Fatigue Behaviour of 3D-Printed Solid Liquid Composite (SLC) Orthotic Insole: Experimental Study

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Summary

A 3D-printed Solid Liquid Composite (SLC) orthotic insole is a novel design showing potential capability to enhance cushion and reduce pressure on the foot, suitable for individuals with Diabetic [1]. However, durability testing remains a challenge, as there is currently no standard method for assessing orthotic insole durability [2]. This study aimed to evaluate durability of this insole adopting ISO 10328. Prosthetic foot used as setup instrument attached directly with the designed insole in configuration II simulated dynamic push-off (PO) [3]. The insole can withstand the load of nearly 100,000 cycles, equivalent to four months normal wearing.

Introduction

A developed 3D-printed SLC orthotic insole at the University of Auckland, incorporating functionally graded lattice inner structures filled with viscous liquid, ideal for ulcer development prevention due to its ability to respond impact forces, dissipated energy, and reduced peak pressure (20%) during walking [1]. Current studies evaluated durability of commercial orthotic insoles [2,4], yet no standardized testing method currently exists, especially for lattice structures. This study proposed using experimental design to evaluate durability of novel SLC insole, adopting ISO 10328-Prosthetic Foot Structural Testing's configuration set-up [3].

Methods

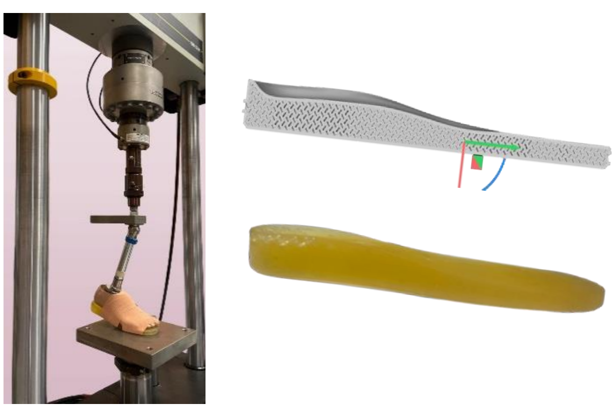

Figure 1. Fatigue cyclic experimental test set-up (right) and SLC pressure-driven lattice insole design (left)

A 3D final insole design was customized from prosthetic foot scanned, while internal lattice structure gradient was created in nTopology v4.40.02, derived from pressure data collected in a previous study [1]. SLA technology was used to manufacture the insole from Rasionate F39T resin. Final 3D-printed insole was injected with silicone oil (see Figure 1). The insole then was tested in position where shank alignment was set to 20º, mimicking PO [4]. It was secured beneath prosthetic foot using elastic tape to prevent movement and 785 N uniaxial compression load applied up to 100,000 cycles, mimicking four months normal wearing time [4]. Observations recorded every 10,000 cycles, with 30 minutes resting time.

Results and Discussion

Stress response remained plateau throughout cycles (Table 1) until material exhibited internal structural damage, indicated by a slight decrease in stress near the end of cycles. While a sudden dropped at the end of $100,000^{th}$ signalling failure, without cracked surface and oil leakage. Despite energy dissipation enhancement featured in SLC with viscous liquid [1], under fatigue load, it continued decreasing up to 30% at the end of cycle. The shift in the hysteresis loop from initial to 10^{5th} cycles (0.9 mm), depicted plastic deformation occurred, reducing material ability to deform further [2] and dissipate energy.

Table 1. Experimental Analysis on SLC orthotic insole's material properties throughout lifecycles

Cycle	Energy Dissipation (J)	Stress (MPa)	Strain (%)
100	0.56	125.965	0.351731
1000	0.49	126.003	0.341435
10000	0.43	125.924	0.325155
100000	0.40	82.795	0.30803

Conclusions

SLC orthotic insole offers promising fatigue compression resistance for mid-term life. However, energy dissipation reduction throughout cycles' time suggesting gradual loss in shock absorption, which is essential to prevent ulcer development in individuals with Diabetic. Therefore, it warrants further analysis and improvement.

Acknowledgments

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References

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