Internship subject M1 or M2 or PFE engineer internship

Automatic and robot-based ossicular chain repair in human ear

Management: Carlos Mateo — Email: Carlos-Manuel.Mateo-Agullo@u-bourgogne.fr
Renato Martins — Email: renato.martins@u-bourgogne.fr
Alain Lalande — Email: alain.lalande@u-bourgogne.fr
Alexis Bozorg Grayeli — Email: alexis.bozorggrayeli@chu-dijon.fr

Place: ICB Laboratory UMR 6303 CNRS (Dijon) / ICMUB Laboratory UMR 6302 (Dijon)
Duration: 16 to 24 weeks from February-March 2024

Background: Ossicular chain interruption or displacement is one of the most frequent causes of hearing loss in clinical practice. These situations may be a consequence of chronic inflammation (chronic otitis media) or trauma (head injury, rapid changes of pressure in the ear during scuba diving, sky diving, explosions, slaps on the ear, …).
In routine surgical procedures, ossicular chain repair is performed under local or general anesthesia. Visual control is provided by a surgical microscope or a rigid endoscope through the external auditory canal (Figure 1). The tympanic membrane is elevated and an ossicular prosthesis or a cartilage graft is placed in the middle ear to fill the gap between the inner ear (cochlea) and the tympanic membrane. The shape and the size of the prosthesis varies depending on the scenario (Figure 2). For small interruptions between incus and stapes with no dislocations and normal mobility, bone cement (hydroxylapatite or polyacrylate) can be used to repair the chain (Figure 3). These prostheses are unstable and can be displaced in the postoperative period. Today, bone cement cannot be used for large disruptions or complex repairs. A robot has been designed for middle ear surgery and is commercially available internationally (Robotol, Collin medical, Bagneux, France). To our knowledge, no procedure has been developed or tested for the ossicular chain repair with any robot.

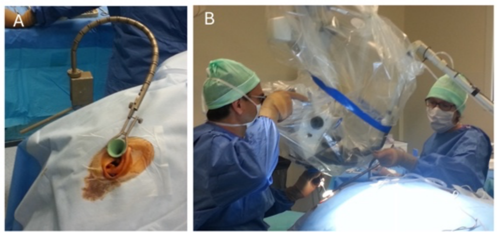

Figure 1- Patient installation for a right ear tympanoplasty through the external auditory canal (A), under operative microscope coupled to a CO_2 LASER (B).

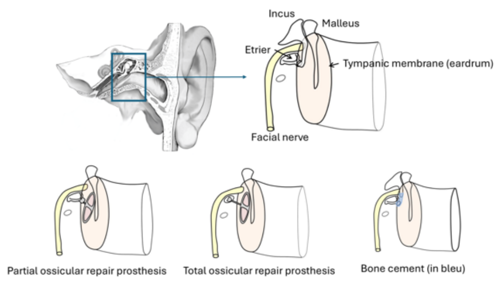

Figure 2- Schematic human ear anatomy and 3 scenarios of ossicular chain repair.

Objective: The objective of this project is to develop and validate a robot-based procedure to repair the ossicular chain with bone cement in various scenarios using a master-slave configuration control scheme with visual servoing.

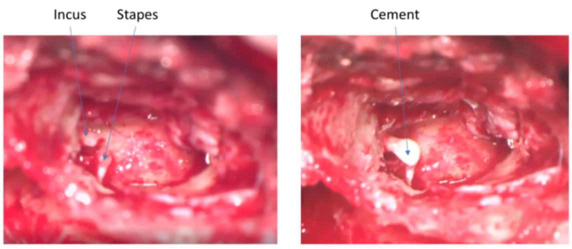

Figure 3- *Surgical view under operative microscope during ossicular chain repair by cement.*

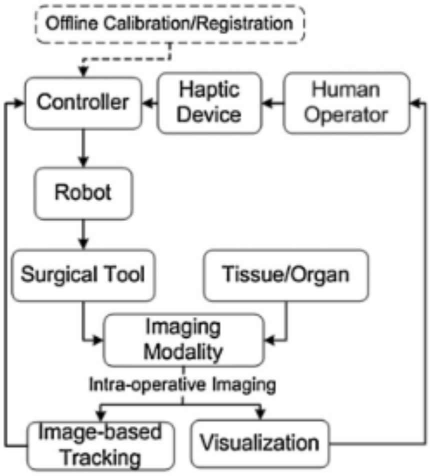

Figure 4- *Master-slave control with visual servoing (image source: [Azizian 2104])*

Materials and Methods: The first phase of the study will be conducted on resin human temporal bone models in which the long process of incus has been resected. A collaborative robot (Franka research 3) with 7 degrees of freedom connected to a needle and a powered syringe will be used to perform the task. Concretely, the control configuration will follow the master-slave configuration, where the human operator will define the high-level planning, and the controller will resolve the low-level operations (Figure 4) [Azizian2014]. Particularly, the controller will be implemented using visual servoing [Chaumette2016]. Regarding the image modality (Figure 4), the task will be controlled under operative microscope.

The operative microscope will be connected to a HD camera to obtain a real-time image of the surgical field. A high-resolution CT-scan of the resin temporal bone will be available. The CT-scan data will be registered to the video feed to obtain an augmented reality display. This can be solved using more traditional optimization task such as proposed for reality guided laparoscopic surgery [Collins2020]. But in this project we propose to use approaches like the one proposed by Van Houtte et al. [Houtte2022], where the authors proposed a neural network scheme to resolve the problem for registering a 3D atlas image to a 2D radiograph image. The ossicular chain repair will be preplanned on the CT-scan by determining the area in which the bone cement should be injected.
After validation, the robot will automatically execute the ossicular repair. The procedure will be conducted in different temporal bone models with anatomical variations. Temporal bones will undergo a post procedure CT-scan and the quality of the repair will be evaluated by comparing the final result to the preplanning.

Expected results: The preplanned repair zone should be injected with a 5% precision margin. In case of technical difficulties, the scenario can be simplified. In case of success, more complex scenarios such as a stapedial repair can be attempted.

Expected profile: Initial training at Bac+5 in computer science or robotics, with prior knowledge in computer vision.
Taste for programming (especially in python) and experimentation.
Good level of written and spoken English and French.
Creativity, imagination and curiosity, interest in the world of academic research.
Reliability.

Application: Send CV + cover letter to Carlos-Manuel.Mateo-Agullo@u-bourgogne.fr ; Renato.martins@u-bourgogne.fr; alain.lalande@u-bourgogne.fr and alexis.bozorggrayeli@chu-dijon.fr

References:

[Azizian2014] Azizian, Mahdi, et al. "Visual servoing in medical robotics: a survey. Part I: endoscopic and direct vision imaging–techniques and applications." The international journal of medical robotics and computer assisted surgery 10.3 (2014): 263-274.

[Chaumette2016] Chaumette, François, Seth Hutchinson, and Peter Corke. "Visual servoing." *Springer handbook of robotics* (2016): 841-866.

[Collins2020] Collins, Toby, et al. "Augmented reality guided laparoscopic surgery of the uterus." *IEEE Transactions on Medical Imaging* 40.1 (2020): 371-380.

[Houtte2022] Van Houtte, Jeroen, et al. "Deep learning-based 2D/3D registration of an atlas to biplanar X-ray images." *International Journal of Computer Assisted Radiology and Surgery* 17.7 (2022): 1333-1342.