

# Custom-Made Insoles Using 3-D Technology for Foot Pain and Gait: An Exploratory Study

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## Introduction

Custom-made insoles can help alleviate foot pain and discomfort by fitting an individual's foot shape and needs. 3D scanning and printing advancements allow efficient and cost-effective production of custom-made insoles, improving accessibility. This explorative study aims to assess the feasibility and user satisfaction of these insoles.

## Methods

We enrolled participants based on following criteria; being 18 years or older, experiencing foot pain or discomfort lasting at least four weeks, and having no history of lower limb surgery or fractures in the past year. Exclusion criteria included pregnancy, use of medications that may affect foot function or mobility, history of neurological disorders affecting the lower limbs, and presence of open sores, wounds, or infections on the feet. All participants were provided with custom-made insoles created using 3-D scanning and printing technology to alleviate their foot discomfort or pain.



Figure 1. 3-D scanner and its application

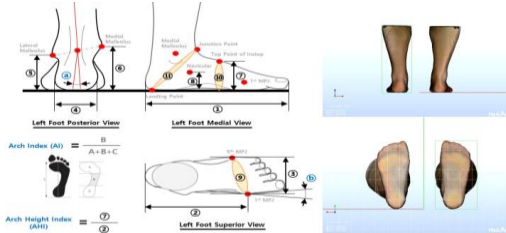


Figure 2. Foot 3-D scanning anatomical data analysis

To compare the effectiveness of these custom-made insoles, we conducted gait analysis and radiologic examination twice, once with the custom-made insoles and once with conventional insoles. During the gait analysis, we examined spatiotemporal parameters and kinematic parameters, while in foot radiology, we measured Meary's angle, Calcaneal pitch angle, and Navicular coverage angle. The participants' subjective foot pain or discomfort was measured using a Patient-Reported Outcome Measure (PROM) and was expressed on a Numeric Rating Scale (NRS).



Figure 3. Gait analysis



Figure 4. Radiographic analysis: the left image presents without the insole, and the right image shows with the insole. Red dotted line: Meary's angle, Yellow dotted line: Calcaneal pitch angle.

## Results

We recruited 20 participants, of whom 16 were female and 4 were male. Table 1 displays demographic characteristics including age, gender, height and weight of the subjects. Gait analysis showed that wearing customized insoles significantly improved gait speed and step length compared to before wearing them, as presented in Table 2. However, no significant changes were observed in other spatiotemporal or kinematic parameters.

Table 1. Demographic characteristics of participants

Sex (M:F)	4:16
Age (years)	43.80 ± 16.65
Height (cm)	161.45 ± 7.43
Weight (kg)	60.95 ± 9.45

Table 2. Effect on the spatiotemporal parameters of gait analysis

	Before	After	P-value
Gait speed (m/s)	1.07 (1.00-1.12)	1.08 (1.05-1.18)	0.008
Stride length (m)	1.15 (1.11-1.24)	1.17 (1.13-1.28)	0.500
Stance time (sec)			
- Left	0.71 (0.66-0.74)	0.69 (0.65-0.74)	0.062
- Right	0.70 (0.67-0.74)	0.71 (0.66-0.75)	0.636
Swing time (sec)			
- Left	0.43 (0.39-0.45)	0.42 (0.39-0.45)	0.847
- Right	0.40 (0.39-0.43)	0.41 (0.38-0.43)	0.356
Step length (m)			
- Left	0.54 (0.52-0.60)	0.55 (0.53-0.65)	0.008
- Right	0.61 (0.57-0.66)	0.62 (0.59-0.66)	0.014
Step length ratio (R/L)	1.14 (1.02-1.19)	1.09 (1.04-1.15)	0.132

The assessment of foot pain or discomfort using the PROM showed a significant decrease in the NRS score after wearing the customized insole, as illustrated in Figure 1. Radiographic examination revealed a significant improvement in all measured angles after wearing the insoles, as presented in Table 3.

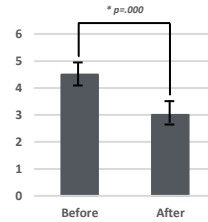


Figure 1. Change of the numeric rating scale of foot discomfort/pain after use of the customized insole

Table 3. Effect on the radiologic measurements

Parameters	Before	After	P-value	
Talonavicular coverage angle (°)	Right	15.02 (12.96-23.53)	13.55 (7.66-21.39)	.000
	Left	17.78 (9.91-21.66)	14.57 (8.12-18.95)	.000
Calcaneal pitch angle (°)	Right	20.74 (16.34-25.31)	21.34 (18.44-25.85)	.000
	Left	17.99 (15.99-24.33)	20.15 (18.24-25.17)	.000
Meary's angle (°)	Right	0.02 (-7.34-4.66)	0.49 (-3.59-5.09)	.000
	Left	1.92 (-6.31-3.23)	2.88 (-6.15-5.16)	.000

## Conclusion

The results of this study suggest that custom-made insoles created using 3-D technology can improve symptoms of foot pain and discomfort in patients during gait. This improvement is associated with an increase in gait speed and stride length. However, correction effects are limited to static foot alignment, and dynamic foot function remains inconclusive. Custom-made insoles have a positive impact on foot pain and gait abnormalities, but corrective effects are limited to the static foot position.

## Acknowledgement

This work was supported by the Korea Medical Device Development Fund grant funded by the Korea government (the Ministry of Science and ICT, the Ministry of Trade, Industry and Energy, the Ministry of Health & Welfare, the Ministry of Food and Drug Safety) (Project Number: 1711174488, RS-2020-KD000000)