Robotic Orthognathic Surgery: Proof of concept preliminary study

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Introduction

Robotic surgery was first introduced to the medical field in 1985, whereas the first preclinical test in the Oral and Maxillofacial surgery (OMFS) field was performed in 1994 and the first approved robotic system in OMFS was in 1999. [1]

In the literature, robotics has been studied and utilized in several domains in the field of OMFS, including TMJ surgery, tumor resection, dental implantology, cleft lip and palate repair, microvascular and nerve repair procedures, and trauma. [2] To date, most robotic surgery has utilized surgeon-controlled machines that allow for minimally invasive surgery rather than a robot moving autonomously.

Objective/Methodology

This is a proof-of-concept trial to test the application of the technology for orthognathic surgery in 3D printed models. We are testing a robotic device that allows for the automatic position in space, of bone fragments or segments.

By utilizing commercially available robots and specialized software developed by the Surgical Performance Enhancement and Robotics Centre at McGill University Health Center, we have trialed the use of the robots, which can be tracked in real time, performing the pre-planned movements for a mandibular osteotomy, specifically to reposition the mandibular condyles.

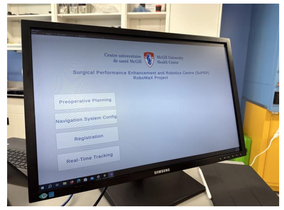
3D models of the mandible and maxilla were printed from a real CBCT case; the preoperative occlusion position was scanned, then a mandibular osteotomy was performed to place the occlusion by utilizing a final splint according to the pre-plan. The maxillo-mandibular complex and distal segment were fixated. Postop position were scanned for robotic execution.

Results

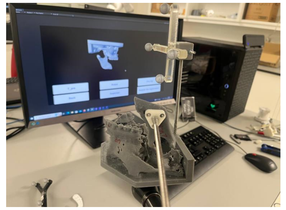
An innovative robotic platform is created, which constitutes an integration of hardware and software designed to execute the pre-operative plan. On the software front, 3D models of the mandible and maxilla are extracted and imported into a virtual planning environment, in which the algorithm facilitates the determination of geometric transformations of the 3D models, subsequently translating them into robotic commands to execute the surgical plan. Prior to executing robotic commands, a registration process is necessary to match the 3D models in the software with the actual mandible or maxilla. This registration process employs an optical tracker to identify corresponding landmarks on the bone structure. Upon completion of registration, the software can transmit commands to the robotic arm for manipulation of the attached segments. Notably, the NDI VEGA XT optical tracker and the KINOVA 7-DOF robotic arm are utilized in this research endeavor. Furthermore, the user interface and pre-operative virtual environment are developed utilizing the UNITY 3D engine

This pilot study demonstrates that the robot can move the fragments to the planned position and shows promise for future development.

Images



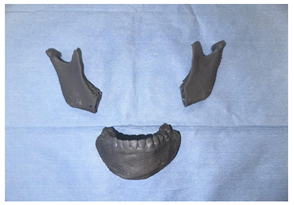
Software interface



Real time tracking

Robotic-Tracker set up

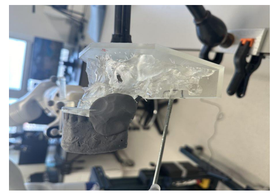
Maxillary model



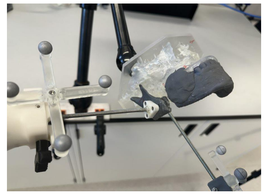
Mandibular models post Bilateral osteotomy

Proximal segment with robotic arm attachment

Robotic Execution



Maxillomandibular fixation



Robotic-proximal segment

Proximal segment positioning

Osteotomy fixation

Conclusions

Robotic automatic positioning of the bony segments during orthognathic surgery model can be achieved according the pre-plan position. We believe this will have applications not only in orthognathic surgery but in trauma field as well. The technology will also be applicable to other surgical specialties.

Future Directions

The next stage of development is to verify the accuracy of the robotic positioning.

References

[1] De Ceulaer J, De Clercq C, Swennen GR. Robotic surgery in oral and maxillofacial, craniofacial and head and neck surgery: a systematic review of the literature. Int J Oral Maxillofac Surg. 2012 Nov;41(11):1311-24. doi: 10.1016/j.ijom.2012.05.035. Epub 2012 Aug 19. PMID: 22910368.
[2] Liu HH, Li LJ, Shi B, Xu CW, Luo E. Robotic surgical systems in maxillofacial surgery: a review. Int J Oral Sci. 2017 Jun;9(2):63-73. doi: 10.1038/ijos.2017.24. PMID: 28660906; PMCID: PMC5518975.

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