A new device for motion tracking and forces measurement in minimally invasive surgery

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Aims: The goal of this study is to develop a new device for measuring forces and motion of surgical instruments for the simulation of minimally invasive surgery.
The training of orthopaedic surgeons in minimally invasive surgery outside the operating room is limited by the lack of portability and prohibitive cost of high-fidelity simulators. Currently, there is an increasing demand for technological tools for the training of psychomotor skills [1].

Materials and Methods: We have developed a portable, high-fidelity and low-cost knee arthroscopic virtual simulator with the measurement of forces with three DOFs and the tracking with four DOFs for surgical instruments, Fig 1.

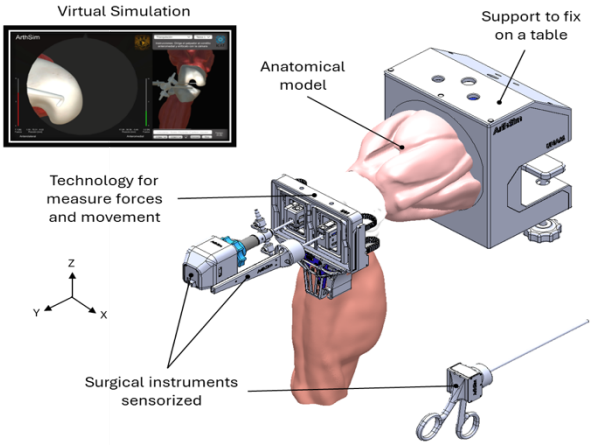

Fig. 1 Device for simulation of arthroscopy surgery, with measurement of movement and forces.

The anatomical model and mechanical components were made with 3D printing technology.
Magnetic and inertial sensors were used to measure the movement of the surgical instruments and the anatomical model. A mechanism with load cells was implemented to measure the forces directly in the instruments.
To validate this new technology, we developed a calibration procedure, Fig 2. For the movement, the tip of the instrument was fixed to the actuator of the CNC. For the forces, the tip of the instruments was fixed to dynamometers, and the instrument was fixed to the actuator of the CNC. The measurements of the CNC and dynamometers were used as reference to comparison with our system.
A group of 8 arthroscopic surgeons from the "Instituto Nacional de Rehabilitación", in Mexico, used the device and provided feedback to improve our system.

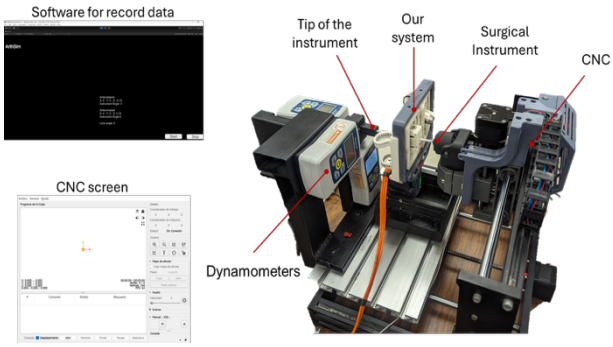

Fig 2. Set up for the calibration of forces and motion of surgical instruments.

Results: The system can measure the movements and forces of surgical instruments. In motion measurement we calculate a resolution of 0.01mm, a precision of 0.14mm and an accuracy of 0.43mm. For force measurement we obtained a resolution of 0.01N, precision of 0.02N and accuracy of 0.09N. The arthroscopy surgeons concluded that the device is suitable for surgical skills training.

Conclusions: This study presented a new device to measure the movements and forces of surgical instruments, showing technical validation. Based on the feedback of arthroscopic surgeons, our system is characterized by its high fidelity, compact design and low-cost. Future work includes the clinical validation of the simulator.

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References:

[1] Lakhani S, Selim O and Saeed M. "Arthroscopic Simulation: The Future of Surgical Training: A Systematic Review". JBJS, (2021).