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INVESTIGATION OF ENDOSCOPE CAPSULE DESIGN ON THE FRICTIONAL RESISTANCE INSIDE THE INTESTINE

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The design of capsule body for self-propelled endoscope is important from the frictional resistance point of view. The capsule should be able to overcome the frictional resistance in order to move along the intestine. The motivation of this work was to gain a better understanding of the capsule body design on the frictional resistance of the capsule inside an intestine. A special experimental set-up was built to measure the frictional resistance as the capsule was being pulled inside the pig intestine specimen. Tests were performed with open and closed intestine specimens. Experimental data showed that smooth cylindrical capsule geometry resulted in the least frictional resistance. The resistance inside the closed intestine specimen was about four times higher than that of the open specimen. It is expected that the results of this work will be used to design the optimum propulsion system for the microendoscope.

Keywords : Capsule-type micro-endoscope, Intestine, Friction

1. INTRODUCTION

With the advent of MEMS (Micro-Electro-Mechanical Systems) technology, development of self-propelled endoscope of capsule type has been the topic of interest. There are advantages that capsule endoscopes can reduce the pain and displeasure of patient during the examination since the patient just swallows it and can be used easily without training for a long time [1,2]. Especially, it is expected that the use of micro-endoscope will make possible the examination of small intestine which has been difficult with traditional endoscopy.

Self-propelled robotic endoscope is an intelligent microsystem. It collects the information on the internal organs by imaging and sampling for diagnosis and injects medicine into specific region. Therefore, it is very important to have excellent handling performance, position sensing and enough propulsion power. In order to have these capabilities, the information on the friction in the body and the optimum shape design of endoscope are required. The design of capsule body for self-propelled endoscope is important from the frictional resistance point of view. The capsule should be able to overcome the frictional resistance in order to move along the intestine. Also, the motion of the capsule should not be too fast that the data transmitted from the capsule is insufficient.

A small intestine of a pig was used to perform the frictional resistance tests because it has similar features to those of human intestine. Small intestine is the longest digestive organ in the human body and its diameter is relatively very small (10-15 mm). In addition, there is a special physiological peristalsis in the small intestine which is called MMC (Migrating Motor Complex) [3]. For these reasons, it is likely that the micro-endoscopic capsule may experience higher frictional resistance in the small intestine than in other organs. Another point to note is that the surface area of the small intestine expands for digestion. Therefore, the change in the frictional force with respect to the change in contact area can be expected.

2. EXPERIMENTAL DETAILS

Capsules of various shapes and geometries were designed and fabricated with both aluminum and plastic, as can be seen in Fig. 1. The shapes were varied to provide different degrees of surface area as well as interaction against the wall of the intestine. The sizes and weights of the capsules are summarized in Table 1. The diameter and length is the same as those of the capsule type endoscope which will be ultimately.

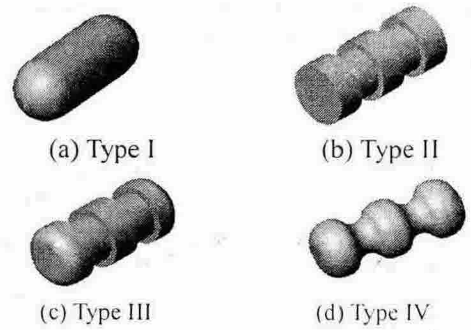

Fig. 1 Capsule design

Table 1 Specifications of the capsule specimens

	Type I	Type II	Type III	Type IV
Weight (mN)	31.2	31.4	29.4	28.1
Surface area (mm^2)	565.5	743.0	690.9	645.1
Size	Diameter – 9 mm / Length – 20 mm			

A special experimental set-up was designed and built to measure the frictional resistance as the capsule is being pulled inside the intestine specimen. A series of semiconductor strain gages was used for the measurement of the friction force. The conditions inside the test specimen were set to those similar to a human intestine with respect to pH level and temperature. In order to prevent the intestine specimen from drying during the experiment, the isotonic solution was sprayed over the intestine specimen. The speed of the intestine specimen was controlled by a motor controller and was set to 3 cm/min which corresponds to the average speed of peristalsis.

Tests were performed with open and closed forms of intestine specimens. In the case of the open form, the capsule was placed on the intestine under its own weight and pulled along the surface of the intestine. In the case of closed form, the capsule was placed inside the circular section of the intestine and pulled. Thus, the normal force applied to the capsule was mainly due to the elastic force of the intestine.

3. RESULTS AND DISCUSSIONS

Preliminary tests showed that the friction between the capsule and the small intestine was significantly dependent on the internal surface condition of the small intestine. In order to compare the frictional forces with respect to the changes in various parameters, for all experiments the frictional forces were measured while the capsule was sliding in the same region of the intestine.

Fig. 2 shows that the friction force of the open intestine is much smaller that of the closed form of intestine. This means that friction force is affected more by the contact area rather than by the weight of capsule.

The frictional forces of different types of capsules are presented in Fig. 3. From this result, it can be found that type I, which is smooth cylindrical capsule geometry, resulted in the least frictional resistance, and type II showed the largest frictional resistance. It is suggested that the sharp corners of the capsule raise the friction force while the cylindrical shape reduces the friction. Also, it was found that the magnitude order of the frictional forces of various capsule geometries corresponds well to the surface area of the capsules, as shown in Table 1. Type IV has the largest surface area and shows the largest frictional force.

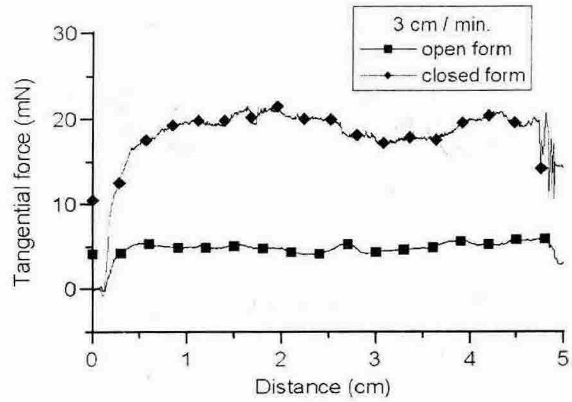

Fig. 2 Comparison of friction between spread and original forms of small intestines

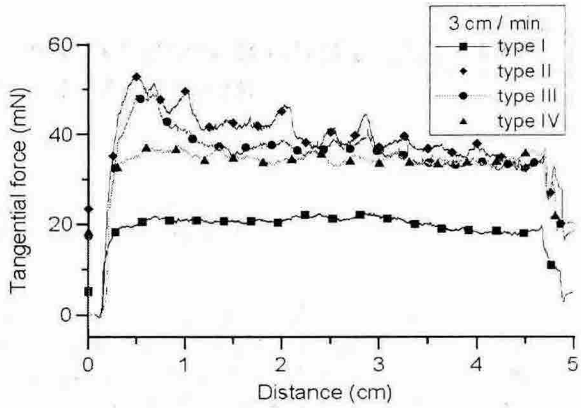

Fig. 3 Friction forces of different types of capsules

4. CONCLUSIONS

In this work, the characteristics of frictional resistance inside the small intestine with respect to various capsule shape were investigated using a specially designed tribotester. Average friction force of capsules was 20~50 mN. Experimental data showed that smooth cylindrical capsule geometry resulted in the least frictional resistance. The resistance inside the closed intestine specimen was about four times higher than that of the open specimen. Also, it was found that the frictional force was affected more by surface geometry rather than by the weight of capsule due to material characteristics of the intestine which is soft and flexible.

The results of this work are expected to aid in the design of self-propelling endoscope capsule with optimum propulsion characteristics.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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