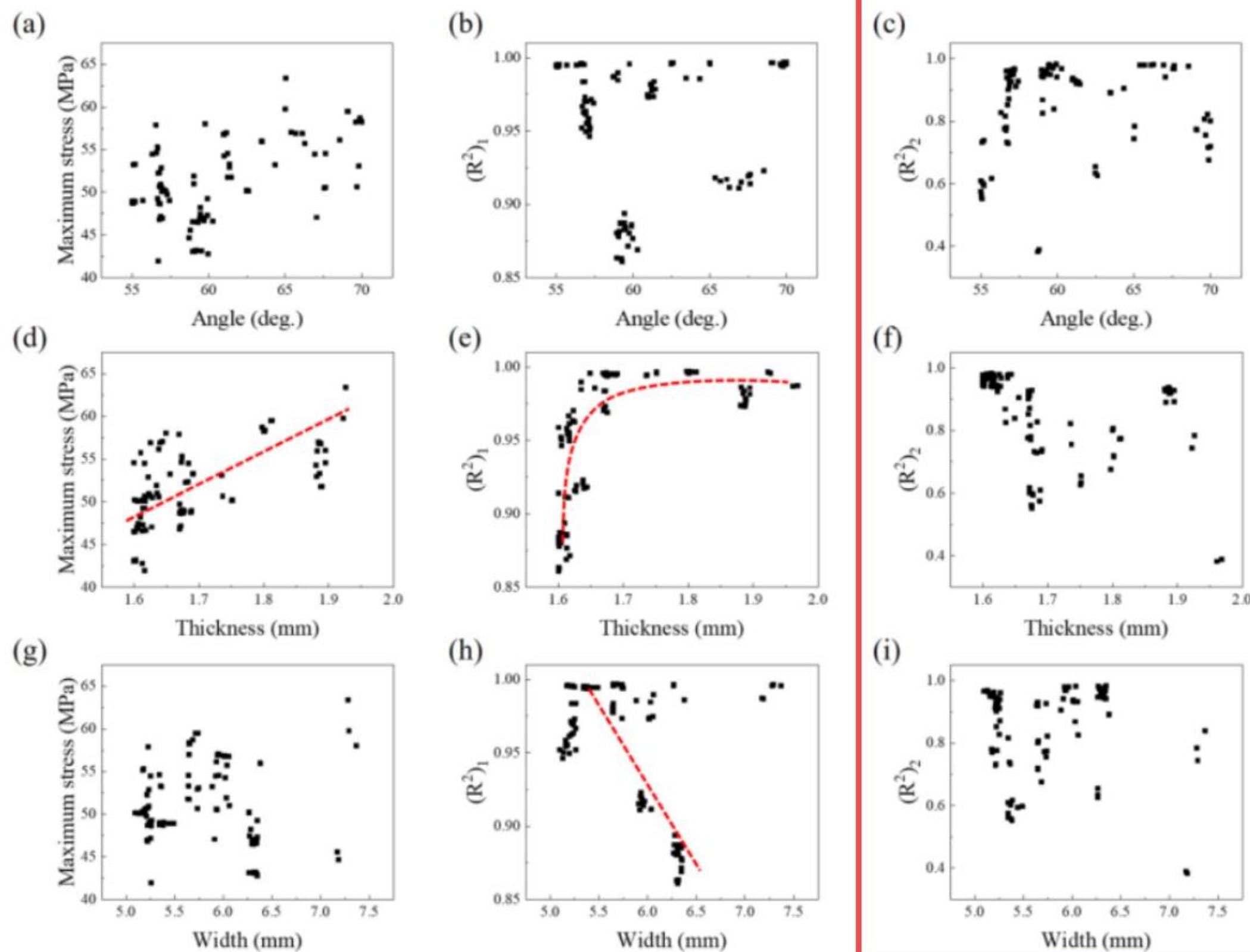


최적화 후 toe 토크-각 그래프

# Design of 3D printable prosthetic foot

## ► Results

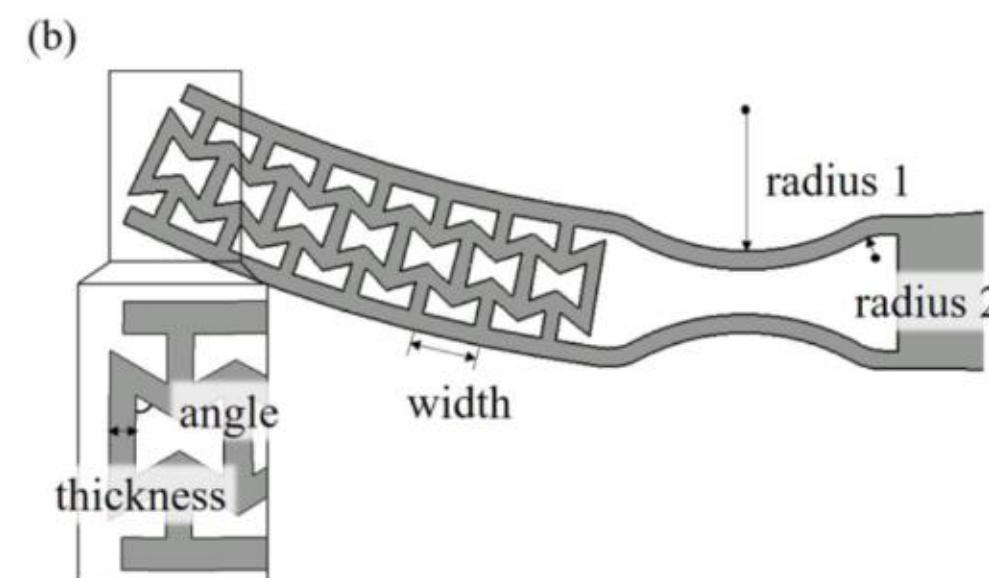
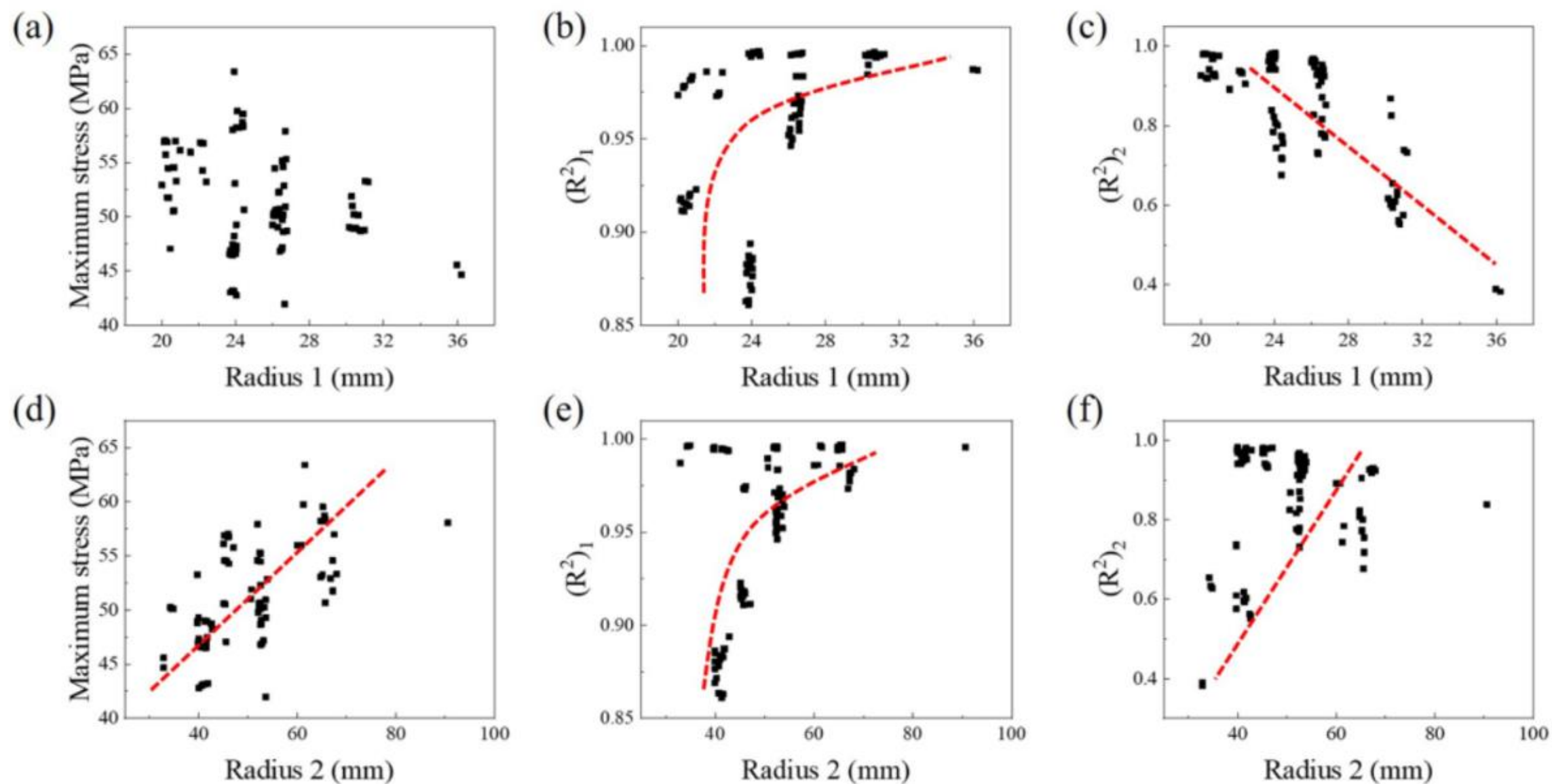
Effect of the design variables (Auxetic structure)



# Design of 3D printable prosthetic foot

## ► Results

Effect of the design variables(Bending Zone)

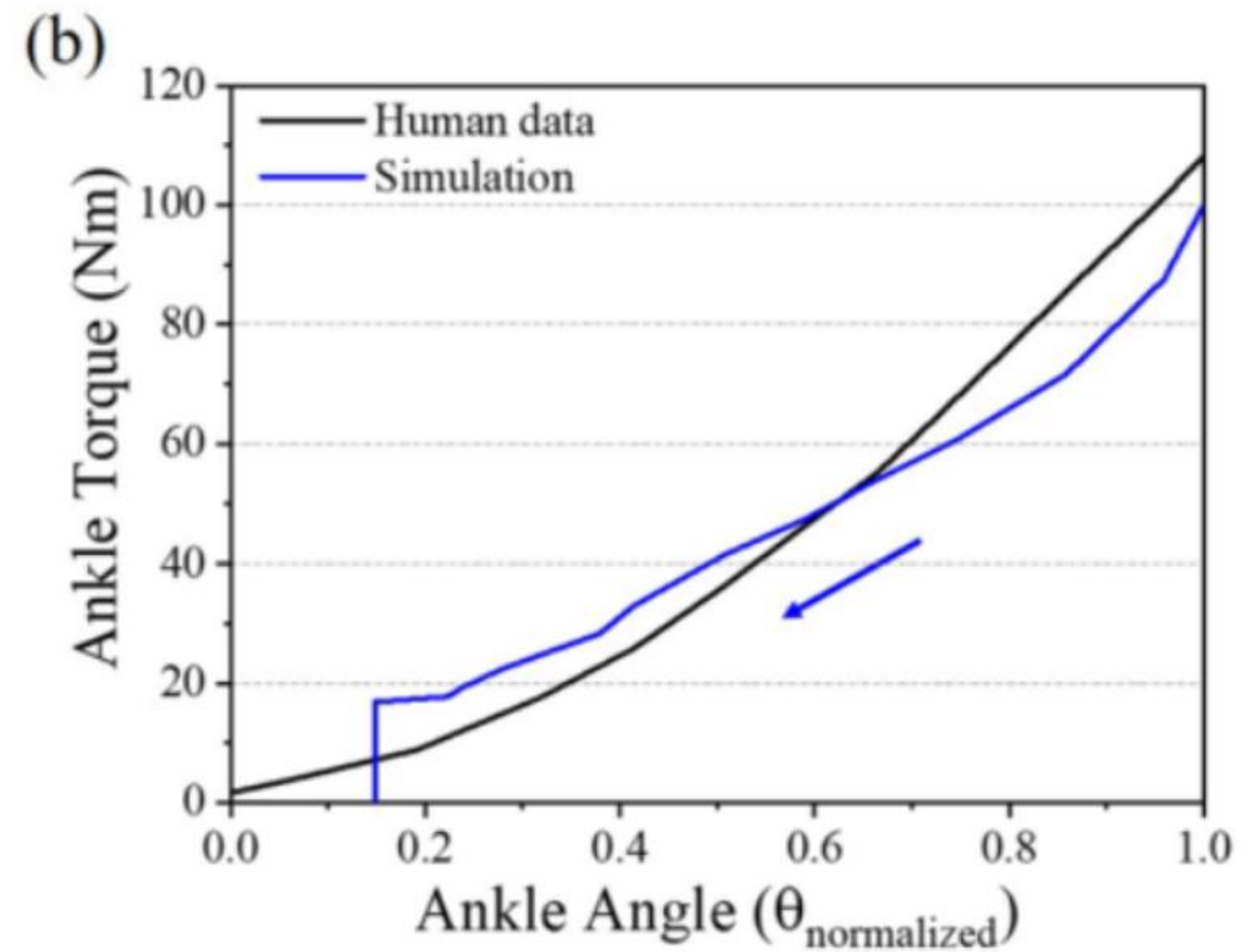
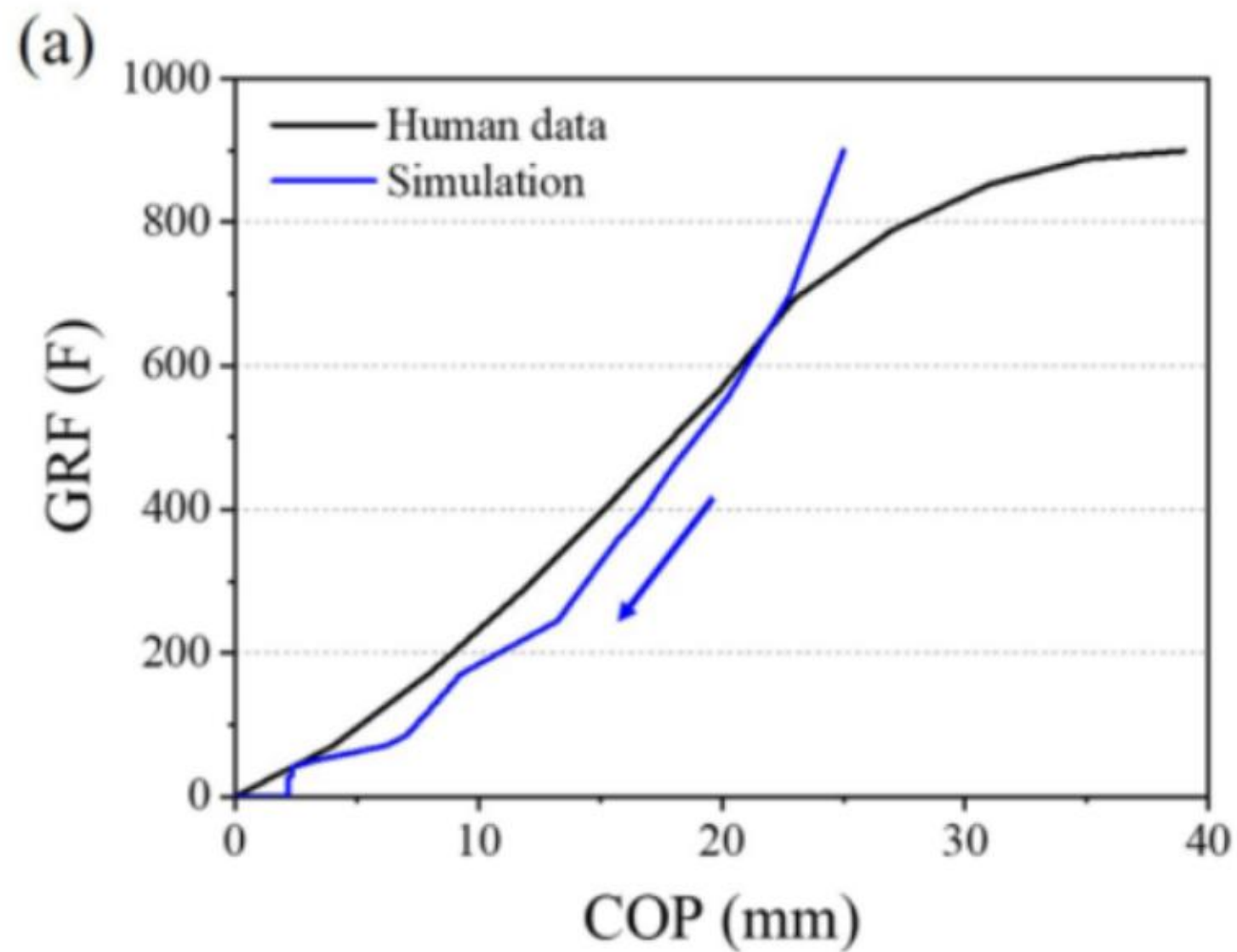




# Design of 3D printable prosthetic foot

## ► Results

### Simulation condition validation



# Design of 3D printable prosthetic foot

## ► Conclusion

본 연구의 3D printing foot design은 인간 발가락의 비선형 탄성 거동이 구현  
20도 이상 파손없이 변형이 가능

그러므로, 이 design은 다리 절단 환자의 재활 치료에 큰 도움이 될 것이라 예상

limitation

1. 설계된 foot의 강성 곡선이 완만한 형태로 나타나, 인간의 발 특성과 다름
2. 설정한 체중 범위를 벗어난 환자가 사용할 경우 foot design 변수 수정 필요

future work

1. 디자인 된 foot을 사용하여 실내 실험을 통한 비선형 강성 특성 및 foot강도 검증
2. 전체 보행 단계에서의 비선형 인간 걸음걸이 행동을 모방