# Magnetic Mechanism for Wireless Capsule Biopsy

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## 1 Background

One of the main diagnostic limitations of current gastrointestinal (GI) capsule endoscopes is that they cannot get biopsies, thus requiring follow-up with flexible endoscopy whenever a suspicious lesion is identified. The ability of getting biopsies from a wireless capsule would save time and costs associated with the procedure, reducing at the same time invasiveness and discomfort for the patient.

The Crosby capsule, designed in 1957, exploits a small tether to suck tissue, to activate spring-loaded knife and to manage device retrieval. However, invasiveness of the procedure is still relevant and requires sedation [1]. Two compact mechanisms have been recently proposed for wireless biopsy. The first takes advantage of a spring actuated rotational razor [2], while the second exploits Shape Memory Alloy (SMA) to actuate a micro-biopsy spike [3]. Due to the harsh environment of the GI tract and the absence of stabilization during sampling, both these devices have a limited efficacy. In order to improve efficacy while reducing capsule size, we propose a completely magneto-mechanical mechanism which does not require onboard batteries and actuators.

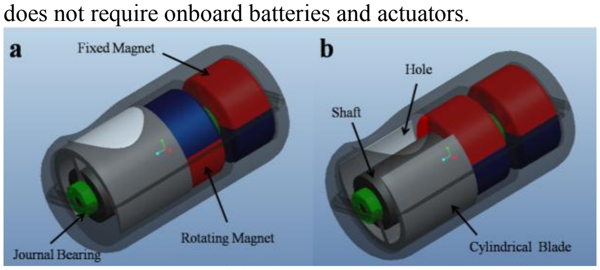


*Fig.1 Drawings of the closed (a) and open (b) capsule.*

## 2 Methods

The proposed mechanism is composed by two cylindrical diametrically-magnetized permanent magnets (6.3 mm in diameter and 3.2 mm in thickness, NdFeB, N52), coaxially placed in a polymeric shell (9.5 mm in diameter and 17 mm in length) with a 5-mm hole along its profile (Fig.1a,b). While one magnet is integrated in the chassis and cannot move, the second one is fixed on a shaft and is free to rotate under the effect of magnetic torque. Finally, a cylindrical Ergal blade, fabricated by micro-wire electro-discharge machining, is connected to the rotating magnet on the shaft.

Magnetic simulations performed with COMSOL Multiphysics® were used to obtain an accurate analysis and optimization of magneto-mechanical parameters.

The coupling between the fixed and rotating magnets forces the blade to close the lateral hole (Fig.1a). By providing a strong external magnetic field (i.e. placing a permanent magnet upon the patient abdomen), the magnet mounted on the shaft rotates together with the blade, thus exposing the cavity. At the same time, the device is attracted towards the lumen wall by magnetic coupling (Fig.2a) and applies a pressure onto the mucosa. This promotes tissue penetration inside the cavity. By gradually taking the external magnet away from the capsule (Fig.2b), the rotating magnet-blade assembly moves back to its original position, cutting the tissue inside the cavity. It is worth mentioning that the magnetic coupling at this stage is still strong enough to keep the capsule in contact with the lumen wall. By further moving the external magnet away (Fig.2c), the capsules detaches from the lumen wall under the effect of the gravity force and is again free to move in the GI tract.

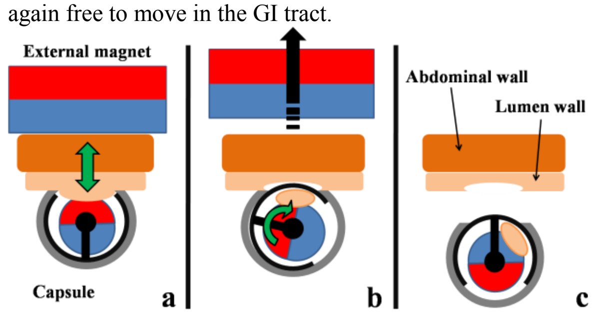


*Fig.2 a) Attraction and opening phase; b) Cutting phase; c) Storage phase.*

## 3 Results and Discussion

A prototype implementing the mechanism described above has been fabricated and tested, confirming the feasibility of the novel approach. In particular, the mechanism can be activated with an external cylindrical permanent magnet (5 cm in diameter and 2 cm in thickness, NdFeB, N52) at a distance of 3 cm. A typical magnetic force of 0.7 N is achieved during adhesion and opening phase (Fig.2a), whereas during the cutting phase (Fig.2b) the maximum toque exerted by the blade on the tissue was measured to be 5.3 mNm. Preliminary ex-vivo trials demonstrated the ability to take 1.5 mm deep tissue sample.

Thanks to the innovative magnetic mechanism, battery and actuators are not required onboard, thus allowing a very compact size and potentially extending the reach of this technology to pediatric patients. The magnetic field required for mechanism actuation falls within safety regulations [4]. The absence of protruding parts makes the proposed capsule fail-safe. Finally, the device is composed by bio-compatible low cost parts and is suitable for sterilization.

## References

[1] Crosby W. et al. Intraluminal biopsy of the small intestine. Digestive Diseases and Sciences, 2:236-241, 1957.

[2] Kong K. et al. A rotational micro biopsy device for the capsule endoscope. In Intelligent Robots and Systems, 2005.(IROS 2005). pp. 1839-1843. IEEE, 2005.

[3] Park S. et al. A novel microactuator for microbiopsy in capsular endoscopes. Journal of Micromechanics and Microengineering, 18:25-32, 2008.

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