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Development of Surgical Instruments for Endoscopic Ear Surgery

Background:

Imagine a world where all surgeries are performed minimally invasively, a technique that reduces trauma to the body, scarring, recovery time and length of hospital stay [1]. Middle ear surgery is traditionally performed through an external incision with visualisation of delicate anatomical structures using a microscope. More recently, surgical techniques have been developed using endoscopes to access the middle ear through the ear canal without an external incision [2, 3]. As with open microscope-guided surgery, this transcanal endoscopic ear surgery (TEES) technique, allows the surgeon to perform procedures such as ear drum reconstruction, skin growth removal and hearing bone repair [2]. The principle challenge with TEES is that a one-handed surgical technique is required as the endoscope is held in the other hand. Otologic instruments were developed for two-handed microscope-guided surgery so they are not all well suited to TEES conditions [3]. These shortcomings have hindered the use of TEES and will be addressed by this project which will utilize mechanical engineering principles to develop specialized instruments for TEES [4, 3]. While previous instruments were developed by surgeons over decades through trial and error, modern engineering techniques provide the opportunity to rapidly design and produce ergonomic functional instruments optimised to facilitate this new branch of surgery.

Objectives and Hypothesis:

To develop surgical instruments that facilitate one-handed surgery for TEES. To achieve this, tools will be designed to improve grip and manoeuvrability of synthetic grafts and enable accessibility in hard to reach places within the middle ear. Increasing functionality of surgical instruments by manipulating angular geometry, adding pushing mechanisms and adding suction capabilities, will increase control during TEES, replicating manoeuvres for which two hands are traditionally required.

Experimental Approach:

Development of the tools will follow an iterative engineering design process. Initial prototypes will be virtual and 3D printed, and will be tested in virtual and 3D printed ear models, respectively. Test results will drive further iterations of the design and functional prototypes will be designed for machinability to produce final prototypes.

Methods/Procedures:

To achieve the desired functionalities, prototypes will: use suction capabilities to grip objects, employ spring-loaded or track-guided mechanisms to push objects off the instrument, and manipulate angular geometry to achieve accessibility. Virtual 3D instrument models will be integrated with virtual 3D ear canal models, constructed using CT scans from patients with ear disease, to optimize dimensions and angular geometry. As well, existing instruments that enable grip, such as the T-Tube inserter and alligator forceps, will be incorporated in prototypes to provide gripping functionality [5, 6].

Prototypes will then be fabricated and tested by an ear surgeon on a 3D printed ear canal with an endoscope and a synthetic graft, to assess improvements in grip, maneuverability and accessibility. Engineering drawings of functional prototypes will then be drafted for professional machining of the instruments.

Significance of Proposed Research to Biomedical Engineering and Surgery:

This project will demonstrate the feasibility of using modern CAD, modelling and printing technologies to expedite design of novel surgical instruments for new procedures. It is anticipated that new TEES instruments will increase the range of ear procedures that can be completed minimally invasively and increase the speed and effectiveness of surgery. The design techniques and instruments created will also be applicable to other minimally invasive surgery in bony cavities such as sinus, nasal, spinal and arthroscopic surgery [1, 7, 8]. It could be envisaged that ultimately, virtual patient models could be used with rapid prototyping and fabrication to create patient specific specialist instruments so extending the limits of minimally invasive surgery even further.

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