MECHANICS OF SMART NEEDLE WITHIN TISSUE

N. V. Datla[1], T. K. Podder[2], Y. Yu[3], A. P. Dicker[3], P. Hutapea[1]
1) Temple University, Philadelphia, PA 19122
2) Case Western Reserve University, Cleveland, OH 44106
3) Thomas Jefferson University, Philadelphia, PA 19107

Introduction: Needle insertion is a common surgical technique used in diagnosis (e.g. biopsy) and prognosis (e.g. brachytherapy) of several diseases. The success in these procedures depends on the accuracy of needle placement to the target location. Presently the accuracy of needle placement is limited primarily due to movement of the tissue, inability to control needle deflection, and inaccessibility of image monitoring techniques. These limitations are being addressed by smart needles (e.g. see Fig. 1) that can be steered within the body with the aid of actuators attached to the needle body [1-3]. However, in these studies smart needles were studied in air and not within the tissue, where they are supposed to be used. Therefore, to develop smart needles that are feasible for clinical applications, it is necessary to understand the mechanics of smart needle within tissue. This work will extend the present understanding on interaction mechanics of needle within tissue to smart needles (with external forces).

Materials and Methods: Needle insertion experiments were done to study the interaction forces between smart needle and tissue. Bevel-tipped spring steel needles of 0.5 and 0.81 mm diameter were inserted in soft PVC phantom (3:1 ratio of plastic to softener to mimic elasticity of prostate tissue). External, or actuation, forces acting on smart needle were simulated by magnetic forces that were achieved by placing a permanent magnet in the vicinity of the ferromagnetic needle. From these studies, a numerical model based on energy method was developed that can predict the deflection of smart needle within the tissue.

Results and Discussion: Table 1 shows that, for both needle diameters, external (magnetic) forces decreased the deflection of needle. More importantly, it also shows that the predictions of needle deflections from the developed numerical model are close to the experiments; thereby, validating the predictions of the numerical model. As expected, needle deflections are higher for the needle with smaller diameter because of smaller reaction forces.

Table 1 Needle deflection without and with magnet.

	Experiment (Numerical model), mm	
Needle diameter (mm)	Without external force	With external force
0.5	31.3 (31.9)	22.3 (19.7)
0.81	20.0 (20.4)	14.5 (13.7)

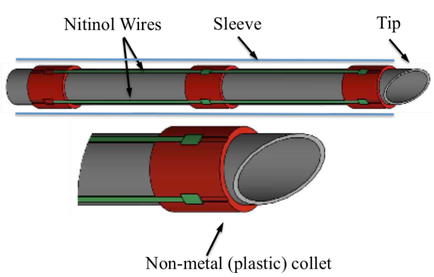

Figure 1. Schematic of smart needle.

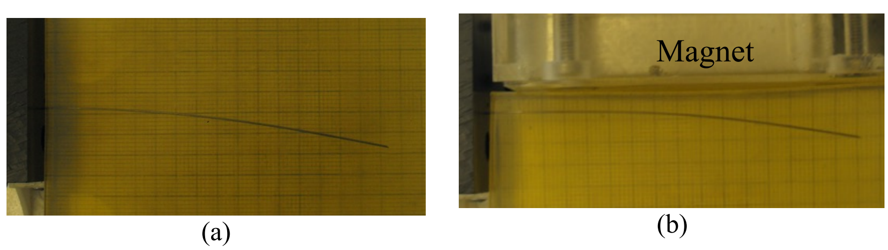

Fig. 2 Deflection of 0.81 mm needle (a) without and (b) with magnetic forces.

Conclusions: Smart needle mechanics within tissue has been studied experimentally using needle insertion tests. From these studies a numerical model was developed, based on energy method, to predict the deflection of smart needle within tissue. Negligible differences were observed between experiments and model predictions, thereby validating the developed model. This model can be used to design smart needles, as well as for steering of smart needles by avoiding obstacles.

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