Düzce University Journal of Science & Technology, 7 (2019) 1335-1340

Düzce University
Journal of Science & Technology

Research Article

Grasping of Soft Tissues by Means of Non-Contact Gripper in Minimally Invasive Surgery

Şenol ERTÜRK[a,*], Fehmi ERZİNCANLI[b]

[a] *Department of Mechanical Engineering, Faculty of Engineering, Düzce University, Düzce, TURKEY*
[b] *Department of Mechanical Engineering, Faculty of Engineering, Düzce University, Düzce,, TURKEY*
* *Corresponding author's e-mail address: senolerturk540@hotmail.com*
DOI : 10.29130/dubited.518202

ABSTRACT

Surgeons need grippers to grasp and handling organs when performing Laparoscopic interventions. These grippers usually have toothed profile to prevent the slippage of the organs and therefore, tissue damage may occur during the operation. There should be a solution to this risk of damage. The tissue can manipulate without pinching or even touching it. Non-contact grippers that work with Bernoulli principle are used in the industrial field. The aim of the study investigates the feasibility of Bernoulli principle for manipulation soft tissues along minimally invasive surgery. In this study, a contactless gripper working with the principle of Bernoulli has been developed. Lifting force increases as a result of increasing the air flow velocity, gripper surface and nozzle radius. In order to prevent tissue damage, air deflector is used on gripper to change the direction of the air flow. The robot gripper was designed with venturi channels to increase the radial flow velocity. The effect of venturi channels on the lifting force were tested. This study demonstrate that a non-contact gripping device is applicable to lift flexible materials such as soft tissues in Minimally invasive surgery.

Keywords: *Non-contact handling, Bernoulli gripper, Radial flow*

Laparoskopik Cerrahide Yumuşak Dokuların Temassız Tutucu ile Kavranması

ÖZET

Cerrahlar, Laparoskopik müdahale yaparken organları tutmak ve hareket ettirmek için tutucuya ihtiyaç duyarlar. Bu tutucular genellikle organların kaymasını önlemek için dişli profillere sahiptir ve bu nedenle ameliyat sırasında doku hasarı oluşabilir. Bu hasar riski için bir çözüm bulunmalıdır. Doku sıkıştırmadan hatta dokunmadan hareket edebilir. Bernoulli prensibi ile çalışan temassız tutucular endüstriyel alanda kullanılmaktadır. Bu çalışmanın amacı Laparoskopik cerrahi sırasında yumuşak dokuların hareketi için Bernoulli prensibinin uygulanabilirliğini araştırmaktır. Bu çalışmada Bernoulli prensibi ile çalışan temassız bir tutucu geliştirilmiştir. Kaldırma kuvveti, hava akış hızının, tutucu yüzeyin ve nozul yarıçapının arttırılması sonucunda

Received: 26/01/2019, Revised: 27/03/2019, Accepted: 03/04/2019

artar.
Doku hasarını önlemek için, hava akış yönünü değiştirmek üzere tutucu üzerinde hava yön değiştirici kullanılmıştır. Radyal akış hızını arttırmak için venturi kanallı robot tutucu tasarlanmıştır. Ventiri kanalların kaldırma kuvveti üzerindeki etkisi test edilmiştir. Bu çalışma Laparoskopik cerrahide yumuşak doku gibi esnek malzemeleri kaldırmak için temassız bir tutucunun uygulanabilir olduğunu göstermektedir.

Anahtar Kelimeler: Temassız taşıma, Bernoulli tutucu, Radyal akış

I. INTRODUCTION

Minimally invasive surgery is a fast growing branch [1]. According to a report on laparoscopic devices recently released by Global Industry Analysts Inc., 7.5 million laparoscopic operation were performed worldwide in 2015 [2]. Large incisions are not made in the body during procedure, only a few small cuts are needed to insert the tools. The small incisions have advantageous for the patient due to result smaller scars and less pain, but they prevent the grasping capacity for the surgeon. The organ is a difficult object to grasping because of wet, delicate surface, low stiffness and diversity in feature, sizes, and shape. The typical grasping devices used in Laparoscopic surgery are toothed and require pinching of the organ for not to slip, entailing the risk of tissue damage. Although different alternatives for the toothed gripper have been developed [3], toothed grippers are still used in the majority of Laparoscopic interventions.

Due to the geometric properties of existing grippers, during surgery tissue damage occurs as a result of excessive clamping force. Surgeons also do not feel how much force they are applying at the grasper tip. Additionally, surgeons who use current gripper for long time are often subject to hand strain injuries due to poor handle design. A more ergonomic gripper design can relieve the strain on muscles during surgery and prevent nerve damage [4].

The aim of the study is to develop and test a non-contact gripper that prevents tissue damage during minimally invasive surgery. This could only be achieved if tissue could be gripped without contact. Non-contact handling technique is used for a variety of delicate materials, including jelly blocks [5], woven fabrics [6,7], vegetables [8], slicing wafers [9] and leather plies [10].

II. WORKING PRINCIPLE OF A BERNOULLI GRIPPER

In conventional Bernoulli gripper, compressed air is flow to the gripper through a central circular channel as can be shown in Figure 1(a). The air flows through this channel until it touches the object. This creates a repulsive force on the object, *Fjet*, which pushes it away from the gripper. At the same time, the air is forced in lateral direction between the gripper and object. The air is spread all the way away from the central channel due to circular structure of the gripper [8]. Due to the difference between the upper and lower surfaces of the object, an attractive force occurs between the holder and the object. When the gripper is brought closer to the object for lifted, the space between it and the gripper is reduced. In order to provide same volumetric air flow to exit the gripper, the air have to travel faster and so the closer the gripper is brought to the object the higher the air velocity across its upper surface becomes [8]. This increase in air speed results in an increased in the lift force. When the lifting force is greater than the repelling force, the object is pulled towards the surface of gripper. As the gripper continues to approach the object, the attractive force and repulsive force will increase. Eventually the object reaches an equilibrium point and is gripped without any contact between the gripper and object.

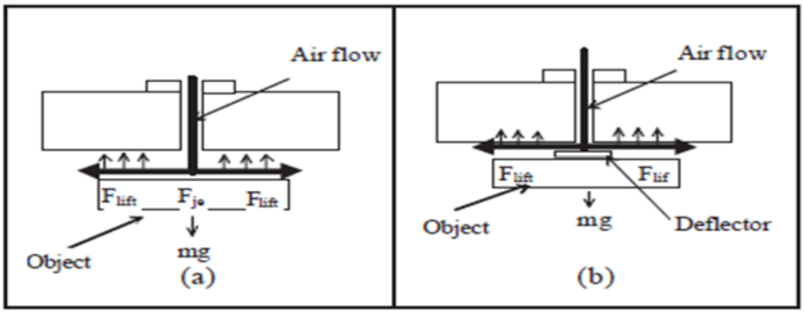

Figure 1. *Bernoulli gripper working principle* [11]

In conventional Bernoulli gripper, Because of the forces acting on the object are not distributed evenly along the surface, the gripper can not grasp soft materials such as tissue. To solve this problem, an air deflector was used in the gripper design. Figure 1(b) shows that the addition of an air deflector on gripper. The air is forced to flow the horizontal direction after it strikes the deflector as it flows down the center channel. Consequently of this, when the gripper approaches an object surface an attractive force generates without the central repulsive force.

III. Proposal Of A Non-Contact Gripper For Grasping Soft Tissues

In this study, a non-contact gripper has been proposed and tested on chicken tissues as seen gripper features Table 1.

Table 1. *Gripper features*

Internal radius *(mm)*	3,75
External radius *(mm)*	7
Deflector angle	90^0
Gripper face	venturi channel

The goal of the design is to increase the radial air flow against the vertical air flow to reduce the repelling force. Therefore an air deflector has been used 90^o angle even if it reduces the working area of the Bernoulli effect and therefore the lifting force. As indicated in Fig. 2, 12 radial venturi channels has been designed on gripper face. The reason is that should be a further contribution to the lifting action exerted by the gripper, exploiting the vacuum created in the central part of each venturi channel.

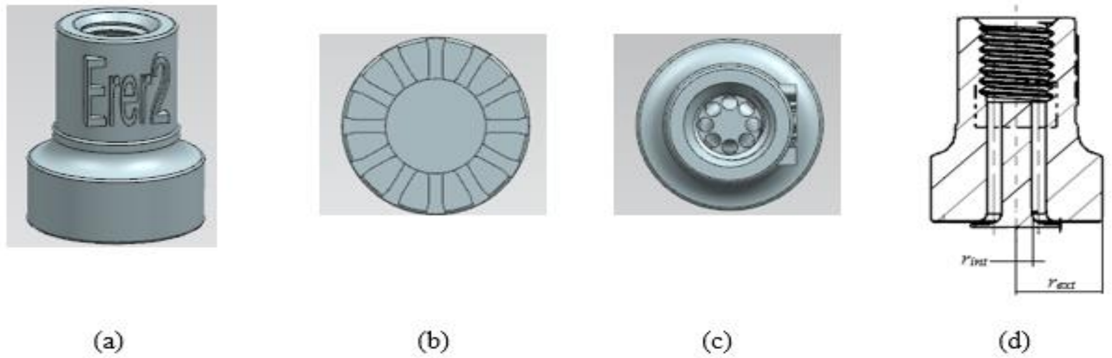

Figure 2. *Non-contact gripper with the deflector and Venturi channels (a) front view, (b) bottom view, (c) top view, (d) sectional view*

IV. EXPERIMENTS

An experimental setting is used to manipulate chicken infarcts by means of non-contact gripper. This gripper is constructed by 3D Printer technology and fit through a 15 mm trocar. Prototype is connected to compressed air tank for test on chicken tissues and has two control options, grasping tissues and releasing tissues. In order to grasp, the gripper is held close on the tissue surface and air is open by manually. The tissue is lifted towards the nozzle surface by Bernoulli principle. In order to release the grasped tissue, air flow is closed which decreases the vacuum level causing the tissue to slip down of the gripper face. A simple manipulation is carried out by prototype. The chicken liver, lung, skin, gizzard and hearth are grasped and lifted vertically upwards 200 mm as shown Figure 3. This manipulation during test is repeated 10 times at the different air flow level as seen Table 2.

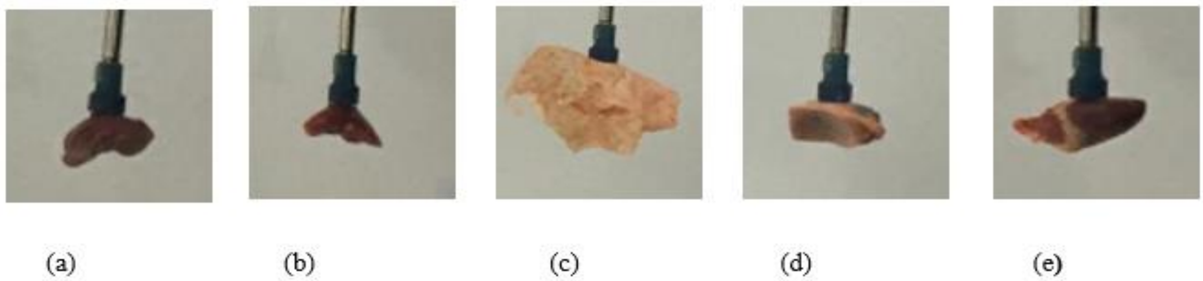

Figure 3. *Non-contact handling of tissues by gripper (a) liver, (b) lung,(c) skin, (d) gizzard, (e) hearth*

Table 2.*Gripper test conditions*

Gripper name	Experiment number	Tissues name	Tissues weight *(gr)*	Fluid pressure *(bar)*	Fluid velocity *(m^3/h)*	Lifting height *(mm)*	Levitation time *(sn)*	Retries
Erer 2	1	Liver	8	3	1,8	200	15	10
	2	Lung	5,27	2	1,6	200	15	10
	3	Skin	8,64	3	1,2	200	15	10
	4	Gizzard	13,93	3	1,2	200	15	10
	5	Hearth	6,28	3	1,2	200	15	10

For the experiments dead chicken tissues are used. All effects of the manipulations are macroscopically assessed regarding tissue damage and visible damage can not find on all tissues.

V. CONCLUSION

In this research, the goal was to explore the probability of applying Bernoulli principle for chicken tissues grasping during minimal invasive surgery. The gripper is able to handling flexible soft tissues. Due to the deflector, which is to prevent the tissue from damage due to the air flow, the gripper is not completely non-contact, it has minimal contact with the tissue.

Chicken tissues have been used for the experiments. The physical principles of the non-contact gripper prototype allowed chicken tissues to be grasped safely, up to air flow rate between 1,2 m^3/h and 1,8 m^3/h. No tears or holes were seen on the tissues. No user-controlled moving parts in the nozzle. The forces that grasp and lift the organ are determined by the level of air flow, preset at a constant level independently of the user. Therefore, when a non-contact gripper is used, any surgeon can apply the same forces to grasp and lift the organ as an expert surgeon, which contributing to patient safety during surgical procedures.

These experiments show that the tested organs can be handling with a gripper that works by the Bernoulli gripper. Especially, the use of a air deflector with 90^0 angle and radial Venturi channels on the gripper face give positive effects to the grasping force and completey eliminates imprints on the tissue surface. These tests show that a non-contact gripper can be used to grasp the liver, the lung, the

skin, the gizzard and the hearth without causing damage as seen Figure 4.

Figure 4. *Observations on test result at an air velocity level of between 1,2 m^3/h and 1,8 m3/h*

Non-contact gripping devices, such as the tested prototype, have the potential to be used as grasper instruments in minimally invasive surgery. As a result of experiments seems that the non-contact gripper is an interesting opportunity to the medical field and it is advised that the gripper is best suited for tissues by deflector.

ACKNOWLEDGEMENTS: This work is supported by Düzce University Scientific Project (Project no: 2018.06.05.675).

VI. REFERENCES

[1] J. Dankelman, C. A. Grimbergen and H. G. Stassen, *Engineering for patient safety: issues in minimally invasive procedures*, 1 st ed., New Jersey, London: Lawrence Erlbaum Associates, 2005, pp 1-322.

[2] "Global Industry Analysts Inc. Laparoscopic Devices" A Global Strategic Business Report. (2015). Available: https://www.strategyr.com/market-report-laparoscopic-devices-forecasts-global-industry-analysts-inc.asp

[3] M. Trommelen, "Development of a medical Bernoulli gripper," M.S. thesis, Department of Biomedical Engineering, Delft University of Technology, Delft, Netherlands, 2010.

[4] C. J. Reyda, "Design of a pressure sensing laparoscopic grasper," B.S. thesis, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Usa, 2011.

[5] F. Erzincanli, J. M. Sharp and A. M. Dore, "Grippers for handling of flexible food products," in *Proceeding of EURISCON'94,* Malaga, Spain: Amarc, vol. 3, 1994, pp. 798–806.

[6] Ozcelik and Erzincanli "A non-contact end-effector for the handling of garments," *Robotica*, vol. 20, no. 4, pp. 447–450, 2002.

[7] Ozcelik and Erzincanli "Examination of the movement of a woven fabric in the horizontal direction using a non-contact end-effector, " *International Journal of Advvanced Manufacturing Technology*, vol. 25, no. 5, pp. 527–532, 2005.

[8] Davis, Gray and Caldwell "An end effector based on the Bernoulli principle for handling sliced fruit and vegetables," *Robotics Computer Integrated. Manuffacturing*, vol. 24, no. 2, pp. 249–257, 2008.

[9] Brun and Melkote "Analysis of stresses and breakage of crystalline silicon wafers during handling and transport," *Solar Energy Materials, Solar Cells*, vol. 93, no. 8, pp. 1238–1247, 2009.

[10] Dini, Fantoni and Failli, "Grasping leather plies by Bernoulli grippers, " *CIRP Annals - Manuffacturing Technology*, vol. 58, no. 1, pp. 21–24, 2009.

[11] R. Sam and S. Nefti "A new design approach of robotic gripper for reducing operating cost for handling food product," presented at IEEE 9th International Conference on Cybernetic Intelligent Systems, UK, 2010.