Development of Single Hole Surgical Robotic Forceps for Reaching Deep Inside the Body 2-DOF Articulated Mechanism

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ABSTRACT

Abdominal surgery has evolved from traditional open surgery to laparoscopic surgery using an endoscope. Laparotomy is highly invasive because it involves a 200[mm] incision in the abdomen. Laparoscopic surgery can be performed through multiple 10[mm] incisions, making it less invasive. Recently, single hole laparoscopic surgery, which is performed through a single 20[mm] incision, has become popular and is becoming even less invasive, but it is a highly challenging procedure for the surgeon due to the difficulty in manipulating the surgical instruments. In this study, we will develop a mechanism for robotic forceps joints that can reduce the technical burden on the surgeon and reach deep inside the body. Currently, the joints of robotic forceps developed in clinical practice and in previous research at our university consist of a two-structure, two-degree-of-freedom mechanism that uses two pulleys and an antagonistic structure of wires to perform movement. The range of motion is set from the range of motion of the wrist. However, the wrist has one structure and two degrees of freedom, and there is a large discrepancy between the possible movements. Therefore, we are developing a joint that consists of one structure and two degrees of freedom for robotic forceps, aiming to create a joint that can perform the same movements as the wrist.

The structure of the joint is a magnet type ball joint with a magnet placed on the socket side and the ball is not fitted into the socket, so that there is little mechanical constraint in the motion and the required motion can be fulfilled.

We fabricated a simple functional testing machine made of acrylic resin and verified the motion of the proposed joint structure, suggesting that joint motion is possible.

Next, a simulation of the required pull force was conducted using a mechanical model of the actual machine size. Based on the moment equation obtained from the mechanical model, the mass, and the length of the structure, a magnetic pull force of 49.7[N] or more was considered necessary to maintain the structure.

Finally, in order to determine the attraction force generated in the ball section, we verified whether the proposed mechanism satisfies the attraction force of 49.7[N] by using the hypothetical magnetic path method in the magnet/yoke/ball section.