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# Designing Smart Surgical Microtools: November 30, 2009

This image shows the size scale of the microgripper relative to a penny. The 0.1-1 mm grippers resemble tiny dust particles. *(Credit: T. G. Leong [Gracias Laboratory, Johns Hopkins University])*

Movement of cells and cellular components on their own is a hallmark of all living systems. Light triggers flowers to open; subtle biochemical cues trigger mass movement of microbes towards the source of food, immune cells towards a wound, and stem cells towards the site of injury; and chemical energy fuels molecular motors that rearrange chromosomes during cell division. All these vital processes occur without wires or batteries. Researchers look to such biological processes to inspire development of improved biomedical tools. Such is the case of one researcher at Johns Hopkins who has succeeded in developing a microgripper that requires no source of electricity to perform its function.

To date, engineers have been largely unsuccessful in designing machines that operate in response to chemical cues – that is, until David H. Gracias, Associate Professor of Chemical and Biomolecular Engineering at The Johns Hopkins University, devised a microscopic-sized tool that opens and closes in response to chemicals. The microgripper does not require batteries or any other electrical power source.

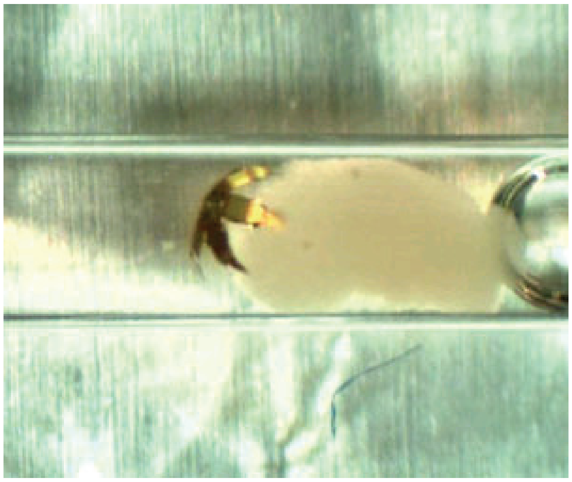
The idea of using chemistry to generate motion for use in surgical applications is decidedly novel. “It is hard to make something autonomous if you need batteries. You have to recharge the batteries, and making small batteries is very difficult. It can also increase the cost a lot,” explains Gracias. Other surgical microtools cannot be used in hard-to-reach places in the body because they are wired. During laboratory tests, Gracias' wireless microgripper easily maneuvered through coiled tubes.

The microgripper is strong yet gentle. During tests, the device efficiently grasped and carried clusters of living cells without damaging them – cells continued to grow after they were released from the gripper. The microgripper can be fitted with sharp tips for cutting through connective tissue and pulling out cells. “This small device, without any electricity, was strong enough to cut out a chunk of cells from a piece of bladder, a tough tissue,” indicates Gracias.

The microgripper is shaped like a fist no wider than a human hair and has several digits attached to a central palm. The digits are composed of a thin two-metal film coated with a layer of polymer that keeps the gripper in an open position. When heated or exposed to certain chemicals, the polymer layer softens, degrades, or delaminates, allowing the gripper to close. Due to the particular metallic composition of the microgripper, an MRI or CT scanner could be used to visualize the microgripper inside a human body, and its movement can be remotely navigated with a simple bar magnet up to 10 cm away or using a more sophisticated magnetic guidance system.

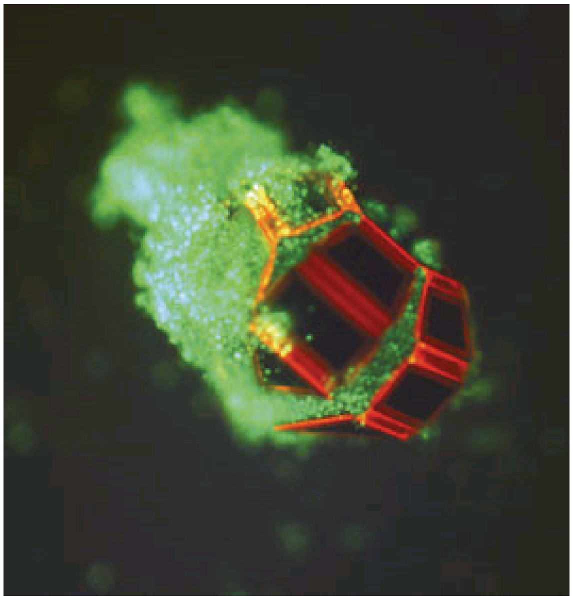
## Possible Applications

Tetherless microgrippers can be mass-produced inexpensively and in smaller sizes than their electrical counterparts. They are currently the right size for microsurgery. “We are working on building an entire surgical toolkit – something that can staple and cut, all without tethers or wires.” If grippers could be made small enough, they could capture single cells, which could be used to test new drugs *in vitro*. Analyzing response to drugs at a single-cell level can give researchers a deeper insight into cellular processes than looking at the average response of many cells.



In response to a temperature change, a tetherless microgripper grabs onto a clump of live cells at the end of a narrow glass capillary tube. The microgripper was guided out of the tube with captured cells in its grasp. Watch a movie. (Reference: T. G. Leong et al. Proc Natl Acad Sci USA. 2009 Jan 20;106(3):703-8.)

If microgrippers were coated with molecules that specifically bind to proteins on the surface of cancer cells, they could be self-guided to tumors for biopsy collection. “The cancer cells themselves would potentially release chemicals that would cause the grippers to close around them,” explains Christina Randall, a graduate student in Gracias’ lab. Once captured, the cells can be grown inside the microgrippers and even frozen until they can be analyzed in a lab. “We are working to make the microgrippers out of polymers versus metals so that they are transparent and we can see what is captured inside them,” adds Randall. The research team found that many biocompatible compounds such as salt solutions, glucose, and amino acids can release the claws of the microgripper. This approach could be useful for delivering drugs to disease sites. Gracias also envisions microgrippers removing blood clots, sealing aneurysms, and acting as artificial immune cells.



In this fluorescence microscopy image, a microgripper closes around live cells (green) in response to a biochemical signal. (Reference: T. G. Leong et al. Proc Natl Acad Sci U S A. 2009 Jan 20;106(3):703-8.)

## Gripping Into the Future

“A next wave of miniature medical devices involves getting rid of the tether so they can be swallowed or injected into the bloodstream. People already make pills containing cameras that you can swallow,” says Gracias. He cautions that injecting the microgrippers into blood vessels is still far in the future. At their current size, the microgrippers could be inserted through other orifices such as those used in minimally invasive surgery.

Although the microgrippers can be controlled by subtle temperature changes, chemical actuation is more interesting in the long term because it would allow the microgripper to respond to chemicals already present in the body, such as signals released by a tumor. Ultimately, the microgrippers will be designed to move autonomously toward the source of a biochemical signal. The immediate next steps are making the microgrippers smaller and making them capable of moving independently (without a magnet), closing around the cells and opening back up, and responding to antibodies and enzymes. Negotiations are underway to test the microgrippers in surgery and license them as medical devices. “Hopefully, down the road, the microgrippers will become part of individual robotic surgeons. They could track down what you wanted to be found using chemical signals, take a sample or do some basic analysis, and send data *via* radio signal. You could do everything with just a needle injection,” reflects Randall.

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