Transactions on Additive Manufacturing Meets Medicine
Trans. AMMM, Vol 3, No 1, 2021, Article ID 540

Infinite Science | Publishing

Novel 3D printed custom kinesiology tape for variable usage scenarios

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Abstract: Kinesiology tape is a commonly used nonpharmacological, pain alleviating treatment modality and its usage is being continually expanded into differing clinical settings such as the reduction of postoperative swelling and injury rehabilitation. At present, it is not possible to customize the mechanical properties of the tape to individual patients or usage scenarios. This paper presents the novel design and method of 3D printing lattice structures directly onto kinesiology tape in order to obtain tailorable mechanical properties, using an economical printing system and materials that are appropriate for a clinical setting.

I. Introduction

Kinesiology tape is used in a range of disciplines, from rehabilitation and prophylaxis of acute injuries to long-term nonpharmacological treatment of conditions such as osteoarthritis. Kinesiology tape is constructed of elastic woven fibers with an acrylic adhesive on one face, to adhere the tape to the user's skin [1]. Limitations exist in the efficacy of tape applications due to the inability to tailor the mechanical properties to the individual patient and usage requirements. It is well documented that as the weight of a patient increases, the force required to support the patient's joints also increases [2]. Furthermore, different muscle groups are capable of attaining differing magnitudes of internal forces [3]. Therefore, tape applications on differing muscle groups, across varying patient sizes, are required to impose differing magnitudes of force onto the patient's skin to elicit the desired support for the individual usage scenario. However, to the best of the author's knowledge, at present, it is not possible to tailor the mechanical properties of kinesiology tape to the individual user, and a 'one size fits all' approach is taken.

II. Material and methods

To create kinesiology tape with tailorable mechanical properties, parametric lattice structures were designed, and 3D printed directly onto the tape. The lattice structures were designed to produce a form of metamaterial, where the mechanical properties of the lattice could be varied by altering the architecture of the repeating unit-cell.

II.I. Lattice design phase

Three lattice designs were efficiently created using a custom G-Code generation software, which eliminated the need for CAD modelling, STL file generation and slicing, and their associated approximations. (FullControl GCode Designer) [4]. The lattice designs are shown in Figure 1. These designs were chosen because sinusoidal structures have several geometric parameters, such as amplitude, period length and phase shift that can be varied to obtain a desired mechanical response. The lattices are composed of sinusoidal waves, with a period of 16mm and an amplitude of 2mm. The extrusion width was set to 0.6mm, with 5 layers deposited at 0.2mm layer height. The lattices were 3D printed in TPU 95A (thermoplastic polyurethane) on an Ultimaker 2+.

When developing the print procedure, a rectangle was first printed to allow for the accurate, reproducible locating of the tape samples onto the print bed. The kinesiology tape sample was secured onto the print bed using adhesive tape and the lattice was printed directly onto the kinesiology tape. The gap between the nozzle and the bed was set at 0.6mm. This was 0.1mm lower than the known thickness of the kinesiology tape, which enabled the print nozzle to slightly compress the tape sample to effectively embed the polymer into the surface of the tape fabric.

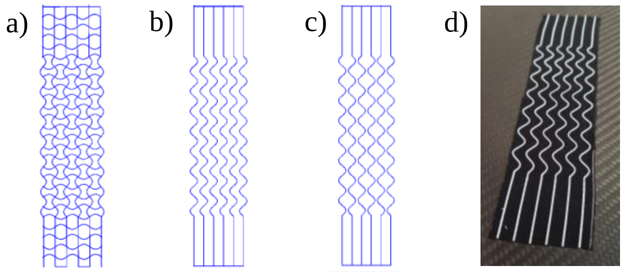

Figure 1: Lattice designs; a) Lattice 1, b) Lattice 2, c) Lattice 3, d) Lattice 2 printed onto kinesiology tape.

II.II. Tensile test parameters

Tensile testing was performed on an Instron 3345 machine with a 5kN load cell to apply a uni-axial tensile force longitudinally on the specimens. The separation speed of the tensile jaws was 100mm/min to ensure quasistatic loading of the samples, without the tests taking excessively long, given the high deformation the tape can undergo.

DOI: 10.18416/AMMM.2021.2109540

Locating nodes were marked on the tensile samples, and the testing video recorded. Individual frames were extracted to measure longitudinal and lateral deformation and thus calculate the Poisson's ratio of the structure.

III. Results and discussion

A notable difference in mechanical behavior between the composite designs and the virgin kinesiology tape was found, as can be seen in Figures 2 and 3.

III.I. Tensile testing

In Figure 2 it is firstly evident that the load required to obtain a given value of strain varies significantly between the virgin tape and lattice-tape composites. The increase in force required to generate a given strain could be well utilized in a clinical setting, with larger patients requiring a greater force to support a given joint. Furthermore, the composites have a more gradual change in stiffness when compared to the virgin kinesiology tape. This is due to the lattice structures allowing the transition of stiffness to be more controlled. This is of benefit in practical usage scenarios, as products with high sudden changes in stiffness have a narrower useful operating window of strain.

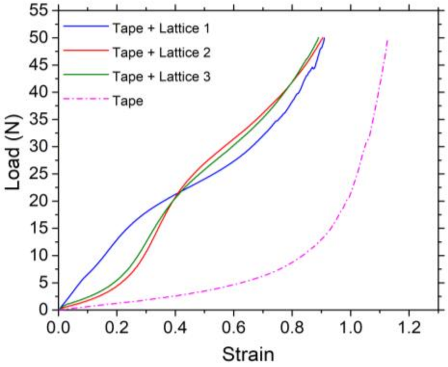

Figure 2: Load-strain curves of the lattice-tape composites and virgin kinesiology tape.

Figures 3a and b highlight the differences in mechanical response at a given applied load. It is of note that whilst 'Tape + Lattice 2' and 'Tape + Lattice 3' behave similarly in Figures 2 and 3a, the composites Poisson's ratio at the same applied load is significantly different. This is indicative of the composites deforming similarly longitudinally, but the differing lattice geometries resulting in varying force distributions across the width of the tape. It is also of interest that virgin kinesiology tape has a Poisson's ratio of zero, thus highlighting the significant impact that the lattice structures have on the force distribution throughout the tape, not only in the direction of applied load.

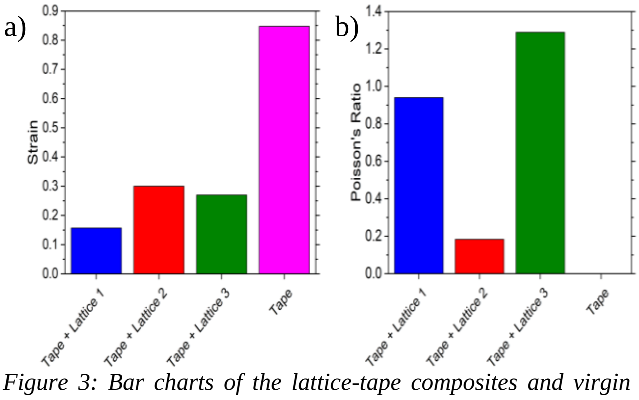

Figure 3: Bar charts of the lattice-tape composites and virgin kinesiology tape at an applied load of 10N; a) Strain at 10N, b) Poisson's Ratio at 10N.

III.II. Demonstrative case study

To assess the real-world usability of the composites, two strips of tape were applied to the author's knee, as can be seen in Figures 4a and b. Light physical activity was undertaken and it was haptically assessed that each strip of tape provided a different magnitude of support to the knee.

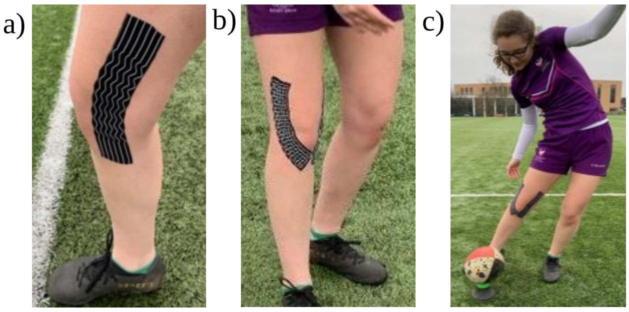

Figure 4: Additive manufactures kinesiology tape application; a) Medial application of 'Tape + Lattice 2', b) Lateral application of 'Tape + Lattice 1', c) Front view of both tape applications.

IV. Conclusions

In conclusion, this study has demonstrated a novel method of producing customizable kinesiology tape. Three differing designs were studied, and results confirm that varying mechanical properties that are significantly different to standard tape can be achieved, indicating that applications in a range of specific usage scenarios could be achieved through the utilization of 3D printed lattice structures. It was found that the mechanical properties not only varied between the virgin tape and the lattice-tape composites, but also between the different composite designs. This demonstrates the future potential to provide tailored support to individual patient and usage requirements through the design and manipulation of differing lattice architectures. A demonstrative case study was also undertaken and when subjected to real-world usage, the additively manufactured tape was successful in providing differing magnitudes of support to the user through utilizing varying lattice designs.

An important area of future research is to correlate specific patient needs to lattice requirements, which will allow effective lattice design. This would involve biomechanical simulations, patient models and clinical trials.

ACKNOWLEDGMENTS

The first author acknowledges facilities made available by Loughborough University. Research funding: The author states no funding involved.

AUTHOR'S STATEMENT

Conflict of interest: Authors state no conflict of interest.

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