Novel Soft Pneumatic Grippers for Surgical Manipulation

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Abstract— **Traditional surgical gripping instruments, such as forceps and laparoscopic graspers, have been invented for the purpose of holding the tissue for observation or surgical manipulation. However, these "hard" gripping instruments inevitably result in unintentional tissue damage during surgical handling of delicate soft tissues, particularly due to the high compression stress applied on the tissue. The skill to grip the tissue safely, though taught and incorporated into surgical practice, remains qualitative and largely experiential as it varies based on different cases. In this study, novel soft pneumatic grippers were designed to provide compliant gripping, so as to eliminate any potential damage in the object under grip. The soft gripper involves very simple design and control to generate actuation. It is fabricated from an elastomeric material using a modified soft lithography technique. The device consists of one or more gripper arms with a pneumatic channel in each arm, and an air-filled chamber. The pneumatic channels are positioned close to the outer wall of the gripper arms and are connected to the chamber. Upon chamber compression, the pneumatic channels will inflate towards the outer walls, and bends the gripper arms, resulting in a closed gripping posture. The soft gripper was able to generate a compressive force that is notably lower than that of the forceps.**

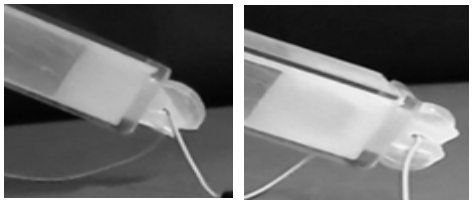
I. Introduction

Surgical gripping, through the use of traditional tissue grippers such as forceps and laparoscopic graspers, is an important and common task in many different kinds of surgery such as cholecystectomy, bariatric and gastrointestinal surgery [1]. However, the hard gripping tips, which are used to hold the soft tissue, frequently induce high compressive stresses on the soft tissues under grip [2]. Hence, there is a need to develop soft grippers that are able to provide compliant gripping and eliminate the risk of tissue trauma.

II. Methods

A modified soft lithography technique was developed to fabricate the device whereby a rod-based approach was adopted to create pneumatic channels. This modified approach is capable of generating miniaturized pneumatic channels by reducing the chance of occlusion during the final sealing process, and making use of a compressible chamber component for direct pneumatic actuation of the gripper, without the need for external pumps. The pneumatic channels are designed close to the outer wall of the gripper arms with a ratio of 3:5 and are linked to the chamber. The difference in stiffness between the thinner outer wall and thicker inner wall allows the gripper arms to bend inwards when pressurized (Fig. 1).

Figure 1. Soft pneumatic single-arm (left) and double-arm (right) grippers gripping a 1mm diameter wire.



III. Results and Discussions

The soft pneumatic single-arm and double-arm grippers underwent bending actuation and adopted a closed grip posture upon compression of the chamber component. Upon removal of the compression, the grippers returned to their original opening resting posture. Our findings demonstrated that the soft pneumatic gripper devices allowed compliant gripping and yet exerted considerably lower maximum compressive forces to the object under grip than the rigid forceps (Table 1). Collectively, our results suggest that the soft grippers may be an ideal candidate that allows the surgeon to grip delicate soft tissue, such as the nerve and blood vessels, without causing substantial mechanical damage to the tissues, while still maintaining an adequately firm grip required for surgical procedures. Future work will focus on investigating the biomechanical effect of the soft grippers on fresh animal soft tissues, especially in terms of the cellular and matrix damage, so as to gain better insights on the potential of the soft grippers

Table 1. Grip compressive forces generated by different grippers

	Single-arm gripper	*Double-arm gripper*	*Forceps*
Maximum Compressive Force (N)	0.3±0.1	0.9±0.1	2.2±0.3

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References

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