3D Printed Orthotic Shoe with Sole Geometry towards Reducing Dynamic Joint Moments

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Summary

This study utilized 3D-printing to develop orthotic shoes with varied sole designs based on novel internal structures as a conservative treatment for knee osteoarthritis (KOA). Shoe gait tests on 18 healthy subjects revealed that the novel designs, particularly the rocker outsole and soft heel shoes, significantly reduced knee adduction moments (KAMs) compared to control shoes. Surpassing lateral-wedged insoles (LWIs), the orthotic shoes demonstrated superior efficacy in lowering both peak KAMs and KAM impulse, indicating their potential for clinical KOA management.

Introduction

Foot orthoses are a clinically recommended conservative treatment for early KOA [1, 2]. Nevertheless, their efficacy remains controversial because of biomechanical non-responders. This study reported a 3D printing concept for manufacturing novel orthotic shoes with varied sole designs, and their biomechanical efficacy for reducing KAMs.

Methods

Shoe mid- and out-soles were designed using CAD software, and fabricated in an Artillery 3D printer (Fig. 1). Leveraging the advantages of 3D printing to create materials with targeted structure based properties, we adjusted the stiffness and geometry for different regions of the sole, enabling the production of three shoe designs: 1) a sole with soft heel (SH); 2) a sole with medial-soft heel in rocker shape (RS); 3) a sole with medial-soft heel in lateral shift shape (LS). For the fore region, a medial-soft design was applied, with a mediolateral separation along the mid-line of the sole. The sole was bonded to a shoe-upper to complete the shoe.

Shod gait tests were performed on 18 healthy subjects for the orthotic shoes, 5° LWIs, and control shoes, in order to evaluate their influence on KAMs and gait patterns. A 20-camera Vicon mocap system and three Kistler force plates were used to collect gait data. Subjects performed level walking trials with different orthoses in a randomized order, with three trials recorded for each condition. Visual3D software was used to process raw data and compute variables of interest. One-way repeated measures ANOVA were performed to assess variable differences across orthoses.

Results and Discussion

ANOVA revealed a significant effect of orthotic shoes on the subject's dynamic KAMs. Post-hoc tests indicated that the 1st and 2nd peak KAMs were significantly smaller in the LS, RS and SH shoes compared to the control shoes, but LWIs only reduced the 1st KAM. Importantly, all the three orthotic shoes significantly reduced the overall KAM impulse compared to the control shoe, but the LWIs failed. In previous studies, the biomechanical efficacy of LWIs was also reported controversially [3]. Our findings suggest that novel shoe designs can potentially replace LWIs as conservative treatment to KOA.

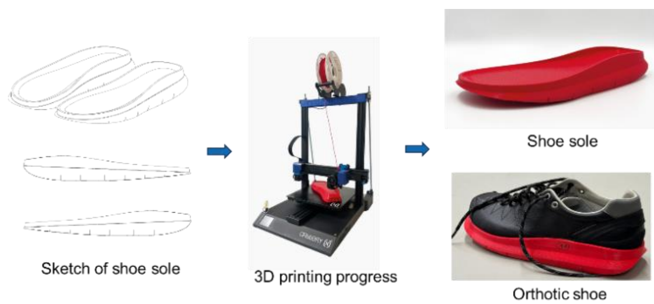

Figure 1: Procedure of 3D printing orthotic shoes.

Conclusions

Biomechanical efficacy of the orthotic shoes on KAMs during walking were greater than common LWIs, highlighting their potential for clinical management of KOA.

Acknowledgments

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References

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Table 1: Peak knee adduction moments (/m·kg) and angular impulse in various orthoses.

Parameters	Control	5° LWI	LS	RS	SH	F	*P*	ES
1st Peak KAM	0.267 ± 0.072	0.246 ± 0.061	0.248 ± 0.056	0.246 ± 0.059	0.240 ± 0.068	5.120	**0.001**	0.204
2nd Peak KAM	0.197 ± 0.047	0.194 ± 0.493	0.189 ± 0.042	0.179 ± 0.045	0.180 ± 0.054	4.677	**0.002**	0.190
KAM impulse	0.094 ± 0.025	0.088 ± 0.023	0.087 ± 0.021	0.082 ± 0.024	0.084 ± 0.024	9.508	**<0.001**	0.322