Reduction of Insertion Force by Coating of Surgical Needles

Kavi I. Patel[1], Samer Al-Safadi, Sai T.R. Gidde, Haoqi Li, Tarun Podder, Fei Ren, Parsaoran Hutapea

Introduction: Insertion of the needle in human body parts with a larger needle often results in severe tissue damage. Tissue damage could potentially be reduced by decreasing the insertion force caused mainly by the friction on the interface of the needle and tissues. We have used Polydopamine (PDA) coating on surgical needle (18g) and were able to get 20-25% of insertion force reduction with some limitations. To overcome those limitations, we propose to use PDA with the mixture of Polytetrafluoroethylene (PTFE) and Carbon as coating. Here, PDA coating should act as adhesive agent between needle surface and PTFE coating; and carbon should work as a filler for PTFE coating's porous and uneven surfaces. PTFE is a synthetic polymer with a great chemical stability because of its high strength of C-H bond. Besides stability, PTFE is non-toxic, and non-flammable, and exhibits negligible water absorption, anti-stick behavior, high thermal stability, and a low dielectric constant. On the other hand, it has very high wear rate and low load bearing capacities. To overcome these disadvantages, PTFE can be combined with other polymers like PDA and is being explored in this research.

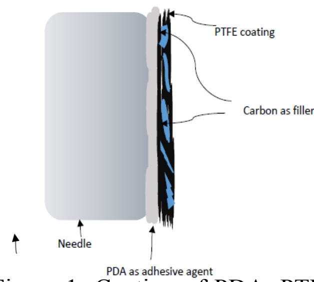

Figure 1: Coating of PDA, PTFE, and Carbon

Materials and Methods: For our preliminary study, the needle was coated using only PDA. To make the coating, 2mg/mL of dopamine (99%, Alfa Aesar, Haverhill, MA) was added into pre-diluted 50mM TRIS buffer (Thermo Fisher Scientific Inc., Walthan, MA) with adjusted pH 8.5. PDA coating was synthesized by immersing the needle in dopamine/Tris solution for 24 hours. The needle was then taken out and rinsed with deionized water three times and dried in the oven overnight for future use. This process typically produces 10µm of a thin coating. We used phantom tissues as an artificial tissue with a dimension of 15cmx15cmx6.5 cm to imitate tissue viscoelastic properties. We conducted five insertions with each PDA coated needle (18g) and four insertions with each uncoated needle (18g). All insertions were performed using a specially designed 3-DOF robot which contain stepper motor actuated linear rail mechanism. 6 DOF F-T sensor Nano17®, was utilized to record insertion forces. Throughout the experiments, the insertion depth was set to be 6.5 cm and the insertion speed was 0.17 cm/sec. On going work is also being conducted to perform PDA, PTFE, and Carbon coating (Fig. 1).

Results and Discussion: From the result in Figure 2, the reduction in the insertion force for PDA coated needles is shown to be about 20-25%. There is no initial spike in the force graph because the needle has a very little diameter and a very sharp trocar tip which was design to enter the tissue effortlessly. We observed that a PDA coated needle can get completely dehydrated which will have a rougher surface compared to an uncoated needle. Ongoing work is being conducted to use PDA with the mixture of PTFE and Carbon as coating to overcome the issue of dehydration.

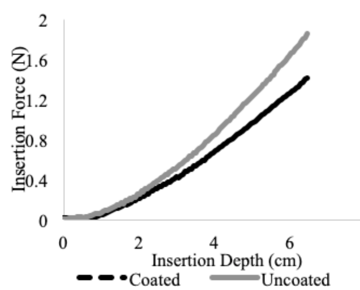

Figure 2: Insertion forces of uncoated and coated needles

Conclusions: It has been demonstrated from our preliminary result that the PDA coating on needles has shown a significant reduction in the insertion force with some limitations. It is hypothesized that the combination of PDA, PTFE and Carbon as needle coating would show much better reduction in insertion forces because of their lubrication properties.

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