Exploring Joint Methods of 3D Printed Fabrics Used for Wearable Products

Yu Li and Young-A Lee, Auburn University, USA

Keywords: 3D printing, joint methods, 3D printed fabrics, wearables

Introduction. The use of 3D printing (3DP) is continuously evolving in the fashion industry. Researchers began to adapt the fused deposition modeling (FDM) 3DP method, one of the most widely used 3DP methods in the industry, especially in the wearable product development (Kim et al., 2019; Spahiu et al., 2020; Uysal & Stubbs, 2019; Valtas & Sun, 2016; Yap & Yeong, 2014). Due to the limited printing volume of commercial FDM 3D printers, most wearable products developed with FDM 3DP method are first completed in multiple panels and then assembled those together (Valtas & Sun, 2016; Yap & Yeong, 2014). Thus, the selection of appropriate joint methods directly influences the ease of the product assembly and disassembly, which is an important design criteria (Bogue, 2007) and can significantly affect the aesthetic and function of 3D printed wearable products (Sun & Valtas, 2019). Joint methods including sewing, adhesive, and physical joining mechanisms were commonly used in previous studies on 3D printed wearable product design and development (Kim et al., 2019; Spahiu et al., 2020; Uysal & Stubbs, 2019; Yap & Yeong, 2014). However, throughout the literature review, no studies were identified to investigate the comparison of different joint methods applied in the 3DP wearable product development using FDM 3D printers. Thus, the purpose of this study was to explore the effectiveness of different types of joint methods (sewing, adhesive, and physical joining) used in the 3DP wearable product development.

Method. Using an FDM 3D printer, this study applied the research through design (RTD) methodology to explore different joint methods used in the 3DP wearable product development. Rhino and Ideamaker programs were used to create and process CAD models for 3DP. The 3D printed fabric samples used in the study were developed using 3D printed layered structures proposed by Pattinson et al. (2019); the 3D printed panels embedded special wave structures with a thickness of 0.4mm. Three fabric samples with sewing, adhesive, and physical joining mechanisms were developed with flexible thermoplastic polyurethane (TPU) filaments and each sample consisted of two identical 3D printed panels with a size of 76.2mm x 76.2mm. Figure 1 presents the final 3D printed fabric samples: (a) Prototype A: Sewing two 3D printed panels with 12.7mm width of cross-sectional areas; (b) Prototype B:

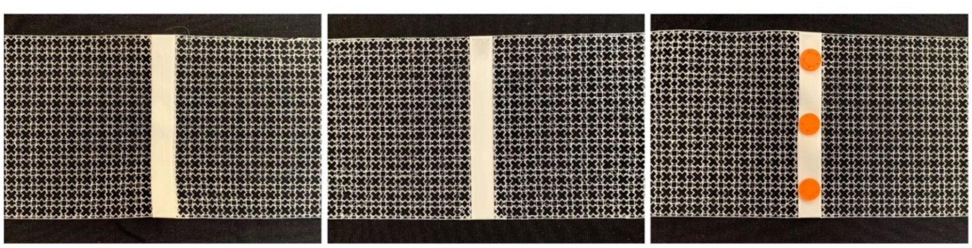

Figure 1. Three 3D printed fabric samples with different joint methods.

Using different adhesive fabric glues to join two 3D printed panels with 12.7mm width of cross-sectional areas; and (c) Prototype C: Physically joining two 3D printed panels with 12.7mm width of cross-sectional areas. For the physical joining mechanism, three 3D printed snap buttons with rigid Polylactic Acid (PLA) filaments were created to assemble two panels together.

Results. It took a total of 63 minutes to print Prototype A with 3g 3DP filaments. The entire sewing process took less than a minute, but this construction time may vary depending on individuals' different sewing capabilities. The results of Prototype A showed that different sewing techniques and choice of threads could affect the appearance of 3D printed wearable products greatly. In addition, unlike traditional fabrics, sewing could lead to permanent and visible damages such as holes on 3D printed fabrics, which lead to decrease the reusability of 3D printed fabrics greatly.

The 3DP time and filament consumption of Prototype B remained the same with Prototype A. However, compared to other prototypes, Prototype B required additional drying time of adhesive fabric glues to firmly join two panels; around 30 minutes and 10 minutes were spent for two different fabric glues to fully dry. Various types of adhesives result in different efficacy of joining 3D printed fabrics; 3D printed panels joined with one fabric glue type felt apart after two days. The result of Prototype B indicated that the residual adhesive left on the 3D printed fabrics is hard to clean, which may influence comfort of wearing 3D printed products.

Because of the additional printing job for 3D printed snap buttons, Prototype C had a longer printing time and greater amount of filament consumption; 63 minutes and 18 minutes were used to print 3D printed panels and snap buttons, respectively. Among all three joint methods experimented in this study, physical joining mechanism used in Prototype C, was more user-friendly; the assembly time was less than 30 seconds and could be reused multiple times. Despite having advantages, this physical joining mechanism with rigid 3DP filaments could greatly reduce wearers' comfort of the product made of 3D printed fabrics. Using a physical joining mechanism printed with additional support rafts could also lead to unavoidable material waste due to the longer travel paths of nozzle in each layer while printing.

Conclusion. The results of this study demonstrate that all sewing, adhesive, and physical joining mechanisms have a great potential for assembling 3D printed fabrics while developing 3D printed wearable products. Specifically, sewing and adhesive joining mechanisms could be used in 3D printed apparel development, and physical joining mechanism could be more applicable in 3D printed fashion accessories development. The findings in this study provides insights for academic researchers and industry professionals in terms of using appropriate joint methods for assembly and disassembly when developing 3D printed wearable products, which relate with wearers' comfort and functionality.

Despite using the unique RTD approach, this study only explored the limited joint method options in developing 3D printed wearable products using FDM 3D printer. Future studies should explore (a) different joint methods used in various 3D printing methods such as Digital Light Processing, Stereolithography, and Selective laser sintering and (b) the influence of diverse 3D printing methods on joint methods selection. Only two fabric glues were tested as adhesives in this study. Further explorations on different glue types are also needed. Using 3DP pen may be an available joint method option to be explored as well. Mechanical properties of 3D printed fabrics with different joint methods were not investigated in this study, which leave rooms for future research. In spite of limitations, this study is unique in terms of showcasing possible joint methods of 3D printed fabrics used for wearable products and providing joint method selection guidelines for future design research in 3D printed wearables.

References

Bogue, R. (2007). Design for disassembly: A critical twenty-first century discipline. *Assembly Automation*, *27*(4), 285-289. https://doi.org/10.1108/01445150710827069

Cui, T., Chattaraman, V., & Sun, L. (2021). Examining consumers' perceptions of a 3D printing integrated apparel: A functional, expressive and aesthetic (FEA) perspective. *Journal of Fashion Marketing and Management, 26*(2), 266-288. https://doi.org/10.1108/jfmm-02-2021-0036

Kim, S., Seong, H., Her, Y., & Chun, J. (2019). A study of the development and improvement of fashion products using a FDM type 3D printer. *Fashion and Textiles*, *6*(9). https://doi.org/10.1186/s40691-018-0162-0

Nervous System. (2013). *Kinematics*. projects by Nervous System. https://n-e-r-v-o-u-s.com/projects/sets/kinematics/

Spahiu, T., Canaj, E., & Shehi, E. (2020). 3D printing for clothing production. *Journal of Engineered Fibers and Fabrics*, *15*. https://doi.org/10.1177/1558925020948216

Sun, D., & Valtasa, A. (2019). 3D printing in modern fashion industry. *Journal of Textile Science & Fashion Technology*, *2*(2). https://doi.org/10.33552/jtsft.2019.02.000535

Sun, L., & Zhao, L. (2017). Envisioning the era of 3d printing: A conceptual model for the fashion industry. *Fashion and Textiles*, *4*(25). https://doi.org/10.1186/s40691-017-0110-4

Uysal, R., & Stubbs, J. B. (2019). A new method of printing multi-material textiles by fused deposition modelling (FDM). *TEKSTILEC*, *62*(4), 248-257. https://doi.org/10.14502/tekstilec2019.62.248-257

Valtas, A., & Sun, D. (2016). 3D printing for garments production: An exploratory study. *Journal of Fashion Technology & Textile Engineering*, *4*(03). https://doi.org/10.4172/2329-9568.1000139

Vanderploeg, A., Lee, S.-E., & Mamp, M. (2016). The application of 3D printing technology in the fashion industry. *International Journal of Fashion Design, Technology and Education*, *10*(2), 170-179. https://doi.org/10.1080/17543266.2016.1223355

Yap, Y. L., & Yeong, W. Y. (2014). Additive manufacture of fashion and jewelry products: A mini review. *Virtual and Physical Prototyping*, *9*(3), 195-201. https://doi.org/10.1080/17452759.2014.938993