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# Construct Validity and Experience of Using a Low-cost Arthroscopic Shoulder Surgery Simulator

## *Validação de constructo e experiência de uso de um simulador de artroscopia de ombro de baixo custo*

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**Abstract**

**Objective** To validate the low-cost model for arthroscopy training and analyze the acceptance and usefulness of the developed simulator in medical teaching and training.
**Method** Ten medical students, ten third-year orthopedic residents, and ten shoulder surgeons performed predetermined tasks on a shoulder simulator twice. The parameters used were time to complete the tasks, number of looks at the hands, GOALS score (Global Operative Assessment of Laparoscopic Skills) and comparison between groups and within groups. An adapted Likert scale was applied addressing the individuals' impressions about the simulator and its applicability.
**Results** In the intergroup comparison, the shoulder surgeons had better scores and times than the other groups. When the tasks were repeated, the group of surgeons had a 59% improvement in time ($p < 0.05$), as did the group of medical students. In the GOALS score, shoulder surgeons had consistently better scores than the other groups. And when we evaluated the evolution from the first to the second test, the group of surgeons and the group of academics had a statistically significant improvement ($p < 0.05$). In terms of lookdowns, there was a decrease in all groups. There was consensus that the simulator is useful in training.

**Keywords**
- arthroscopy
- simulation training
- shoulder
- training technique

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**Conclusion** The simulator developed allowed the differentiation between individuals with different levels of training in arthroscopic surgery. It was accepted by 100% of the participants as a useful tool in arthroscopic shoulder surgical training.

## Resumo

**Objetivo** Validar o modelo de baixo custo para treinamento em artroscopia e analisar a aceitação e utilidade do simulador desenvolvido no ensino e treinamento médico.

**Método** Dez acadêmicos do curso de medicina, dez residentes do terceiro ano em ortopedia e dez cirurgiões de ombro realizaram tarefas pré determinadas em um simulador de ombro duas vezes. Os parâmetros utilizados foram o tempo para completar as tarefas, quantidade de olhares para as mãos, escore de GOALS (Global Operative Assessment of Laparoscopic Skills) e comparados entre os grupos e intragrupos. Uma escala de Likert adaptada foi aplicada abordando as impressões dos indivíduos acerca do simulador e de sua aplicabilidade.

**Resultados** Na comparação intergrupos, os cirurgiões de ombro tiveram melhores escores e tempos que os demais grupos. Quando as tarefas foram repetidas, o grupo de cirurgiões, teve uma melhora de 59% no tempo ($p < 0,05$), assim como no grupo de acadêmicos. No escore de GOALS os cirurgiões de ombro apresentaram escores consistentemente melhores que os demais grupos. E quando avaliamos a evolução do primeiro para o segundo teste, o grupo de cirurgiões e o grupo de acadêmicos tiveram melhora estatisticamente significante ($p < 0,05$). No quesito de lookdowns houve diminuição em todos os grupos. Houve consenso em que o simulador é útil no treinamento.

**Conclusão** O simulador desenvolvido permitiu a diferenciação entre indivíduos com diferentes níveis de treinamento em cirurgia artroscópica. Foi aceito por 100% dos participantes como uma ferramenta útil no treinamento cirúrgico artroscópico do ombro.

**Palavras-chave**
- ► artroscopia
- ► treinamento por simulação
- ► ombro
- ► técnica de treinamento

## Introduction

Teaching residents in the operating room is didactic, but it can increase the cost, morbidity and mortality of patients.[1–5] Scott e Dunnington[6] in a review of the surgical curriculum in the US, recommended in their article "Move the Learning Curve out of the Operating Room", that surgical training should become more efficient by relying on simulations, learning feedback and objective ways of assessing skill gains.

Developing arthroscopic skills can be particularly difficult for some surgeons.[7] The simulator provides unlimited opportunities for training, but with a cost that can exceed 80 thousand dollars, making it unfeasible for several educational institutions.[4,8]

Dry models can be easy to build, inexpensive, and arouse interest in trainees and demonstrate similar efficiency to virtual reality,[8–13] the model studied here was developed with this format and concept of using low-cost materials. The step-by-step material and assembly of the model has already been published,[14] and the present study proposes the validation of this model (►**Fig. 1**).

## Material and Method

Cross-sectional experimental study approved by the Research Ethics Committee of the Hospital do Trabalhador/ SESA/PR with number 1,994,655.

The project consists of validating the shoulder arthroscopy model using the construct methodology, comparing groups with different levels of training (surgeons, residents and medical students). The validation construct method is focused on verifying whether the model demonstrates the difference in dexterity and speed in performing different standardized activities, and evaluating whether there is an improvement in scores and speed with the repetition of the proposed exercises.

In this study, a total of 30 individuals divided into the following groups were used: Ten sixth-year medical students at the Federal University of Paraná (drawn by registration number and invited to participate). Ten third-year orthopedic residents and ten shoulder surgeons from the Hospital de Clínicas / Hospital do Trabalhador (not randomized as they were the total universe)

All invited individuals signed the Free, Prior and Informed Consent and, regardless of the degree of training, were instructed in the operation of the model with a video of about three minutes.

All tests were filmed and analyzed by the authors.

The arthroscope was inserted through a classic viewing port, and a standard port through the pre-made rotator interval and a probe was placed. The individual was instructed to touch points marked on the joint with numbers sequentially.

The second activity was to use the probe to engage in the hole of the elastic mounted there and pull until the line

 

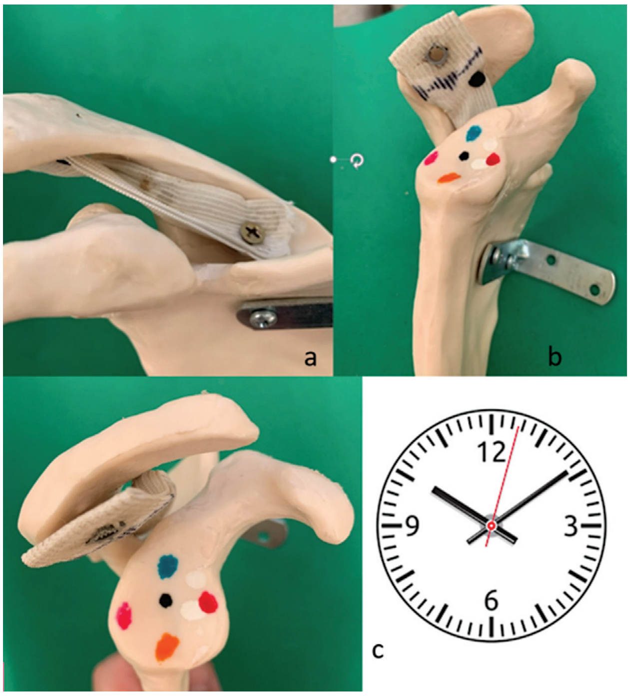


**Fig. 1** (**a**) Fixation of the rotator cuff simulation tape, (**b**) Demonstration of the positions of the structures, (**c**) Positioning of the glenoid reference points. Source: Author (2021).

drawn on the elastic coincides with the edge of the acromion of the model (►**Fig. 2**).

The procedure was reproduced twice by each individual, with 600 seconds (10 minutes) being the time limit to complete each test. After completion, all participants were asked to complete a Likert questionnaire.

The analyzed criteria were time to complete the tasks, count of the number of times of looks down, comparison of the GOALS score. All parameters were evaluated in both tests, both inter and intra groups. Time measurements were performed in seconds, and the parameters according to the GOALS score were developed with questions that assign grades 1, 3 and 5 for each performance item, with five being the maximum score and one the minimum.[15,16]

## GOALS score adaptation

### Item 1 - Depth perception

1. Constantly misses target, moves too wide, takes time to correct
3. A little exaggerated movement or loss of target, quick to correct
5. Positions instruments in the correct plane to hit the target

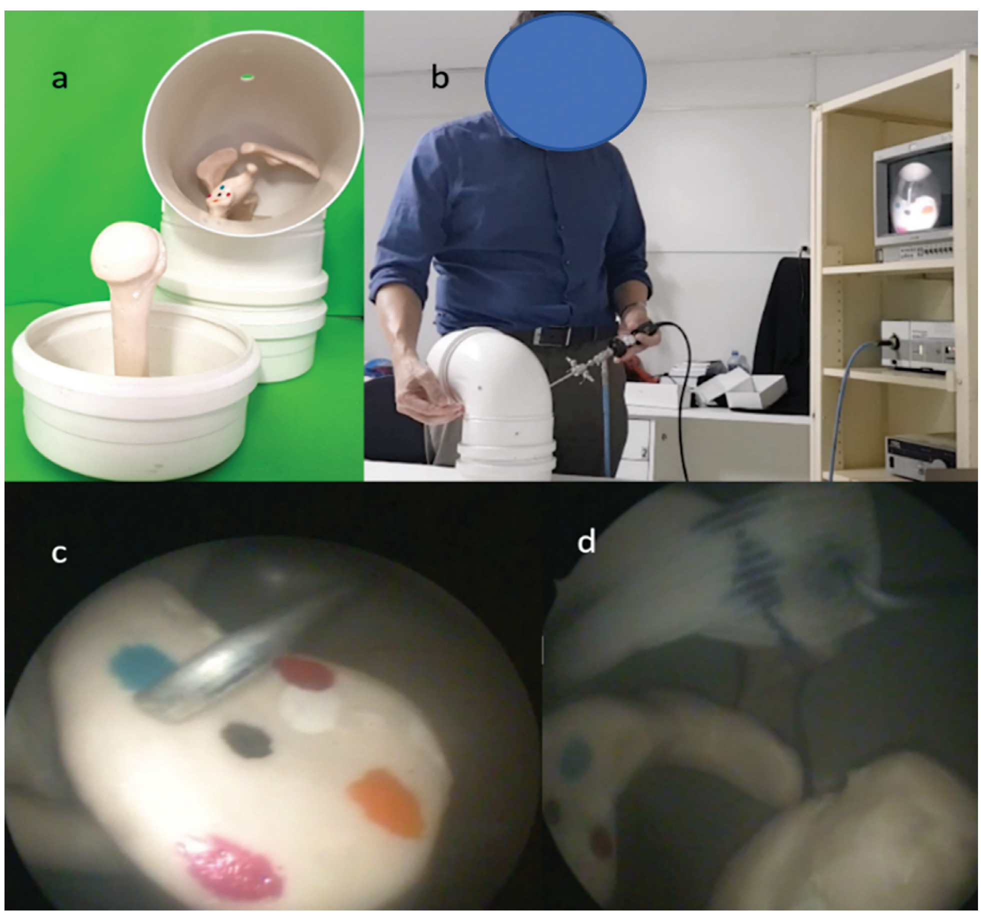


**Fig. 2** Demonstration of model use (**a**) Ready-made shoulder arthroscopy training model; (**b**) model in use with arthroscope; (**c**) triangulation exercise with probe in lateral decubitus; (**d**) tissue manipulation exercise by elastic traction (supraspinal) in a beach chair. Source: Author (2021).

 

We use triangulation time. Up to nine seconds five points, from ten to twenty seconds three points and over twenty seconds one point.

**Item 2 - Bimanual dexterity**

1. Uses only one hand, ignores non-dominant hand, poor coordination between hands
3. Uses both hands, but does not optimize interaction between them
5. Uses both hands in a complementary way, in order to optimize the activity

We used the time delay to introduce the probe into the hole. Up to nine seconds five points, from ten to twenty seconds three points and more than twenty seconds one point.

**Item 3 - Efficiency**

1. Inefficient efforts: too many movement attempts; constantly shifting focus or persisting with no progress
3. Slow, but planned movements are reasonably organized
5. Confident, efficient and safe; stays focused on the task until it is resolved

We used the number of attempts until the probe was properly positioned in the hole to pull the elastic. One attempt equals 5 points, two to five attempts three points, more than five attempts one point.

**Item 4 - Tissue manipulation**

1. Rough movements, tears tissue, damages adjacent tissue, poor grasper control, grasper often releases tissue
3. Handles tissue reasonably, little trauma to adjacent tissues
5. Manipulates tissues well, applies appropriate traction, minimal injury to adjacent tissues

We used the time to pull the cuff tape. Up to five seconds five points, from six to ten seconds three points and more than ten seconds one point.

**Item 5 - Autonomy**

1. Unable to complete task, even with verbal guidance
3. Able to complete task with moderate guidance
5. Able to complete the task without guidance

We used the quantity of guidelines. Five points if no orientation, three points if completed with orientations and one point if not completed.

At the end of the tests, the participants were asked to complete a Likert Scale (modified for this study).

All statistical tests were performed using the free R studios® program.

For the comparison between the values of the first and second attempts, the Wilcoxon test was used. In the paired comparison between groups, the Mann-Whitney test was applied, and the Kruskal-Wallis test was used between the three groups.

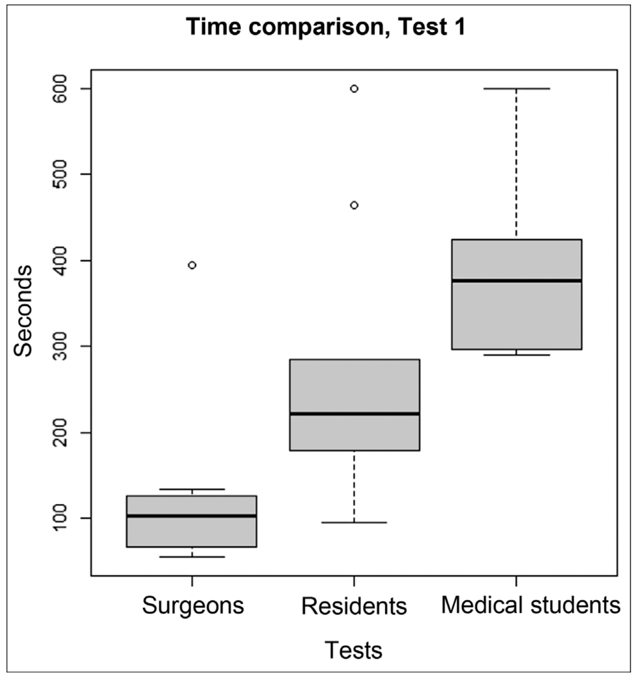


**Fig. 3** Intergroup comparison, time in the first test. Source: The Author (2021).

## Results

Of the group of students, four were male and six were female, with an average age of 23.5 years. Of the residents, nine were male and 1 was female, with an average age of 29.3 years. In surgeons, all were males with a mean age of 36.1 years.

In the intergroup comparison, the average time for the first test, in the group of surgeons, was 102.59 seconds, against 221 seconds in the group of residents and 265 seconds in the group of students, demonstrating a statistical difference. Just like when surgeons and residents, surgeons and students were paired, but not between residents and students. In the second test, there was an average difference of 59 seconds in the group of surgeons, 86 seconds in the group of residents and 146 seconds among students, and again no statistical difference was found only in the comparison between the group of residents and students (►**Figs. 3** e **4**).

In the intragroup comparison, between the first and second tests, the surgeons group showed a statistically significant mean difference of 102.59 seconds to 59 seconds. In the group of residents, the average time decreased from 265.9 to 184.7, but with no statistical difference ($p = 0.08$). In the group of students, the decrease in time was from 376.5 in the first test to 146 in the second test ($p = 0.0039$).

For the comparison between the three groups, a significant difference was observed in the first ($p = 0.00037$) and in the second test ($p = 0.0048$).

The GOALS score in the group of surgeons showed a mean increase from 20.2 to 22.4 from the first to the second test ($p = 0.05$); in the group of residents, it increased from 13.4 to 15.8 ($p = 0.16$); and the group of students from 9.4 to 15.6 ($p = 0.009$).

 

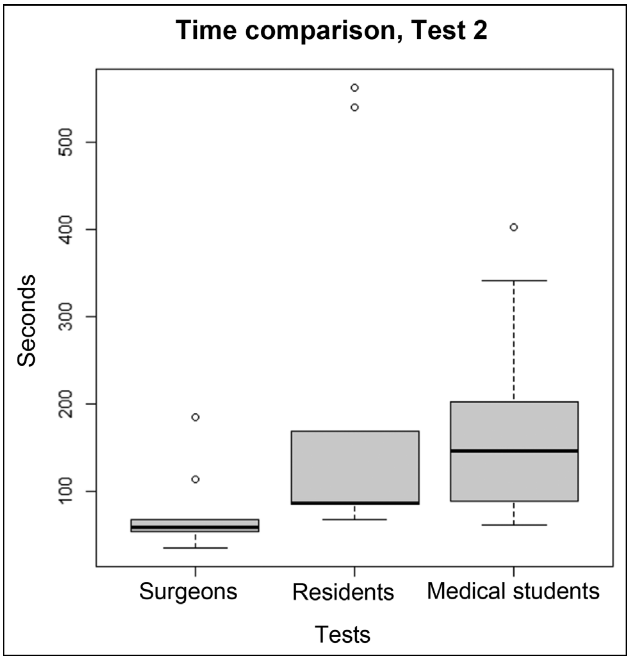


**Fig. 4** Intergroup comparison, time in the second test. Source: The Author (2021).

Comparison of GOALS scores in the first test between surgeons and residents, surgeons and students, and residents and students showed that there was a statistical difference ($p = 0.0035$, $p = 0.0002$, $p = 0.012$, respectively). In the second test, the difference between surgeons and residents and surgeons and students was maintained ($p = 0.011$, $p = 0.0045$). However, no difference was observed between the group of residents and students ($p = 0.73$) (►**Fig. 5**).

The surgeons group showed a mean decrease in the number of lookdowns from 2.6 to 1.2 from the first to the second test, respectively ($p = 0.29$). In the group of residents, we observed an average decrease of 10 lookdowns in the first test to 4.2 in the second test ($p = 0.05$), and in the group of students, from 8.6 to 3.6 when comparing the first and second attempts ($p = 0.009$).

The response to the Likert scale was that the simulator was a useful item both in training surgeons and an item that would be useful and could replace virtual simulators. The simulator just wasn't well accepted as a suitable substitute for training on cadavers (►**Table 1**).

## Discussion

To validate a surgical simulation device, one of the main methods is proficiency differentiation, that is, if the same model is tested by groups of individuals with different learning levels, the performance must be different. In this method, the model must demonstrate difference between groups of different skill levels as well as evolution in skills with the repetition of tasks.[17–23] In our comparison between the three groups, both the first and second tests showed difference in parameters, a distinction that was maintained in the paired comparison of groups, except between residents and students. In another study, an experiment using a laparoscopic model with a cardboard box and top-mounted tablet demonstrated that the group of surgeons was consistently faster than the group of senior and junior residents, results consistent with ours.[24]

When we compared the performance of residents and students in our study, no difference was observed. We noticed, however, that, unlike the group of surgeons, the group of residents showed great variation in the parameters studied, including two outliers with much longer time, a fact that may be related to the fact that training is not uniform in this group.

To determine if the model provides skill improvement, performance should improve with training.[19,22,25–27] In the

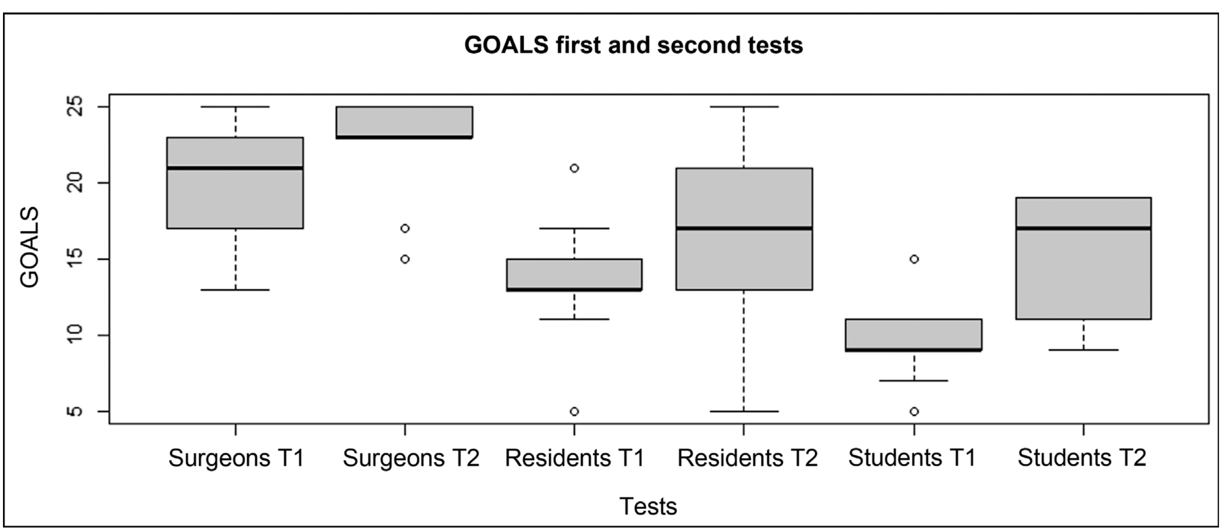


**Fig. 5** GOALS score variation between the first and second tests. Source: The Author (2021).

 

**Table 1** Likert scale

| | Question | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|---|
| | | % | % | % | % | % |
| Surgeons | 1. Is the simulator useful for training beginner surgeons in the area of arthroscopy? | | | | 10 | 90 |
| | 2. Is simulator training a motivating/enjoyable activity? | | | | 20 | 80 |
| | 3. Can the low-cost simulator replace a virtual simulator? | | | 20 | 30 | 50 |
| | 4. Can the implementation of simulator training in the medical residency program improve arthroscopy training? | | | | | 100 |
| | 5. Can the low-cost simulator replace cadaver training? | | 30 | 20 | 40 | 10 |
| Residents | 1. Is the simulator useful for training beginner surgeons in the area of arthroscopy? | | | | | 100 |
| | 2. Is simulator training a motivating/enjoyable activity? | | | 10 | 10 | 80 |
| | 3. Can the low-cost simulator replace a virtual simulator? | | | | 40 | 60 |
| | 4. Can the implementation of simulator training in the medical residency program improve arthroscopy training? | | | | | 100 |
| | 5. Can the low-cost simulator replace cadaver training? | 10 | 20 | 30 | 30 | 10 |
| Medical Students | 1. Is the simulator useful for training beginner surgeons in the area of arthroscopy? | | | | 30 | 70 |
| | 2. Is simulator training a motivating/enjoyable activity? | | | 10 | 30 | 60 |
| | 3. Can the low-cost simulator replace a virtual simulator? | | | 30 | 60 | 10 |
| | 4. Can the implementation of simulator training in the medical residency program improve arthroscopy training? | | | | 20 | 80 |
| | 5. Can the low-cost simulator replace cadaver training? | | 20 | 40 | 30 | 10 |

Source: The Author (2021).

repetition of tasks, the group of surgeons and students had a significant decrease in time. Although the group of residents was able to decrease about 70% of the time, there was no statistical improvement ($p = 0.08$). However, one participant increased the time by four times, we characterized this individual as an outlier and removing this result resulted in no difference. This performance improvement demonstrates that the simulator may have the ability to improve arthroscopic skills.

In a validation study similar to ours, but with a box design, surgeons, residents and students performing procedures six times were evaluated and progress over time was analyzed. Residents and students were, respectively, 56% and 127% slower than surgeons to complete the proposed tasks, and maintained this difference until the last test, corroborating the present study.[22]

When analyzing the evolution of time to perform the tasks, the group of surgeons had an improvement of 44%, residents 39% and students 45% being significant for all groups, findings consistent with ours, but which differed in the group of residents, fact that may have occurred due to the irregular level of training among our residents, as already mentioned.[22]

For a more objective evaluation of the results, it was decided to use the GOALS score, which, despite having been created to evaluate laparoscopic surgeries,[18] had already been used in the evaluation of a shoulder arthroscopy simulator and a training model in flavectomy endoscopic.[15,28] To be as objective as possible, we created a scale of time or number of attempts to perform specific tasks and correlated it with each item of the GOALS score and in the intergroup comparison we observed differences between all groups in the first test. The same results were observed in the second test comparing surgeons and residents, but not when comparing residents and students.

The aforementioned endoscopic flavectomy study, comparing surgeons and students with the GOALS score, showed differences between groups, corroborating the findings of this study.[28] In a knee model, similar to ours and using the ASSET score, students and surgeons were compared and showed statistical difference, again confirming the hypothesis that the construct allows the differentiation between individuals with different levels of experience.[13] For the shoulder, we found a single study that used the GOALS score that evaluated first-year medical students and their evolution with the use of the device, and the authors showed significant improvement, as in our study.[15]

Another objective visual parameter adopted was the number of lookdowns.[29,30] In the group of surgeons, there was only a small difference of 2.6 to 1.2 ($p = 0.29$) in the evolution from the first to the second test, which can be explained by the fact that the subjects were already used to performing arthroscopic surgeries, different from the groups of residents, which showed an average decrease from 10 lookdowns in the first test to 4.2 in the second ($p = 0.05$) and in the group of students, from 8.6 to 3.6 ($p = 0.009$) . When validating a knee simulator, the authors found an average of 47 lookdowns in the group of students, against 16.9 in the group of surgeons, a higher proportion and difference in relation to the present study. As it is a similar proposal, the discrepancy in the observations can be explained by the fact that there is only one test per individual, with no chance of learning in the group of students and the more complex procedure of meniscectomy, which may justify the greater number of looks from surgeons.[30]

A fundamental point for a simulator to work well is the level of acceptance by those who will use it.[31] We used the Likert scale, and the participants were unanimous in stating that the simulator is useful in training surgeons and also that it was a pleasant activity. Similar results were obtained in the study of flavectomy and in the model of .[28,30] Evaluating the simulator box for arthroscopy, the authors observed that 90% of the inexperienced participants agreed. However, in the group, only 58% of the individuals found it valid. The model used by these authors was not an anatomical one, but a box with holes, and the tasks were not correlated with surgeries. Thus, despite improving hand-eye coordination for activities without direct vision, it probably did not convey the feeling of being with a real patient.[21]

The item with the greatest disagreement was whether the simulator could replace cadaver training, with 30% of disagreement between surgeons and residents, while 20% of students disagreed, corresponding to the findings of other authors.[28,30] The cadaver remains the gold standard for simulation, providing identical anatomy, similar tactile sensation, limited only by the lack of bleeding and active muscle contraction.

We agree with McDougal[19] who says that surgical simulation will not replace the need for usual curricular learning, with tutors and practical experience, but that it should allow obtaining basic skills, leaving interaction with patients to improve these skills.

The present study has limitations, the number of trained surgeons and residents was limited by the number of individuals available at the institution. Validity was not compared with another type of simulator already established, and we did not assess whether the acquired skills can be transposed into a real surgical situation. The simulator is designed as similar to a shoulder as possible, however, the lack of soft tissue and bleeding makes it less reliable. In the future, three-dimensional printing using materials with different textures may be used to better reproduce a real surgical environment.

## Conclusions

This study concluded that the simulator developed allowed the differentiation between individuals with different levels of training in arthroscopic surgery. It allowed participants to improve their individual skills as they repeated the proposed tasks. All participants considered the simulator a useful tool in arthroscopic shoulder surgery training.

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**Conflict of interests**

The authors declare no conflict of interest.

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