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Virtual reality training system for portal selection in shoulder arthroscopy

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Abstract

In arthroscopy, the first step is to choose the correct position and orientation of the entry points (portals) by palpating the osseous references. We have built a virtual reality training system for placement of the incisions, with which the novice can touch and feel surface anatomy in order to train, as much as desire, adequate location and orientation angle for portal performance. We present an innovative simulator for Minimal Invasive Surgery that pretends to solve the lack of most simulators, in which simulation starts with predefined entry points, making possible to train this particular skill, so critical in arthroscopic procedures.

1. Introduction

Shoulder arthroscopy is performed through very small incisions (called portals) in which the arthroscope with the camera and the surgical instruments are introduced. Its main advantages over open surgery are less trauma and scarring, reducing postoperative care. However, these procedures are very difficult to master, and they require the surgeon a high degree of expertise and dexterity.

The first problem that arises in all surgical techniques, arthroscopy included, is the access via. An incorrect approach can lead to unsuccessful surgical results. In articular surgery (arthroscopy), it is very important to locate the entry incisions (portals) in the adequate place to be able to reach all the structures. Bad portal placement makes more complicated and sometimes even impossible the intervention. For portal placement, we count with anatomical references (called surface anatomy), that are usually osseous relieves, easily identifiable by palpation.

2. Physical and virtual models

A physical model was constructed to provide haptic rendering. We placed a volunteer in the same start position of arthroscopic surgery [JT01] [Gar04] and we took a mould; while we used bones from Sawbones ® [Saw] for the clavicle, acromion, the spine of scapula and coracoid. The final model was made with silicone and had in its interior the osseus structures made of polyurethane foam. In this way, the surgeon can find anatomical references by palpating the model, thanks to the higher hardness and consistency of the polyurethane, and then locate the portals. The model can simulate both lateral decubitus and beach chair positions. We built a physical simulated retractile arthroscope that incorporates in its interior a 6 DOF tracking system (Flock Of Birds ® [FOB]) to follow its position and orientation. When the apprentice presses the arthroscope against the model, the telescopic stick shortens so that the arthroscope remains near the skin as in a real situation, and the portal is selected.

To build the virtual model, we used the Minolta VIVID 700 ® scanner [Min] to scan our physical model and we simplified the high resolution model extracted from the 3d scan to obtain a lighter mesh with a correct topology.

3. System architecture

The user touches the palpable physical model, and interacts by maneuvering the arthroscope with respect to this model. Once the trainee wants to select the entry point, he or she just presses the arthroscope against the physical model so that the retractile sticks moves back inside the physical arthroscope, while at the same time, in the virtual model, it is possible to observe the virtual arthroscope penetrating the shoulder. Arthroscope's position and orientation are tracked and sent to the simulation module to update the virtual world.

In order to facilitate novice's orientation, this simulator module provides two graphical renders, corresponding to two possible views. One of them, corresponds to what the user would see when looking directly to the physical model (see upper right side on figure 1), showing arthroscope's location and its orientation regarding shoulder's position. The other view simulates that of real arthroscope's vision when introduced through the entry point (see bottom right side on figure 1).

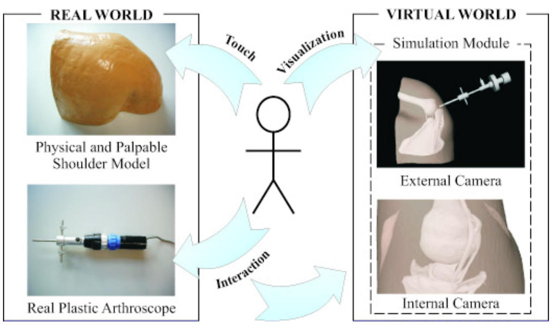

Figure 1: *System architecture. The user interacts with both the real and virtual worlds.*

Our virtual reality system pretends to fulfil all the necessary steps for portal placement. First of all, the apprentice will be able to touch with the hands the physical shoulder constructed specifically for this simulator. The apprentice palpates it to feel the surface anatomy, that is, the osseous structures. This will give him or her the necessary references to be able to decide the portal placement. Once the position is known, the arthroscope must be taken to that point, in the correct orientation to access to glenohumeral joint or to subacromial space. Meanwhile, during the whole process, arthroscope's position and orientation are tracked. When the tip of the artroscope touches the physical model, the system records the portal position and orientation and shows the internal structures that would be seen if a real arthroscope had been inserted through that portal. A portal successfully placed will facilitate a correct vision of the anatomical structures. In this way, the novice can essay and practise the whole portal selection and insertion, within a non-degradable environment.

4. Results

It has been developed a Portal Training System through a physical shoulder model and a simulated arthroscope with an incorporated tracker. Many aspects have been studied and successfully solved in our system:

- Inclusion of the arthroscopic bevel angle. Instead of being oriented to its longitudinal axis, the arthroscopic camera is turned 30 degrees in order to achieve a broader field vision.
- The possibility of visualising the image through two cameras has been added. An external one, which is a panoramic visual orientation help, and an internal one, which simulates the view provided by the camera placed at the tip of the arthroscope (see figure 1).
- Furthermore, our system is adaptable to simulate whether lateral decubitus or beach chair positions.
- A physical shoulder with which we can interact has been developed. The achieved models do not deteriorate themselves with the use, they are easy to construct, and it would not take much effort to extend the simulator to muscled, thinner or wider shoulders.

5. Conclusions and future work

A strengthened knowledge of the portals' location is decisive at the moment of achieving a successful intervention [BF05]. The developed virtual reality training system is a useful tool to touch and feel the shoulder anatomies, deciding where to place the different entry points and the correct position and angle of insertion. It is possible to see which internal vision of the shoulder joint would provide the arthroscope inserted into the selected portal, and so, to check the accuracy of its placement and orientation. It can be used to complete traditional training methods, adding a new functionality to current existing simulators, in which, most of times, the apprentice uses a portal already predetermined.

An important point to keep in mind in a future is the possibility to incorporate our portal simulator to a chain of existing simulators, specialized in different tasks. In that way, the trainee could practise the whole didactic sequence in the learning process of arthroscopy surgery technique.

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