A NOVEL TESTBENCH TO MEASURE SURGICAL INSTRUMENTS LOADS VIA MOTION CAPTURE AND ROBOTIC ARM INTEGRATION

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Introduction

Nowadays, robots are commonly used in clinical practice [1]. However, the potential of robots in assessing the usability of surgical instruments remains an underexplored area [2]. This issue has gained fundamental importance since the entry into force of the new Medical Devices Regulation (MDR). In this framework, exploiting motion capture to record surgeon's maneuver and replicate it through a sensorized robotic arm could be a viable tool to assess the interplaying loads during surgical instruments handling. The aim of this study is to develop a testbench to mimic and analyse a surgical mock maneuver and evaluate its feasibility recurring to a pilot application.

Methods

A movement of a sling introducer, mimicking a trans-obturator tape (TOT) surgery for treating urinary incontinence, was performed on a commercial suture pad (Skillssist DIY) and captured through a 12-camera motion capture system (Figure 1A).

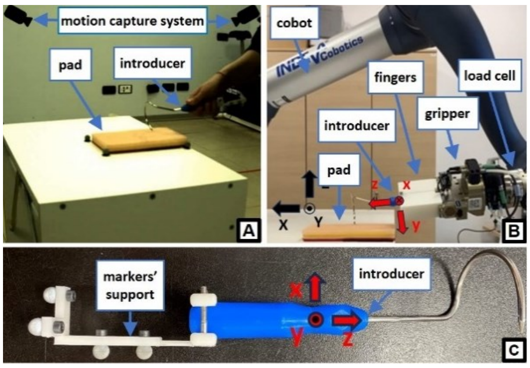

Fig. 1: (A) motion capture of a TOT sling introducer; (B) trajectory reproduction and measure of forces with a robotic arm; (C) 3D-printed support for attaching markers to the introducer.

The movement was measured using 4 reflective markers attached to the introducer's handle through a custom 3D-printed support (Figure 1C). The coordinates of the 4 markers were used to define a local reference system oriented consistently with the introducer and record the displacement of its center of mass. The pose coordinates were then imposed to the end-effector of a robotic arm (6-DOF Doosan H2515 cobot, Figure 1B). The introducer was mounted on the robot's end-effector through a pneumatic gripper (Schunk srl) with custom 3D-printed fingers (Figure 1B). The forces applied on the introducer during the movement reproduction were measured by the 6-axis force-torque sensor in Figure 1B (Schunk srl FT-axia 80, resolution = 0.01 N / 5 N·mm).

Results

The comparison between the displacement (Figure 2A) and orientation (Figure 2B) of the introducer captured by the motion tracking system and the one reproduced with the robotic arm suggests optimal agreement between the pairs of curves (residual lower than 15% of the ROM and 10% of the ROM, in 95% of the samples).

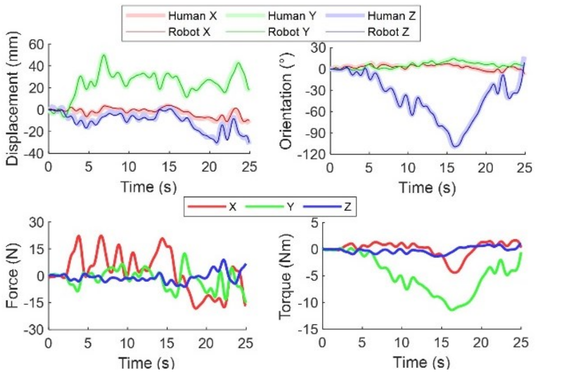

Fig. 2: Introducer displacement (A), with respect to the initial stance in the global reference frame, and orientation (C), represented as ZYX Euler angles in the local reference frame. Force (C) and torque (D) applied on the introducer, in the local reference frame.

Force (Figure 2C) and torque (Figure 2D) measured by the load cell, along the 3 local directions of the introducer frame, are also reported and can be extracted during key phases of a surgical maneuver, thanks to synchronization between kinematics and kinetics.

Discussion

This pilot study presents a novel testbench for assessing medical device usability. It allows to accurately mimic a surgical maneuver, enabling synchronized 6-axis force measure. This approach is promising for enhancing device usability evaluation and compliance with regulatory standards, by assessing the interplaying loads on surgical instruments in a controlled environment.

References

1. Morgan et al., *Current Robotics Reports,* 2022, 3 (4), 271 280.
2. Kyrarini et al, *Technol.,* 2021, 9(1): 8.

Acknowledgements

This publication is part of the project PNRR-NGEU which has received funding from the MUR – DM 351/2022.