**Otology and Neurotology Paper**

Goal: outline the design of the instrument and how design decisions were made. The innovation/theoretical aspect is that patient CT scans were used to develop the surgical workspace and this was used to determine the appropriate curvature of the wrist in order to reach the hidden areas within the middle ear.

Reference: “Lowering the Barrier of Surgical Endoscopy With a Novel Articulating Retractor”

**Abstract:**

**Introduction and Background:**

*Clinical Motivation:*

* TEES is a minimally invasive surgical technique – list benefits
* One-handed surgery
* Tools for TEES (such as...) are being developed but according to Needs Analysis study they are still not sufficient to facilitate the technique
* Current tools used: incorporate suction with dissector tip, round knife, but their tip geometry doesn’t enable reach in hard to reach hidden recesses within the middle ear where cholesteatoma is usually found (sinus tympani and attic) – need to reach areas visualized by the endoscope (as per needs paper)
* include picture of 3D patient model with endoscope and current tools (double bend Thomassin and show that it is unable to reach and barely fits within the ear canal with its double bend)
* Need: a tool to reach structures visualized by the endoscope, as defined by patient CT scans rendered into virtual surgical workspaces of the middle ear, and suction (as per Needs analysis paper) -> nitinol notched tube compliant joints that can accomplish this

**Design Objectives:**

* Size constraints:
  + Size required: 2.7 mm endoscope + tool inside of 5mm average diameter ear canal
  + Average ear canal diameter
  + Size of current instruments that have suction
  + These yielded the current tube diameter (OD, ID)
* Suction and Dissection (as per needs analysis)
* Tip forces required (middle ear surgery forces paper)
* reach required (as per needs analysis)

**Methods:**

*Workspace Analysis/Modeling to Design the Tool Tip:*

* Follows Bennett’s paper where middle ear visualization with endoscopy was modeled and different areas of this surgical workspace were colour-coded
  + Generate this workspace and colour-code the areas that are difficult to reach: sinus tympani, antrum boundary
  + Use Matlab script to import the workspace .stl and generate the curvature to reach defined areas

**Overview of Instrument Design:**

<Figure (picture and CAD?) of instrument with tip and handle labeled – see Kyle’s thesis chapter 6>

*Tool Operation:*

* Use figures to describe how the thumb wheel maps to bending the tool
* Laser and suction

*Tip Design:*

* OD/ID for suction
* size to fit alongside endoscope in ear canal
* bending angle to reach boundary of endoscopic viewing field
  + patient CT scans generated the surgical workspace (Bennett paper as a reference of what is visible by the endoscope 1)
  + experienced otologists identified hard to reach regions (sinus tympani, boundaries of the antrum)
  + Matlab used to generate the curvature of the tip to reach – read: 2 and 3
* material NiTi for superelastic property and biocompatibility
* length is same as current instrument – Rosen Needle
* can withstand tissue forces during dissection or (suction or laser)
* laser cut – reference ASME contact aided compliant joint paper that describes this joint design

*Handle Design:*

* single-handed operation
* ergonomically comfortable handle held like a pen in order to perform precise microscopic movements and so it is used similar to other instruments in ear surgery

*Fabrication Methods:*

* laser cutting nitinol tube
* 3D printing parts (list them)
* milling parts (list them)

**Results**:

*Functional tool validation inside a 3D printed bone model*

* The patient CT scans are 3D printed with highlighted hard to reach areas
* Measure: the number of targets this tool can reach vs. current tools Rosen, Panetti, Thomassin dissector

**Discussion:**

* Limitations of the design, and areas of improvement
* Test results
* Innovation: designing the instrument based on virtual patient surgical workspace models

**Conclusion:**