Mechanical Design for Modularity of Laparoscopic Tools

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Background: A functional analysis of current laparoscopic surgical technology prompted a redesign to provide multiple functionalities within a single tool. Novel mechanisms were needed to actuate and deploy functional tips to the surgical site from their storage locations. Methods: Functional Decomposition was used to determine problems with the current minimally invasive surgery (MIS) paradigm. Axiomatic Design was used to ensure an efficient design. Quality Function Deployment was used to mathematically determine important design criteria. Results: The actuation mechanism transfers squeezing motion from the hand through a gear train to the distal end of the tool where a pin-slot mechanism actuates the tool tip. An ergonomic slider mechanism translates linear thumb motion into rotation of the tool's shaft through a gear train. A binary ratcheting mechanism is used to lock or unlock the tool with identical motions. Methods for indexing functional tips within the tool and interfacing the tips with a lead screw were designed for a modular tool. Rotary indexing of the tool cartridge is done using a Geneva-type mechanism and cam/follower to provide positive locking once the tip is in place. Proper alignment of the tool tip with the actuation/shuttling screw is accomplished using a screw/wedge assembly. Conclusions: Benefits include multiple functionalities in a single tool, ergonomic benefits of an increased I/O force scaling, decreased out-of-plane motion required to rotate the tool's shaft and decreased cognitive effort required to lock and unlock the tool's jaws.

