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INVESTIGATION OF THE INSERTION PROCESS OF NEEDLES ACCOUNTING FOR THE RESTING TENSION IN SKIN

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INTRODUCTION

Skin, in its resting state, exhibits an unequal biaxial tension over most of the body, with the tension dependent on the volume of internal tissue and the position of the limbs [1]. No study found in literature investigates the effects of the resting pre-tension that in-vivo skin exhibits for needle insertions. This study aims to address this gap by developing and using a test system that allows for a repeatable and realistic replication of the insertion of needles into skin, accounting for the resting tension skin exhibits.

MATERIALS AND METHODS

Firstly, a reproducible and replicable skin model must be identified and manufactured. A multi-layered transparent skin model was developed using silicones and Slacker from Smooth-On. A compression test was conducted on samples with varying slacker ratios and compared to compression tests in literature of in-vivo skin to select the most suitable skin model [2].

As the skin model must undergo biaxial tension, FE analysis was used to design a mould shape that would allow for the largest amount of Von Mises stress to be transferred to the centre of the specimen. The final mould consisted of an optimised cruciform shape to replicate the epidermis and the dermis and a cuboid section below the centre of the cruciform to represent the hypodermis and underlying tissue.

The cruciform arms of the skin model were clamped into a biaxial tension device which was developed based on the device used by Gilchrist et al [3]. The design is made up of 4 guide rails and carriages. The distance between the two carriages is controlled using a lead screw with opposite threads connected to pillars sitting on the carriages. There are two load cells used, one on each axis. By varying the distances between the pillars, the tension applied to the skin model can be varied and the record by the loadcells through a LabVIEW programme. This fixture is then placed into a Universal Testing Machine which holds the needle and measures the force and displacement of the needle during insertion. An image of the test set up can be seen in Figure 1.

Insertion tests varying the needle type, the applied tension and the insertion speed were conducted to demonstrate the capabilities and usefulness of the test system and gain a greater understanding of the effects of tension on the needle insertion process (see Table 1 for the parameters of each test). A sample size of 5 was used for each test. The effects of skin tension on insertions is to be measured by looking at the peak insertion force of the needle. Statistical comparisons between studies were made using a Welch ANOVA at a significance of 0.05.

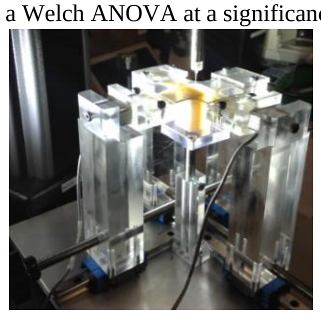

Figure 1 Image of the Test Set-Up.

RESULTS & DISCUSSION

For the 100 mm/min 12.7 mm needle insertions, the mean peak insertion forces at different tension values showed to have statistically significant difference (p-value = 0.021). The two other tests showed no statistical difference between the insertion forces at the different tension values (p-values = 0.209 (1) and 0.098 (3)). Although only one of these three comparisons showed statistically significant differences for penetration forces due to varying tension, the peak insertion forces on all three comparisons tended to increase for decreasing tension values (see results in Table 1). Skin in its resting state exhibits unequal biaxial tension and previously needle insertion studies did not replicate this and therefore a factor that effects the insertion process was excluded. This data also suggests that the faster the needle insertion the more the effects of tension are observed.

Table 1 Mean Peak Insertion Forces for Each Test Set-Up

Needle Length, Gauge, Bevel & Insertion Speed	Biaxial tension applied		
	0: 0 N	10: 10 N	5: 25 N
1. 12.7mm 29 G 3bevel at 24 mm/min	0.9398 N	0.8557 N	0.8269 N
2. 12.7mm 29 G 3bevel at 100 mm/min	1.033 N	0.9857 N	0.8572 N
3. 6mm 32 G 5bevel at 24 mm/min	0.3377 N	0.3374 N	0.2930 N

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