Design and Mechanics of Honeybee-Inspired Surgical Needle

Mohammad Sahlabadi, David Gardell, Jonasan Younan Attia, Parsaoran Hutapea
Temple University, Philadelphia, PA

Introduction: Surgical needles are widely used in minimally invasive surgery procedures such as tissue/tumor biopsy, deep brain stimulation, thermal ablation, brachytherapy and most importantly drug delivery. There has been a growing interest to design and develop innovative needles to improve the current state of the art needling technology. In the aforementioned procedures, needle deviates from the path to its target (e.g., tissue/tumor). This path deviation always poses a problem for example in extracting specific biopsy samples. Our hypothesis is that the insertion and extraction forces on the interface of the needle and tissues play a major role in the needle path deflection and tissue damage. In order to test this hypothesis, insect stingers, particularly honeybee stinger is explored since its stinger has a complex but elegant mechanics when it engages on human skins. Preliminary studies have been conducted to study some designs of the bioinspired needles, such as insertion force and deflection of the needle [1]. The data showed that the insertion force of the needle decreased by 25% using needles mimicking the honeybee stingers. The focus of this work is to study the effect of needle barbs on the extraction forces. Some optimized honeybee-inspired needles have been developed and tested as shown in Fig. 1a. The results showed that the extraction forces can also be reduced.

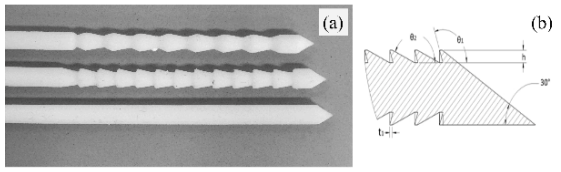

Figure 1: 3D Printed honeybee-inspired needles

Materials and Methods: Honeybee stinger images were obtained using an optical microscope to create 2D drawing of honeybee stinger barbs. The barb geometries mimicking stinger barbs were designed on the needle body (Fig. 1). CAD software was used to develop the 3D modeling of the needles. Connex350 3D printer (Stratasys, Inc., Eden Prairie, MN) was utilized to manufacture polymer-based needle prototypes (Fig. 1a). A needle insertion and extraction test setup was designed and constructed. The needle was mounted on a linear stage and a needle guider was used to guide the needle movement in the gel phantom. A force sensor, 6 DOF F-T sensor Nano17® (ATI Industrial Automation, Apex, NC) was attached at the end of the needle body. A PVC gel phantom (M-F Manufacturing Co., Ft. Worth, TX) was fabricated and used to mimic tissues. Data acquisiton system was utilized to control the insertion and extraction and to record the forces.

Results and Discussion: The proposed bioinspired needle design has raised some concerns regarding the extraction (pull) force and the potential tissue damage during the extraction. In this work, some barbed needles were developed and extraction tests were performed to investigate the influence of barbs on the extraction forces. The forces for the conventional needle and barbed needles with angles of θ_2 = 90°, 150°, and 170° are shown in Fig. 2. The extraction force was reduced by as much as 20% using barbed needles when θ_2 was varied.

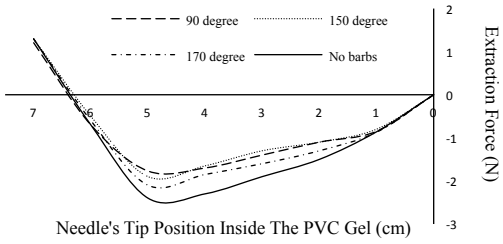

Figure 2: The extraction forces of honeybee-inspired needle

Conclusions: Our results on insertion [1] and extraction tests using honey-bee inspired needles show that both insertion and extraction forces decrease significantly using barbed needles. It has been shown that by changing the barb parameters (Fig. 1b), the forces can be decreased. Ongoing work is undergoing to further assess tissue damage on real tissues (e.g., cow liver and brain). Also, advanced manufacturing techniques are currently being investigated to develop smart (active) bioinspired needles and metal-based bioinspired needles for percutaneous procedure.

Acknowledgements: The authors would like to acknowledge Temple's Center of Excellence in Traumatic Brain Injury Research and the Department of Defense (DOD) CDMRP program for the financial support.

References:

[1] M. Sahlabadi, D. Gardell, J. S.Y. Attia, S. Khodaei, P. Hutapea, "Insertion Mechanics of 3D Printed HoneyBee-Inspired Needle Protoypes for Percutaneous Procedure," *2017 Design of Medical Conference*, Minneapolis, Minnesota, April 10-14, 2017, Minneapolis, Minnesota.