

Design of Controllable Flexible Instruments to Facilitate Endoscopic Ear Surgery

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Transcanal endoscopic ear surgery (TEES) is a new minimally invasive middle ear surgery technique to access otherwise hidden recesses within the middle ear¹⁻⁴. While TEES reduces length of hospital stay and patient morbidity, the surgical technique is challenging since only one hand can handle an instrument which must pass through the narrow ear canal^{5,6}. Presently, surgeons performing TEES use otologic instruments developed for two-handed surgery which are not optimized for the TEES environment.

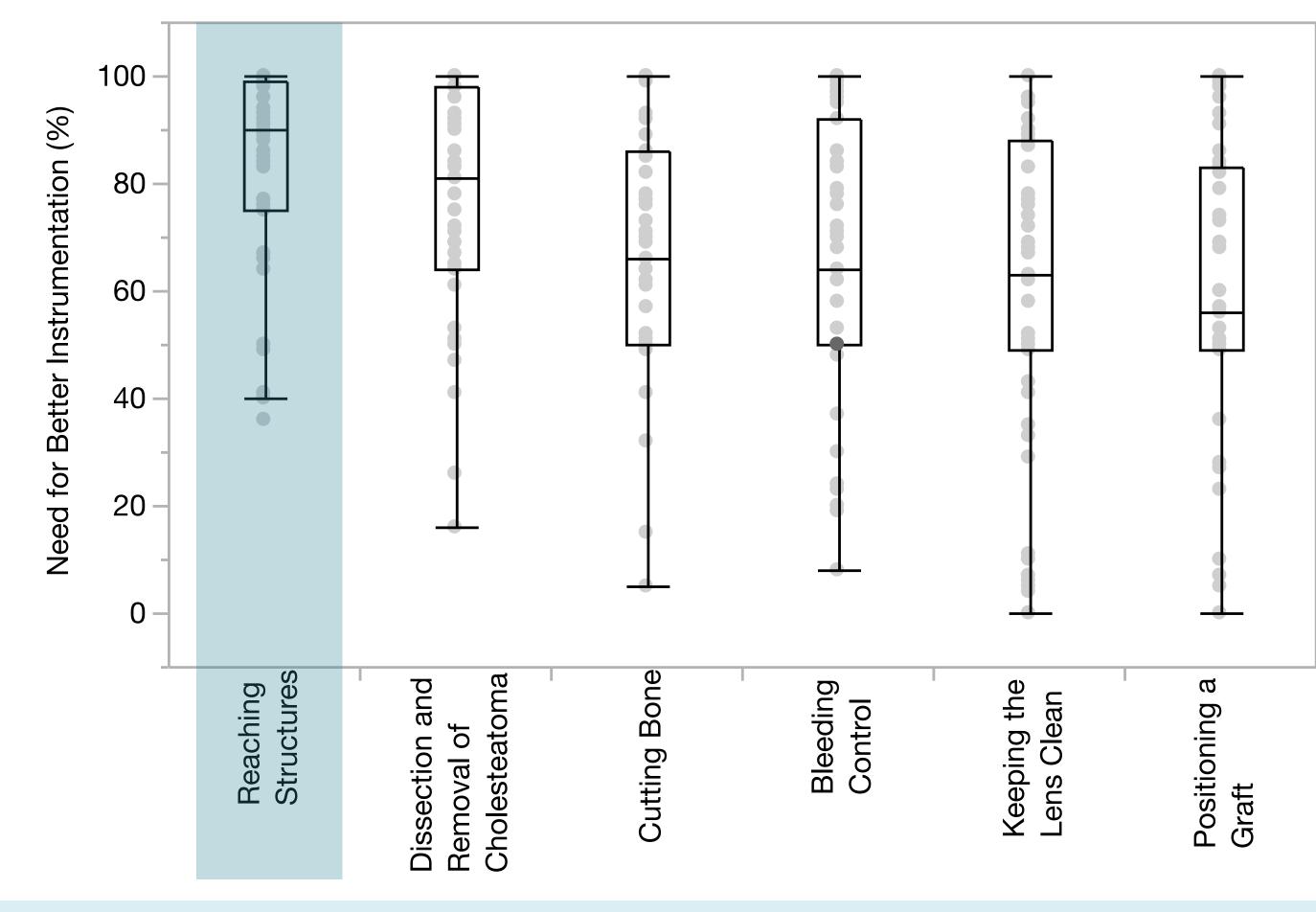
Objective: Design instruments to facilitate the challenges experienced during transcanal endoscopic ear surgery (TEES).

Defining the Challenges of TEES

As TEES is a young field, a needs analysis study was conducted to define the primary challenges faced by surgeons.

Needs Analysis Study TEES Experience: Interviews with 5 local Percent of TEES Cases: otologists Up to 50% 50-90% More than 90% Pilot questionnaire Use of specialized TEES Instruments? TEES skills course Visual Analog Scale: Rate need for better instrumentation to address the following TEES challenges: Reaching structures visualized by the endoscope Cross-sectional mixed methods Dissection and removal of cholesteatoma study questionnaireç Cutting bone Bleeding control Keeping the endoscope lens clean Positioning a graft 51 international TEES Surgeon responses Non-parametric data analysis: "Are there any other instruments that you would like to Kruskal Wallis H-Test see modified or developed for endoscopic ear surgery? Please give examples" Wilcoxon Method

Study Results

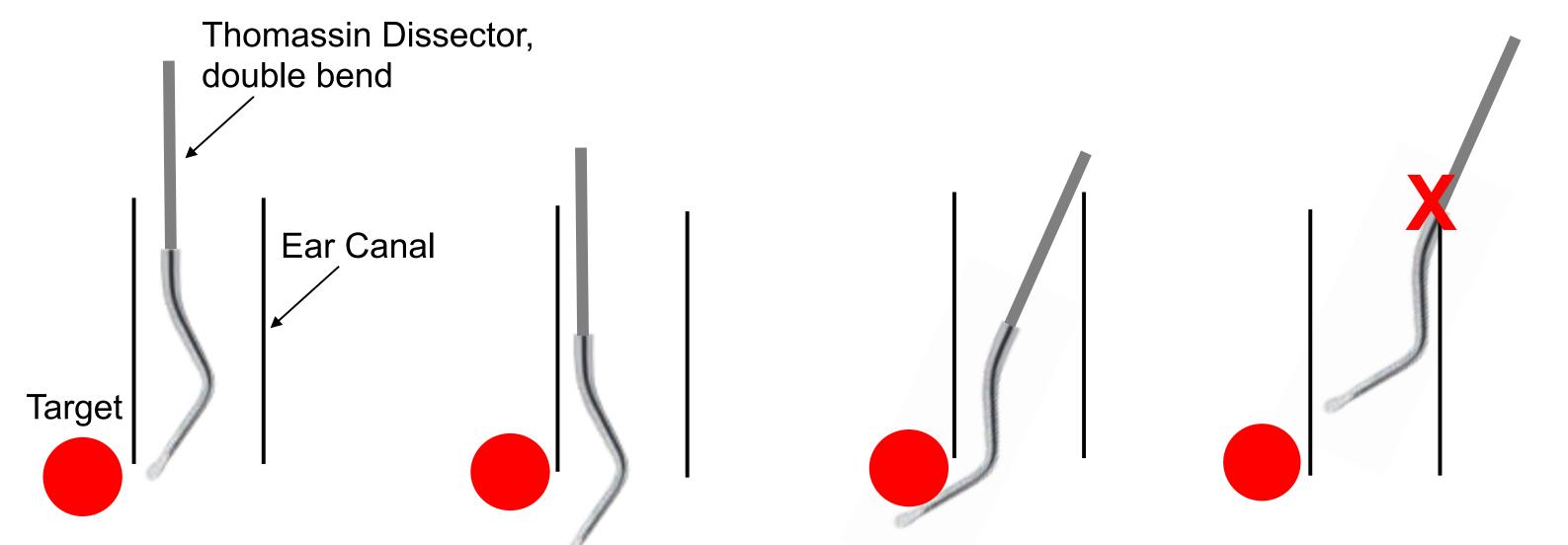


P<0.05 significant

Reaching structures visualized by the endoscope yielded the greatest need for better instruments.

Survey comments called for new instruments to improve reach, dissect and remove cholesteatoma, bone removal, and control bleeding.

Reaching Problem: current instruments cannot reach all structures visualized by the endoscope without the removal of bone.



References

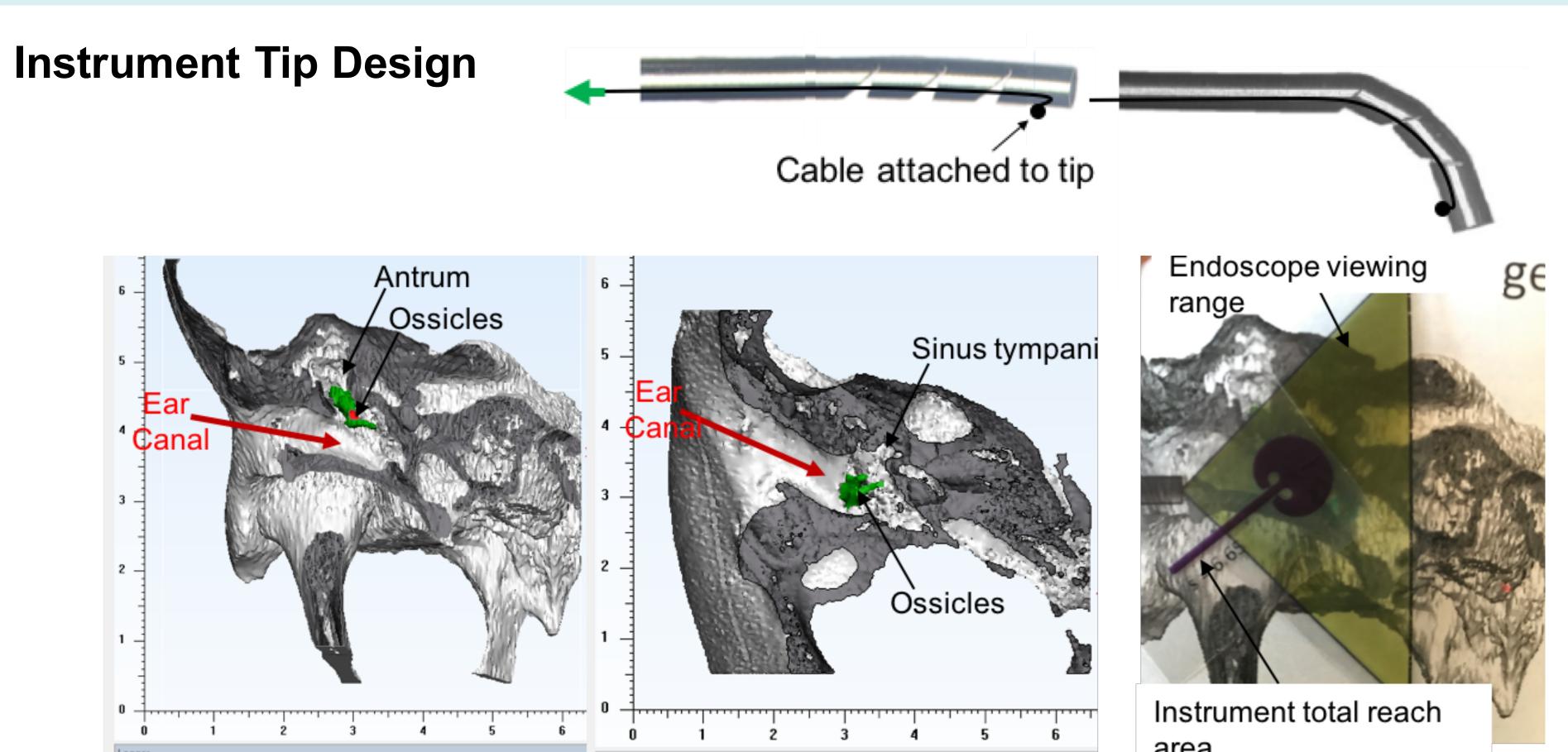
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Development of a New Instrument for TEES

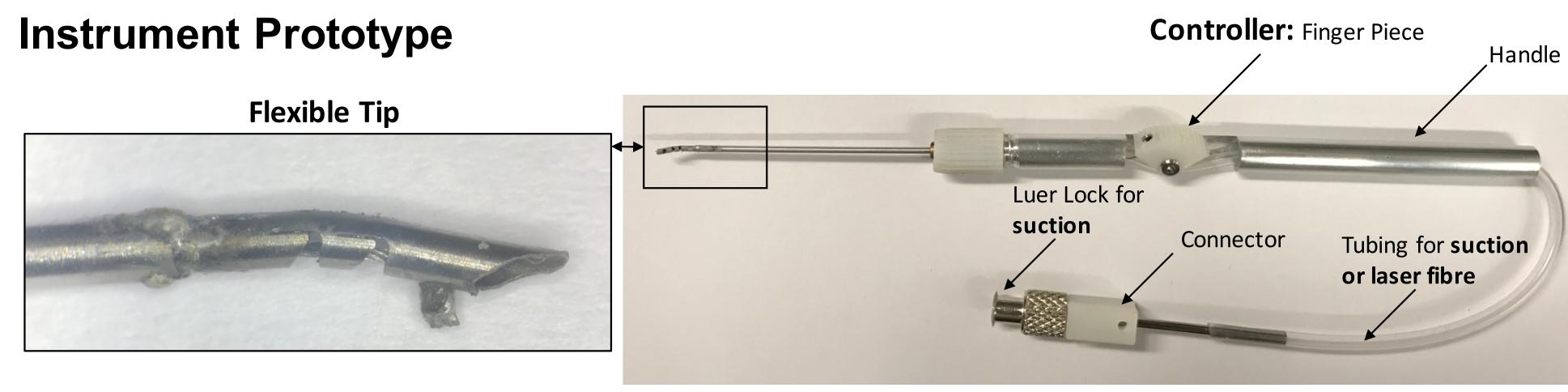
To address the challenges of TEES, an instrument was designed, prototyped and tested to reach the structures visualized by the endoscope.

Reaching Solution: Incorporate a flexible "wrist" at the tip of the instrument.

By cutting notches into a tube made of nitinol (a superelastic metal), the tube can bend by pulling on an attached cable. A specific notch geometry is selected to achieve the desired bending shape while increasing stiffness⁷.



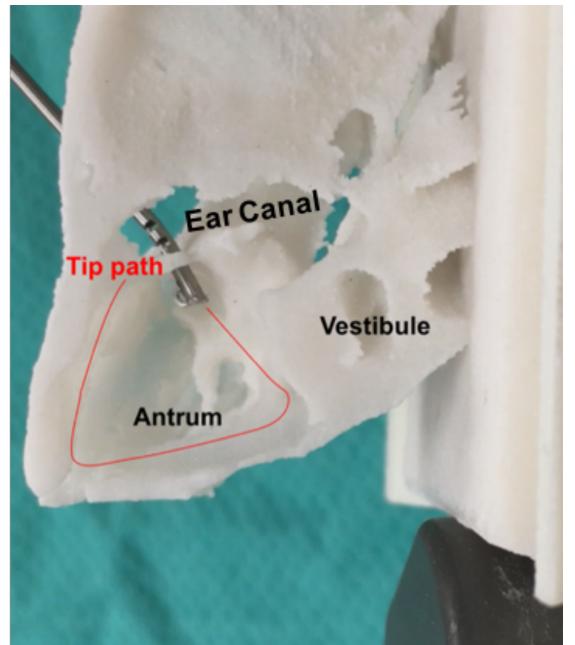
Patient CT scans informed the design of the tip in order to reach the target anatomy, including the antrum and sinus tympani where cholesteatoma is usually found and currently inaccessible without removing bone. The desirable bending angle is 135° which allows the tip to reach the boundary of the endoscope viewing angle.



The tip was manufactured by laser cutting a nitinol tube and attached to a handle which could articulate the joint. The handle is designed to maintain a similar grip used for existing ear surgery instruments with the addition of a finger piece for controlling the tip.

Instrument Testing





The instrument was tested using an endoscope inside 3D printed patient temporal bone models generated from the CT scans. It was possible to reach the sinus tympani and antrum.

Future Work

Future work involves further testing of the tip to ensure it can safely encounter the tissue forces experienced during surgery, orient a laser fibre safely and effectively, and reach the desired targets within the middle ear without significant bone removal and ultimately facilitate endoscopic ear surgery.