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Original Article

Technical description of a low-cost ankle arthroscopy simulator

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Abstract

Objective: To describe a low-cost, accessible, reproducible ankle arthroscopy simulator model which, after validation, will allow the development and improvement of technical skills required in arthroscopic surgical practice.

Methods: This study describes the production of an ankle arthroscopy model that simulates camera, arthroscope, and ankle joint.

Results: The simulator works properly when connected to a monitor, television, computer, or cell phone.

Conclusion: A reproducible, accessible, low-cost ankle arthroscopy simulator can be developed using components available from local and online stores, with an approximate cost of R$232.00.

Level Evidence V; Economic and Decision Analyses – Development of an Economic or Decision Model; Expert Opinion.

Keywords: Arthroscopy; Simulation training; Low cost technology.

Introduction

Technological advances have allowed the development and growth of minimally invasive surgical techniques[1]. This type of surgical approach has become increasingly common in recent years and offers some important advantages, such as reduced trauma to patients and lower costs[2]. Within this context, ankle arthroscopy has become popular with expanded surgical indications. In contrast, the procedure is technically complex, requiring a high degree of dexterity, coordination, triangulation, and knowledge of ankle anatomy[3].

The learning curve of the arthroscopic technique may require extended training, making teaching methods the target of constant improvements. In a traditional surgical training method, students first acquire theoretical knowledge, then observe more experienced surgeons performing operations, and finally start to perform more complex procedures under supervision[4]. This traditional method has some disadvantages, including inefficiency in terms of time and cost, and is associated with iatrogenic injuries[5]. To minimize these disadvantages, arthroscopic training models have become increasingly available. In addition to allowing increased practice with consequent improvement of the technique, they have proved to be an inexpensive and highly effective tool[2].

Some arthroscopic training modalities can be used together with traditional training methods. Options include cadaver, animal, virtual reality, and dry models. Cadaver models, despite being the most reliable option, pose problems related to cost, availability, and storage, as well as the potential biological risk[6]. Animal experiments present difficulties in logistics, such as handling and disposal, in addition to ethical and bureaucratic issues. Virtual reality models simulate very well the three-dimensional environment of arthroscopy, but its main limiting factor is high cost. Thus, the use of dry models emerges as an alternative method characterized by easy production, good availability, and low cost; additionally, quality of training using dry models is comparable to that of training using cadavers[7].

Training with arthroscopic simulators in orthopedic residency programs significantly improves the residents' surgical skills, contributing to a better in vivo performance in the operating room[8,9]. In 2013, the American Board of Orthopaedic Surgery (ABOS) demanded the implementation of skills training programs outside the operating room. The reality in Brazil, with recurrent budget cuts in education and research, leads to a search for affordable, reproducible, low-cost alternative tools to improve orthopedic resident training.

Study performed at the Hospital de Clínicas da Universidade Federal do Paraná, Curitiba, PR, Brazil.

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Given this situation, our study aimed to describe a low-cost, accessible, reproducible ankle arthroscopy simulator model, which, after validation, will allow the development and improvement of technical skills required in arthroscopic surgical practice.

METHODS

Camera and optics

The arthroscope simulator consisted of an NKJ-2M endoscopic camera manufactured by B-MAX, used for cell phones and computers. We chose this camera model because of its availability, dimensions, and malleability similar to that of an actual arthroscope, in addition to its low cost, approximately R$32.00. This allowed us to produce a functional instrument very similar to the usual arthroscope.

The features of the camera include a resolution of 640x480 pixels and 6 built-in white LED lamps with adjustable lighting; it is 7mm thick and is attached to a 2-m USB 2.0 cable, which can be connected to a computer or cell phone. The camera was introduced into a metal tube 8mm in diameter and 21.5cm in length (simulating the body of the arthroscope), and the ends were bonded with acrylic adhesive.

To simulate the arthroscope handle and sheath, the other end of the metal tube was inserted into a set of three 20-mm polyvinyl chloride (PVC) fittings (90° tee, weldable adapter, and 90° elbow). The structures were bonded with polyester resin (Figure 1).

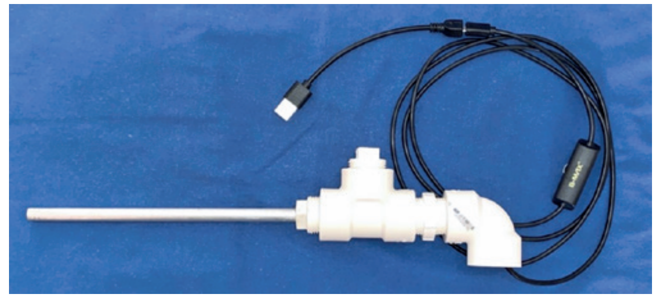

Figure 1. Arthroscope simulator.

Ankle model

The material used to produce the ankle simulator was a PVC tee described as 100mm with a 75-mm view, in which 100mm refers to the diameter of the pipe ends and 75mm to an opening hole on the top. One pipe end was closed with a specific cap (100mm), to which a synthetic left foot model was attached after being cut and fitted so that the articular component of the model (talus) was placed in the center of the pipe. The other end was closed with a wooden support through which a nail was inserted, transfixing the calcaneus, which increased the stability of the model inside the pipe and prevented external light from entering.

The proximal end of the ankle joint (tibia) was fixed to a PVC cap (75mm) with 2 screws and then fitted into a straight PVC pipe 75mm in diameter and 24.5cm in length. This set was connected to the upper hole on the PVC tee.

Two holes 1.8cm in diameter were made in the body of the PVC tee, close to the connection to the upper hole, to simulate the anteromedial and anterolateral portals of ankle arthroscopy. The simulator kit was placed on a wooden support that provided a straight surface for use (Figures 2-4).

Figure 2. Components of the ankle model.

Costs

The total costs of the simulator, including the synthetic ankle model, the endoscopic camera, and other products used to prepare the external and internal structures, were approximately R$232.00, as shown in table 1.

Figure 3. Ankle model – front view.

Figure 4. Ankle model – side view.

Results

The simulator works properly when connected to a monitor, television, computer, or cell phone (Figure 5). The model also allows triangulation (Figure 6).

Discussion

The surgical technique initially developed through large incisions and direct visualization of the anatomical structures. With advances in research and technology, traditional open surgery was found to lead to high morbidity and greater risks to patients; therefore, the concept of minimally invasive surgery was developed and then disseminated worldwide. Within the context of orthopedics, intra-articular injuries were most favored by minimally invasive procedures. With the development of arthroscopy using small incisions and indirect visualization, the surgeon was able to visualize the structures on a screen. The technique requires additional training to obtain visuospatial coordination for interpreting three-dimensional structures on a two-dimensional image[5]. It also requires triangulation, which is the meeting of the arthroscope and instruments within a joint[10].

Table 1. Costs for making an arthroscopy simulator

Item	Cost (R$)
Synthetic ankle model	150.00
Endoscopic camera for cell phone + adapter	32.00
Materials for making the body of the arthroscope, external and internal structure of the simulator (PVC components, metal tube, wood, adhesive, various construction supplies)	50.00

PVC: polyvinyl chloride.

Figure 5. Final simulator kit in use.

Figure 6. Triangulation.

The advantages of arthroscopy include the visualization of anatomical structures in their natural state, reduced loss of synovial fluid, lower morbidity, shorter length of stay, and faster recovery of the patient[2,10]. While the technique offers several advantages, it requires unconventional technical skills and practical abilities that are very different from those of open surgery. Thus, arthroscopy has a longer learning curve.

Historically, the surgical unit has been the place where trainees have acquired and developed their initial surgical skills. Today, this training model faces some difficulties, such as the increasing institutional demand for the procedure to be as fast as possible, the ethical factor related to in vivo training, and the complexity of some cases that require experienced professionals[7]. Surgical simulation is therefore a method to address multiple problems inherent to teaching arthroscopic skills in a traditional setting, as it avoids surgical prolongation and reduces patients' exposure to risks[11].

Training with low-cost arthroscopic models provides technical growth similar to that with high-tech simulators, improving surgical skills and thus the quality of patient care. A randomized study that included a control group showed that arthroscopic training with low-cost cameras and devices has the same effectiveness as training with commercial arthroscopic models, as both significantly improved skills and reduced surgical time[2].

The development of surgical skills is the hallmark of education in orthopedic residency. As previously mentioned, the traditional training method increases surgical time and hospital costs, in addition to exposing the patient to potential risks of adverse outcomes[11]. In a study that included orthopedic residents divided into an arthroscopic training simulator group and a control group, the simulator group was found to have greater intraoperative technical development, with shorter distances traveled by the camera, less time to perform the same task, and fewer moves to achieve the same target[12].

Commercially available ankle arthroscopy simulator models are usually expensive, preventing most orthopedic training institutions in Brazil from purchasing those tools. Moreover, most of them cannot be reused, which is another limiting factor.

Our ankle simulator model is easy to reproduce and inexpensive, does not require frequent synthetic bone replacements, allows for continuous training, and is available for most residency programs. Our simulator also allows triangulation and simulates the inventory of the ankle joint despite suboptimal anatomical replication because of the use of synthetic, noncadaveric models. In the future, simulations of conditions such as anterior ankle impingement and osteochondral injuries may be designed in order to improve the development of surgical skills in ankle arthroscopy.

In addition to ignoring some intra-articular changes in the ankle, our simulator provides limited learning of some surgical steps, such as patient positioning, arthroscopic portals, and intra-articular exposure techniques. Another limitation is that this study is only descriptive and still needs validation in Brazil. Thus, the simulator must be validated as an arthroscopic training tool.

Conclusion

A reproducible, accessible, low-cost ankle arthroscopy simulator can be developed using components available from local and online stores, with an approximate cost of R$232.00. The simulator still requires validation to then be considered a tool that will improve the acquisition of arthroscopic surgical skills.

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