Enhancing Stage Range via Mechanical Redesign

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Introduction

Microneedle technology represents a cutting-edge advancement in transdermal drug delivery, offering a less invasive and more accessible alternative to traditional injection methods. Before these devices can be safely used in healthcare settings, precise fabrication and testing are essential to ensure their performance and reliability.
The process to create the microneedle involves dispensing a polymer solution through a precision nozzle onto a heated substrate, where the material rapidly solidifies into a sharp, consistent microneedle structure.
In the original experimental setup, the 3DMA fixture — which holds the microneedle substrate — was fixed directly to the optical breadboard, while the nozzle above was mounted to a stage that allowed only limited movement. This configuration posed significant challenges to the design process because restricted control over the nozzle's positioning, and limited flexibility in alignment. These constraints highlighted the need for a more adaptable and secure mounting system to support ongoing microneedle development.

Objectives

- Develop a stable and customizable mounting system for the microneedle fabrication process that allows for precise control of nozzle positioning in the X, Y, and Z directions.
- Improve alignment flexibility and ease of setup by designing custom conversion plates that allow the stages to be reconfigured as needed for different experimental requirements.

Methodology

Determining the Configuration
The system consists of three optical stages, each with a stage capable of linear movement in a single axis. One stage is used to hold the nozzle fixture, while another supports the 3DMA fixture. Using SolidWorks, several potential stage configurations were modeled and evaluated through iterative design and virtual assembly. The final and most effective setup placed Stage A and Stage B directly on the breadboard in a T-configuration. The 3DMA fixture was mounted on Stage A, while Stage C was attached vertically to the sliding plate of Stage B. The nozzle was secured to Stage C, allowing it to move freely above the microneedle. This configuration provided secure support and allowed precise control over nozzle placement.

Creating the Conversion Plates
To complete this setup, four custom conversion plates were designed to interface between components with differing mounting patterns. These included:
- A plate between the stages and the optical breadboard
- A plate between the 3DMA fixture and its stage
- A plate connecting two stages
- A plate attaching the nozzle fixture to its stage

Each plate was carefully dimensioned to accommodate specific bore or thread hole patterns used by the stages and fixtures. Special attention was given to the plate between two stages, which was designed to allow the stages to be mounted either parallel or perpendicular to one another, providing flexibility in reconfiguring the system. The plate for the 3DMA fixture was also designed with multiple mounting options, allowing the fixture to be positioned in different orientations depending on the user's needs.

Results

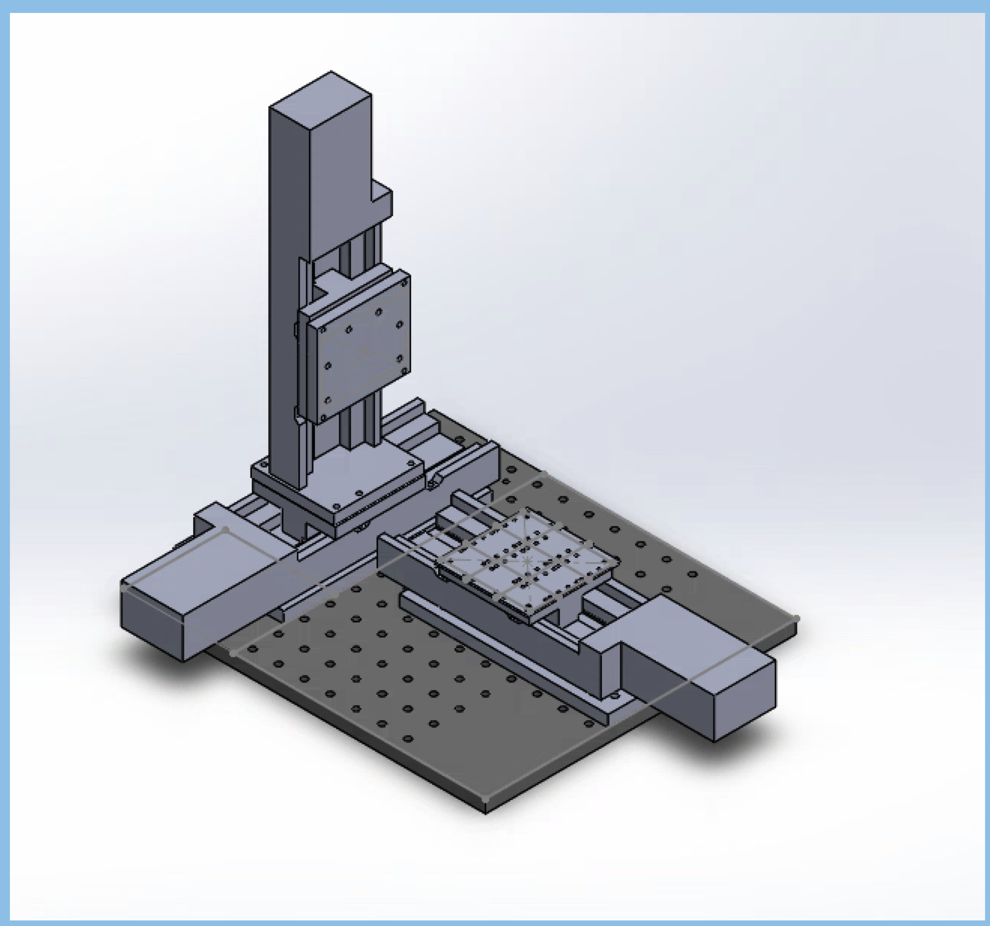
Figure 1 – Final Configuration

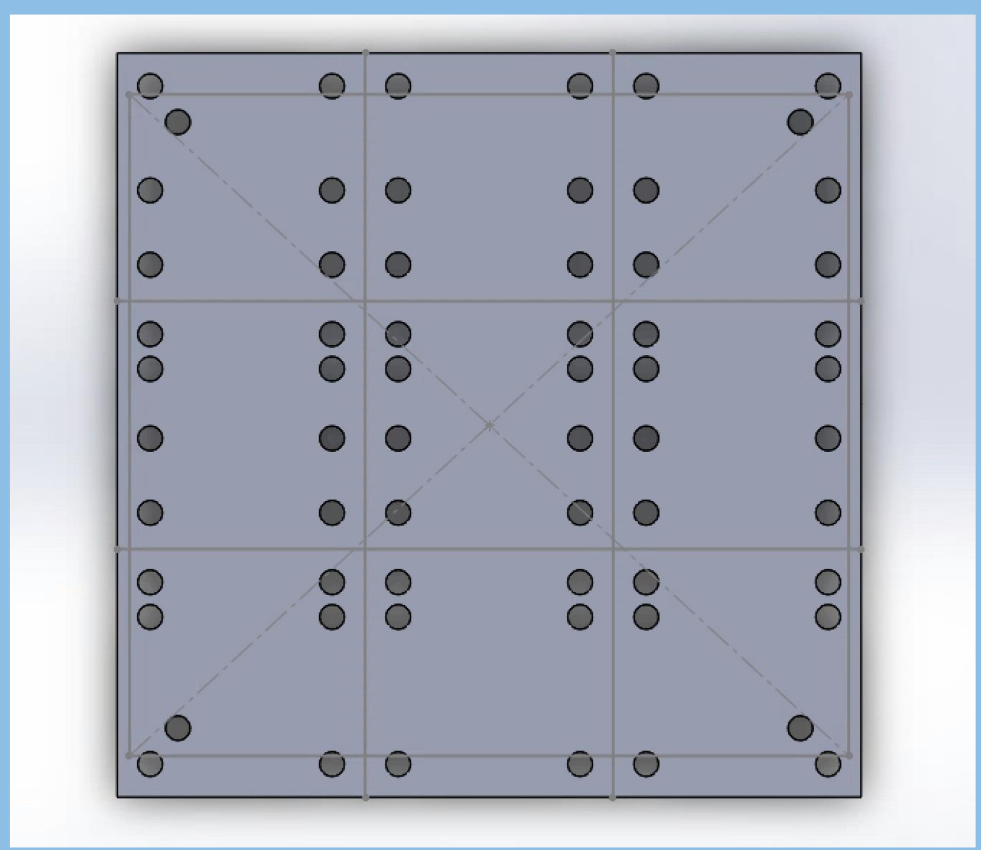
Figure 2 – Conversion Plate Between Stage A and 3DMA Fixture

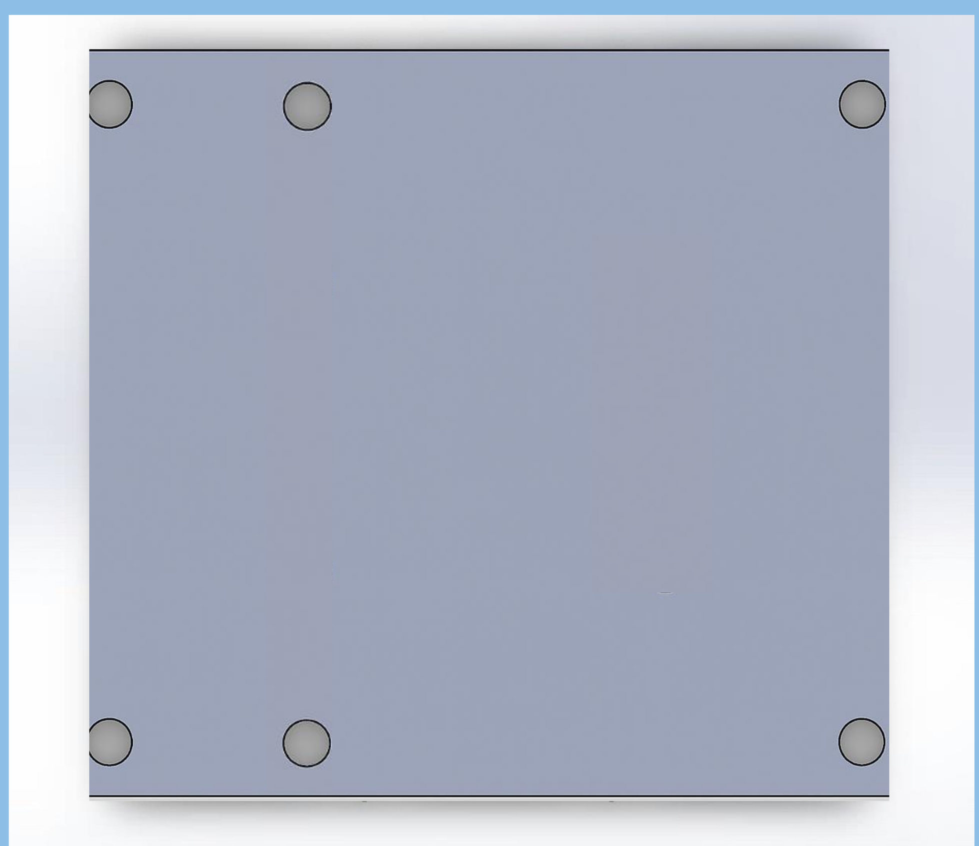
Figure 3 – Conversion Plate Between Stages

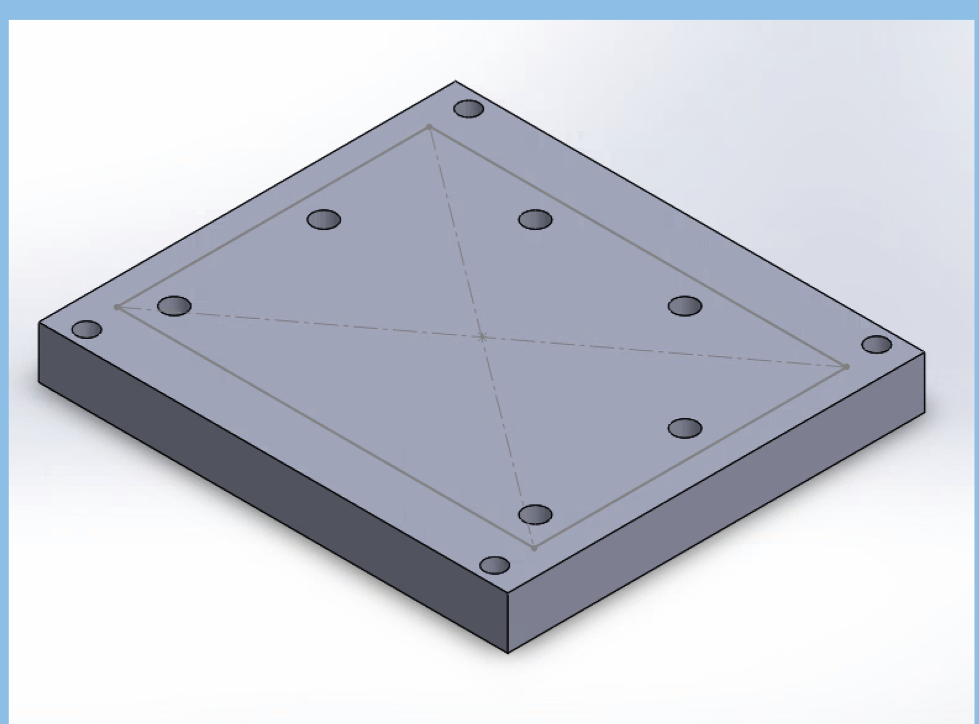
Figure 4 – Conversion Plate Between C and Nozzle Fixture

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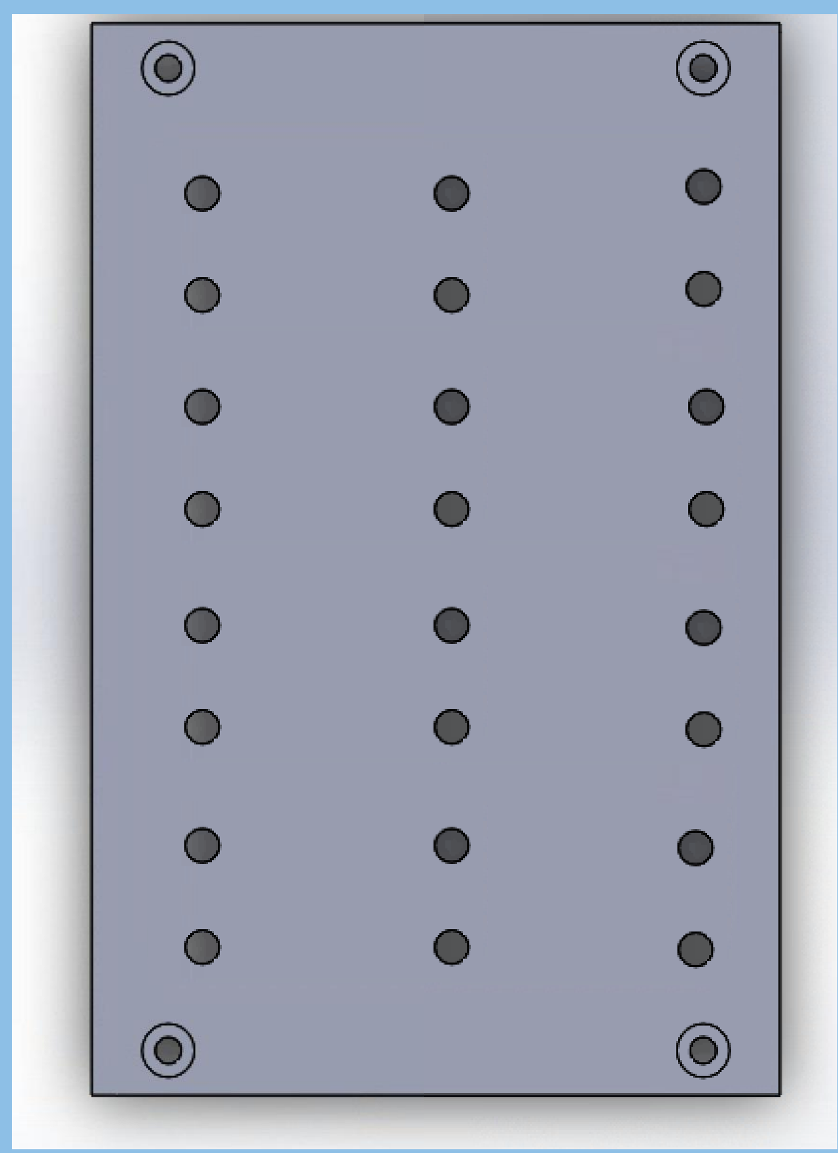
Figure 5 – Conversion Plate Between Stages and Breadboard

Results

The reconfiguration of the microneedle fabrication setup addressed critical limitations in the original design, particularly the lack of precision and adaptability in nozzle positioning. By introducing a modular system with linear stages and custom conversion plates, the new setup enables more accurate alignment and easier adjustments during experimentation. This flexibility is especially important in research environments where iterative changes are common and different configurations must be tested rapidly.
The custom conversion plates not only resolved compatibility issues between components but also introduced new functionality—such as adjustable orientation and multi-axial movement—that was not possible in the initial configuration. This adaptability makes the system more future-proof, allowing for modifications without the need for entirely new infrastructure.
The improved control over nozzle movement directly contributes to more consistent microneedle formation, which is a crucial factor for ensuring device reliability and safety. These enhancements collectively represent a significant step forward in the development of precise and scalable microneedle manufacturing processes.

References and Acknowledgements

Zhang, J. (2025, January 22). *Anywhere, anytime, anybody: Administering medication at home with microneedle injection*. UCD Research.

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