The Potential Use of PLA and Soft PLA in 3D Printing for Sustainable Wearables

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Introduction and Background. In recent years, 3D printing, a form of additive manufacturing, has been widely used in various industries. Especially in the fashion industry, 3D printing has been primarily explored by innovative product design and development leaders to manufacture wearable products. For example, Nike utilized 3D printing to design cleat plates in their Vapor Laser Talon shoes, which greatly sped up the traditional manufacturing process (Molitch-Hou, 2016). 3D printing also plays a significant role in sustainability practices (Woodson, 2015). For instance, a sustainable manufacturing process can be achieved by using 3D printing materials that have a less negative impact on the environment (Wijk & Wijk, 2015).

Polylactide (PLA) is the most widely used plastic filament material in 3D printing, which is biodegradable and can be produced with renewable resources such as potatoes, sugarcane, and soybeans (Wijk & Wijk, 2015). Soft PLA is a special type of PLA that is more flexible than traditional PLA and still biodegradable (All3DP, 2019). Although an increasing number of studies have explored the potential use of 3D printed textiles for wearable products (e.g., Beecroft, 2019; Pattinson et al., 2019; Uysal & Stubbs, 2019), only a few studies applied PLA or soft PLA in developing 3D layered structure textiles. Uysal and Stubbs (2019) demonstrated a great benefit of using this layered structure for 3D printed textiles, which greatly reduces the material waste. Grames (2020) argued that the height of each layer of 3D printed materials influences the appearance of 3D printed products. However, no previous studies have investigated the appearance change of 3D layered printed textiles with different layer heights. Thus, the purpose of this study was to explore the possibility of using 3D printed layered structure textiles with PLA and soft PLA for developing sustainable wearables.

Study Design. Using an entry-level fused deposition modeling (FDM) 3D printer, this study applied the research through design (RTD) methodology to prototype 3D layered structure textiles with the biodegradable material (PLA and soft PLA) and different layer heights (0.2mm and 0.28mm). For this experiment, Rhino and Cura programs were used to develop 3D models of layered structure textiles that were based on the 3D printed textile proposed by Pattinson et al. (2019). The layered structure textile consists of repeated cells; each cell has an identical size of 9.5mm x 9.5mm with a thickness of 0.4mm. The wave pattern utilized in the cells allows the 3D textile to be stretched in multiple directions.

Four prototypes of 3D layered structure textiles with two different materials and two layer heights were created for this experiment. Each prototype was printed as follows: (a) Prototype A: PLA with 0.2mm layer height extruded by the 3D printer; (b) Prototype B: PLA with 0.28mm layer height; (c) Prototype C: soft PLA with 0.2mm layer height; and (d) Prototype D: soft PLA with 0.28mm layer height.

Results. As shown in Figure 1, Prototypes A and B printed with PLA had more consistent forms compared to Prototypes C and D printed with soft PLA because soft PLA filament spat out of the extruder occasionally in the 3D printing process, which made it difficult to retain the precise string-like shapes of the textiles. Due to the different material properties of PLA and soft PLA, Prototypes C and D presented higher elongation than Prototypes A and B; PLA and soft PLA showing elongation at break are 6% and 600%, respectively (Filament2Print, n.d.; Giang, n.d.). Prototypes C and D tightly stuck to the build plate in the 3D printer, which made it harder to remove from it compared to Prototypes A and B. The forms of Prototypes C and D also deformed when detaching from the printing bed.

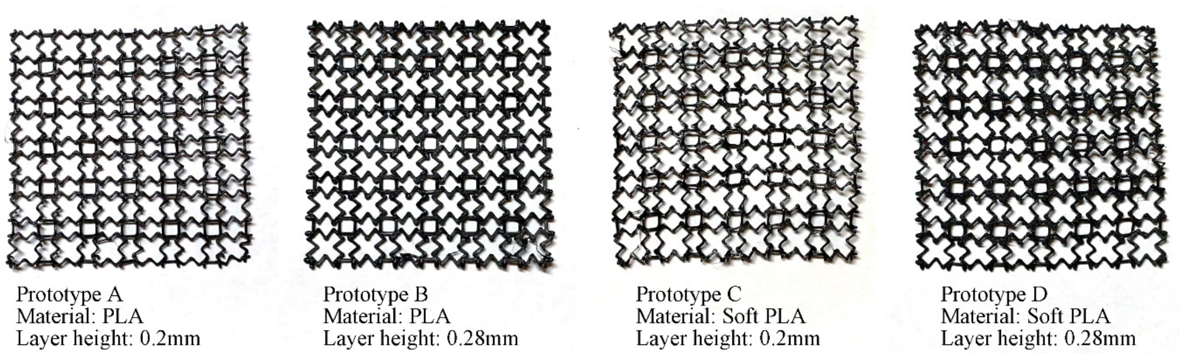

Figure 1. Four prototypes of 3D layered structure textiles.

The results also demonstrated the positive influence of the layer height of 3D printed materials on the appearance of 3D printed layered structure textiles. Prototypes B and D with 0.28mm layer height maintained smoother surfaces than Prototypes A and C with 0.2mm layer height because the 3D printed layered structure textiles with low layer height required more layers to complete the printing, which resulted in more visual seams on the surface. The layer height also influenced the 3D printing speed; Prototypes A and C took 10 minutes to print, and Prototypes B and D took 5 minutes to print.

Conclusion. The findings of this exploratory study imply that both PLA and soft PLA have great potential for manufacturing 3D printed wearables while having a less negative impact on the environment. Specifically, soft PLA with higher elongation could be used to print apparel (e.g., dresses, shirts, gloves). PLA with low elongation could be applied to fashion accessories printing (e.g., bracelets, necklaces, earrings), which do not require much flexibility. The findings also suggest the proper layer height of the materials to refine the appearance of 3D printed wearables. This study addressed the current literature gap in which no studies applied PLA and soft PLA in 3D printed layered structure textiles considering different layer heights. The RTD methodology used in this study can be useful for designers and product developers to create sustainable 3D printed wearables using the entry-level FDM 3D printer.

Despite using the unique RTD approach, this study only utilized one entry-level FDM 3D printer for the 3D textile prototype development. Using professional-level 3D printers may generate different printing results. Further testing is needed using different types of 3D printers. The prototypes created in this study were limited to using the same layered structure textile. More 3D printed textiles with different layered structures and layer heights need to be proposed and tested in future studies. Lastly, this exploratory study was not involved in testing 3D printed textiles' mechanical properties, which should be performed for future research. In spite of these limitations, this study proposes a novel method of manufacturing wearables using 3D printing with sustainability practices in mind.

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