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ORIGINAL ARTICLE

Tendon repair simulation: a comparison of training models

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Abstract

Introduction: Surgical training has undergone many changes in the last few decades from the apprenticeship model of the past and a focus currently on shift patterns and working time directives. These have placed greater stresses on the current surgical trainees to obtain training opportunities, thus increasing the role for simulation activities and models. There is a need for reproducible, low cost and realistic training models for all surgical subspecialties. These allow the training exercise to be undertaken at any time, with supervision, and in a safe environment without compromise to patient care. As a training model for tendon repair, we created a simulated tendon that we believe is an excellent alternative to cadaveric, porcine or other materials such as liquorice. **Methods:** Experienced trainees and consultants with exposure and experience in performing human tendon repair were asked to perform a simulated repair on each of three models: silicone bathroom sealant, porcine tendon and liquorice. Each model tendon was secured to a wooden board and cut at its midpoint. The models were 5 mm in diameter and between 5 and 10 cm long. Participants performed a modified Kessler repair using standard surgical instruments and a 3-0 monofilament suture, and rated each model using a five-point Likert scale to assess suture gliding, likeness to human tendon, tendon handling and usefulness for training. **Results:** The porcine tendon was considered the most realistic (90.5%); however, the silicone model was a close second (86.5%). Silicone compared well for handling (4.4/5) and was considered superior to liquorice on all points. **Conclusion:** Silicone sealant as a model tendon is cheap, reproducible and a satisfactory alternative to other models of tendon simulation repair, and can be used to provide training opportunities.

Keywords: *tendon repair simulator; simulation; surgical education; silicone model; liquorice model*

Introduction

Changes to the surgeon's working pattern and the European Working Time Directive have greatly reduced the opportunities for surgical training in the operating theatre.[1] The traditional apprenticeship model of surgical training was case and opportunity dependent, but time in training was long enough to ensure that trainees were exposed to a greater quantity and variety of cases.[2] The European Working Time Directive in combination with a shorter training period has changed the dynamic and trainer–trainee relationship in surgery.

For these reasons, interest in simulator-based surgical training has developed.[1–3] Simulator-based training has many positive benefits. Trainees can practice a procedure multiple times in a safe environment. Skills can be assessed away from the stressful operating theatre environment.[4]

In the last decade, there has been an increase in the literature describing various physical, virtual reality and cadaveric simulator models. Relatively few of these simulators have been assimilated into the surgical training curriculum.[5] Many of these models are expensive to produce, difficult to replicate, and animal/cadaveric models may carry a risk of zoonotic disease transmission or hepatitis.

Simulator models are described in the literature according to their fidelity. Fidelity can be defined as how exact the simulator is in comparison with the real operation or procedure. Models can be divided into low-fidelity simulator models such as box trainers (laparoscopic simulators used to develop hand–eye coordination or laparoscopic instrument handling) and high-fidelity models such as virtual reality models and robotic trainers.[2]

This study was presented at the Association of Surgeons in Training Conference, Glasgow, 2015.[6]

Tendon repair is a generic basic surgical skill undertaken by orthopaedic and plastic surgeons. In the UK, it is covered in the Royal College of Surgeons basic surgical skills course and other surgical courses. Traditionally, porcine tendons have been used as simulator models but there are disadvantages, including perishability, theoretical risk of zoonotic infection transmission, animal welfare and religious objections, and the time and effort required to procure and prepare them for use.

Non-animal tendon repair simulation models have been described in the literature such as soft liquorice sticks and rubber bait worms for fishing.[7–11] A silicone tendon model appeared the most appealing, but the method described for preparation is complicated.[12]

We discovered that preparing model tendons from silicone bathroom sealant is less complicated than previously described and postulated that its qualities as a simulation model may compare favourably with other models. Silicone sealant is readily available, low in cost and silicone "tendons" may be formed into any shape or size. Flat "extensor tendons" can be made by running the sealant between two pieces of plastic and squashing them flat before the sealant has cured. Cylindrical "flexor tendons" can be made with varying diameters depending on how the nozzle on the sealant tube is cut.

In this study, we asked individuals experienced in human tendon repair to compare our new silicone sealant tendon model with porcine tendon and liquorice sticks. Handling properties, similarity to human tendon, suture gliding and validity as a training model were compared.

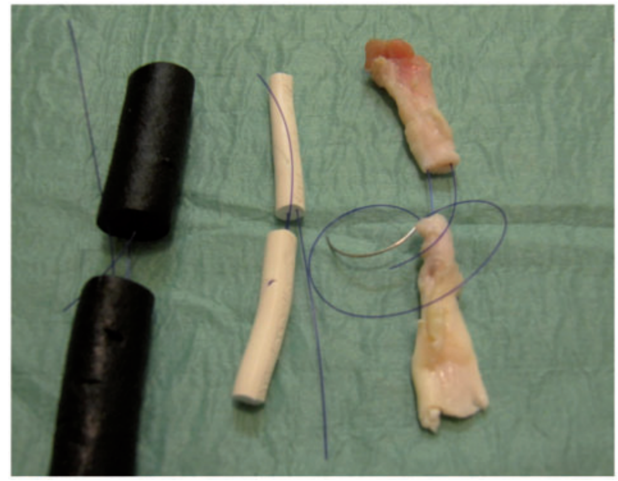

Figure 1. Tendon simulator models. Left to right: liquorice, sealant, porcine.

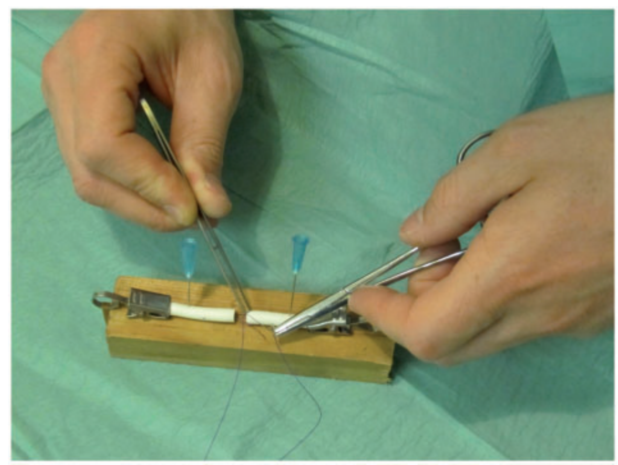

Figure 2. Set-up for the silicone sealant tendon repair model.

Materials and methods

Three tendon simulation models were assessed and compared: silicone sealant, porcine flexor tendons and liquorice sticks. Porcine tendon was chosen because it is the traditional simulator model used in surgical training courses. The liquorice model tendon was chosen because it is easily available (Fig. 1).

All models were cut in half and mounted on wooden boards. The ends were secured with clips attached to rubber bands to put mild tension on the tendon ends when performing the repair (Fig. 2). Hypodermic needles were used to secure the tendon onto the boards until the core suture was placed. Then, by removing the needles and tightening the repair, it was possible to see how the suture glided through the material as the repaired ends came together.

The tendon simulator models were prepared as follows. Bathroom silicone sealant was extruded into lengths approximately 10 cm long, with a diameter of 5 mm onto plastic food wrap. It was allowed to cure for 12 h. The sealant "tendon" was then peeled off the cling film ready for use. Porcine flexor tendons were obtained by purchasing fresh pigs' trotters and removing the tendons with a kitchen knife. The porcine tendons were then stored in a freezer to be defrosted as required. Liquorice simulated tendons were 5 cm long liquorice sticks obtained from a local food shop. The diameter of 5 mm matched the diameter of the silicone sealant tendon.

Tendon repair

In a non-clinical environment, seven individuals (five trainees and two consultants) experienced in human tendon repair were asked to perform a modified Kessler core suture repair on each of the tendon models using standard instruments and a 3-0 monofilament suture. The trainees were core surgical trainees and specialist registrars. The modified Kessler repair was chosen because it is usually taught on basic surgical skills courses.[13] Participants were asked to rate each model using a 5-point Likert scale to assess suture gliding, likeness to human tendon, tendon handling and usefulness for training.

Results

Results are displayed as a mean value on a 5-point scale for each property and each tendon (Table 1). A total score out of 20 was also calculated for each tendon and expressed as a percentage of "usefulness".

Porcine tendon scored highest for all properties and scored the overall highest percentage (90.5%). The sealant model tendon was a close second in all categories and scored 86.5% overall. The liquorice model tendon was a distant third in all categories and scored only 37.5% overall.

Table 1. Summary of Likert scale ratings of the seven participants for each model

	Suture gliding	Tendon handling	Likeness to human tendon	Usefulness for training
Pig tendon	5	5	5	5
	5	5	4	5
	5	5	5	5
	4	4	4	5
	4	4	4	4
	4	4	4	5
	4	3	4	4
Average	4.5	4.5	4.33	4.83
Silicone sealant tendon	4	5	4	4
	4	4	3	5
	4	5	4	5
	4	3	4	5
	5	4	4	4
	4	3	3	5
	5	5	5	5
Average	4.286	4.413	3.857	4.714
Liquorice model tendon	2	2	1	1
	3	3	2	2
	3	1	1	1
	1	1	1	1
	3	2	2	2
	4	2	1	2
	3	2	1	2
Average	2.714	1.857	1.286	1.571

Discussion

Individuals familiar with the feel and handling of human tendon tested each model and found the silicone sealant model to be an acceptable and inorganic alternative to porcine tendon, although it was not thought to be superior. Silicone sealant model tendons are cheap to produce, can be made in any size and several can be produced from a single tube. Unlike cadaver and porcine tendon, there is no risk of infection and silicone is non-perishable. One potential downside of silicone is the 12 h period needed for most silicones to cure, although fast "cure in 1 h" sealants are available at a premium price from some retailers. When preparing the tendon simulation stations, it was thought that preparing the silicone tendon models was easier than removing porcine tendons from trotters, which yield only four reasonable flexor tendons per trotter. The liquorice model tendon was shown to be inferior to the other two tendon materials. This was mainly because of the stitch cheese-wiring through the liquorice.

Since 2000, more than 200 studies have been published on the topic of simulator validity. This has gained increased weight as a result of the popularity of development of various simulator models. Two studies in particular explore tendon repair simulators: one on a liquorice model tendon and the other using bait worm.[7,11]

The main limitation of our tendon repair models is that the repair of the tendon itself is only a small part of the operation. Exploring the wound, dissecting the tissues, preserving the vessels and nerves as well as wound closure and haemostasis are important parts of the procedure that are not conveyed in any simulator model to date. The reliability with which the repair technique can be transferred to the operating theatre from a simulator model is another parameter that requires further study. Another limitation to this study is the relatively small sample size. In addition, the simulation exercises may not have been long enough to adequately assess differences in perceived benefit to training, and trainees testing the models had varying degrees of experience in human tendon repairs.

Future directions for this kind of simulator model include establishing a curriculum of tendon repairs for the simulator models, including modified Kessler as well as four- and six-strand repairs. This would enable assessment of trainees before performing cases independently, as well as practice outside the operating theatre. Using simulators as part of a continuous assessment and monitoring process is the next step in the evolution of simulator-based training. The future of surgical simulation is also looking towards virtual reality-based surgical simulation and its role in education, and this could be extrapolated in future to tendon repair techniques.[14]

Conclusion

The silicone sealant tendon model is a cheap, reproducible, inorganic alternative to pig tendon models, although inferior to it in its likeness to human tendon.

Conflict of interest

None declared.

References

1. Banks EH, Chudnoff S, Karmin I, Wang C, Pardanani S. Does a surgical simulator improve resident operative performance of laparoscopic tubal ligation. Am J Obstet Gynecol 2007; 197: 541. e1–5. https://doi.org/10.1016/j.ajog.2007.07.028.
2. Hosny S, Johnston MJ, Pucher PH, Erridge S, Darzi A. Barriers to the implementation and uptake of simulation-based training programs in general surgery: a multinational qualitative study. J Surg Res 2017; 220: 419–426. https://doi.org/10.1016/j.jss.2017.07.020.
3. Cooke JM, Larsen J, Hamstra SJ, Andreatta PB. Simulation enhances resident confidence in critical care and procedural skills. Fam Med 2008; 40: 165–167.
4. Brindley PG, Jones DB, Grantcharov T, de Gara C. Canadian Association of University Surgeons' Annual Symposium. Surgical simulation: the solution to safe training or a promise unfulfilled? Victoria, BC, September 10, 2009. Can J Surg 2012; 55(4 Suppl 2): S200–S206. https://doi.org/10.1503/cjs.027910.
5. Stirling ER, Lewis TL, Ferran NA. Surgical skills simulation in trauma and orthopaedic training. J Orthop Surg Res 2014; 9: 126. https://doi.org/10.1186/s13018-014-0126-z.
6. Musbahi A, Henton J, Longhi P. Simulated tendon repairs: validating a new synthetic model. Int J Surg 2015; 23(Suppl 1): S94. https://doi.org/10.1016/j.ijsu.2015.07.432.
7. Ingraham JM, Weber RA, Weber RA. Utilizing a simulated tendon to teach tendon repair technique. Hand 2009; 4: 150–155. https://doi.org/10.1007/s11552-009-9184-9.
8. Shaharan S, Neary P. Evaluation of surgical training in the era of simulation. World J Gastrointest Endosc 2014; 6: 436–447. https://doi.org/10.4253/wjge.v6.i9.436.
9. Thomas MP. The role of simulation in the development of technical competence during surgical training: a literature review. Int J Med Educ 2013; 4: 48–58. https://doi.org/10.5116/ijme.513b.2df7.
10. De Montbrun SL, MacRae H. Simulation in surgical education. Clin Colon Rectal Surg 2012; 25: 156–165. https://doi.org/10.1055/s-0032-1322553.
11. Rufai SR. Simulation for tendon repair. Ann R Coll Surg Engl 2013; 95: 374–380. https://doi.org/10.1308/003588413X13629960046877a.
12. Holmes WJ, Tehrani H, Mishra A, McPhail J, McArthur P. The use of a silicone flexor tendon as a teaching model for flexor tendon repair: a clear view [letter]. J Plast Reconstr Aesthet Surg 2013; 66: 294–295. https://doi.org/10.1016/j.bjps.2012.08.022.
13. The Royal College of Surgeons of England. Basic surgical skills: participant handbook. London: The Royal College of Surgeons of England; 2015. p. 35–38.
14. Lee GI, Lee MR. Can a virtual reality surgical simulation training provide a self-driven and mentor-free skills learning? Investigation of the practical influence of the performance metrics from the virtual reality robotic surgery simulator on the skill learning and associated cognitive workloads. Surg Endosc 2018; 32: 62–72. https://doi.org/10.1007/s00464-017-5634-6.