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ORIGINAL ARTICLE

A validated benchtop simulation model for flexor tendon repair

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Abstract

Background: The coronavirus disease 2019 pandemic has had an unprecedented impact on surgical training. Innovative approaches should be sought to aid the acquisition of technical skills to maximise intra-operative learning opportunities. This study evaluates the validity and reliability of low-cost low-fidelity flexor tendon repair simulators. **Methods:** Qualitative and quantitative data were gathered from participants working in a plastic surgery department through the performance of a simulation task and completion of a validation questionnaire. **Results:** Most of the participants (75%) agreed that the model accurately represents the intended procedure, demonstrating an overall high content validity. The three materials used in the model were found to have beneficial features. Participants, overall, did not have a clear preference for the material used, suggesting that the material itself is inconsequential. **Conclusions:** The skill acquisition of a flexor tendon repair is gained through repeated deliberate practice. Providing a vessel for practice is more important than replicating the biological tissue.

Keywords: *education; simulation; surgical training; hand trauma; COVID-19*

Introduction

Background

Since the introduction of the European Working Time Directive, clinical and operative exposure time has reduced for surgical trainees.[1] The coronavirus disease 2019 (COVID-19) pandemic has further complicated matters by impacting surgical practice, as it has led to staffing issues and workforce redeployment, prioritisation of procedures, risk of COVID-19 transmission and changes to peri-operative practice.[2] Adjuncts to the surgical curriculum are restricted by both trainer and trainee time, resources and funding in an ever-struggling healthcare system. These factors have come together to have an unprecedented impact on training and education within surgical practice, with a considerable hit being taken by core surgical trainees (CSTs) in the UK on a two-year surgical training programme.[3] In Scotland, over 70% of CSTs reported fewer opportunities to operate and their confidence being negatively impacted in performing surgical skills.[4]

COVID-19 has brought to light many of the issues within surgical training, and we are now faced with an opportunity to improve surgical training for the better. We must adapt how we train surgical trainees to ensure that adequate support, clinical experience and skill acquisition are all achieved in an increasingly restricted environment.[5] Innovative approaches to surgical training should be sought to aid the acquisition of technical skills to maximise the intra-operative learning opportunities.[6,7]

The aim of this study is to explore low-cost simulation models to assist surgical trainees in a plastic and hand surgery unit. To ensure sustainability, we must explore low-cost, easily accessible consumables to create valid and reliable simulation models.

Skills required for speciality training in plastic surgery

The Plastic Surgery Specialty Training Programme is for speciality trainees who have completed their core surgical training, with entry level named ST3 progressing to ST8. The Intercollegiate Surgical Curriculum for ST3 (Specialty Training) states that those aiming to enter Plastic Surgery ST3 level training must demonstrate Level 2 competence in performing: flexor tendon repair, extensor tendon repair, K-wire fixation of closed metacarpal and phalangeal fractures, digital nerve repair, washout of hand infection and revision

amputation of digit.[8,9] These operations are common in surgical practice and thus the ability to perform them is required to treat the patient population.

We must endeavour for our CSTs rotating through a plastic surgery department, with a desire to enter speciality registrar training, to achieve these competencies. Heightened by the difficulties explored above, with increasing restrictions on working times and limitations on operative access due to COVID-19, we suggest CSTs gain competence at these skills through a simulated environment. This would allow them to enter the operating theatre with some technical experience, thus optimising their learning during this valuable time.

Simulation

Simulation is an education tool that allows performance in an environment which recreates a real-life scenario.[10,11] Simulation allows the acquisition of skill to be practised prior to performing a surgical skill on a patient. The ethical implications of performing an unpractised skill on patients mean that we must balance patient safety whilst training our future generation surgeons.[11,12] The degree of 'realism' is manifested through the term fidelity.[13,14] Low-fidelity benchtop models can be used for technical skill simulation, whereas high-fidelity models can replicate an entire surgery with a high degree of realism. High-fidelity models will become increasingly accessible with advancing technology in virtual reality; however, this remains a costly field.[15,16]

When introducing a simulation as a tool, one must assess the reliability and validity of the simulation. Reliability is the reproducibility. Validity measures whether the simulation is actually teaching what it is intended to teach, which can be broken down further, into face, content and construct validity.[17–20] Content validity refers to the realism and surgical content of a simulation and is assessed by experts. Face validation assesses the simulator as an educational tool.[20,21] Construct validity is whether the simulator can distinguish the experienced from the inexperienced surgeon.[21–23]

Tendon simulation

The average diameter of a flexor tendon is 5–6 mm,[24,25] and composed of groups of collagen bundles known as fascicles separated by endotendon and surrounded by epitendon. Tendons are composed of elastin, proteoglycans and type I and type III collagen.[26–28] Repair of a flexor tendon is a skill which requires practice of the techniques available to create a two–six strand core suture and epitendinous repair. Benchtop models have been described in the literature for surgical trainees to simulate the technique of flexor tendon repair.[29]

The most realistic materials to replicate the intra-operative experience of a flexor tendon repair are cadavers and animal models; however, these come with restrictions of availability, disposal, cost and licencing.[30,31] Alternative materials have been discussed in the literature, such as rubber worms,[32] liquorice,[33] feeding tubes,[34] catheters,[35] drinking straws[36] and microfoam tape[37]; however, few have been validated.

Aim

Our aim was to develop a low-cost low-fidelity flexor tendon repair simulator model for training.

Methods

This study gathered qualitative and quantitative data from participants working in a plastic surgery department through the performance of a simulation task and completion of a validation questionnaire.

Participant selection

Participants were verbally invited to participate in the study which involved performing a flexor tendon repair on three different materials for comparison. Participants were informed that the purpose of this study was not an assessment of their ability to perform a flexor tendon repair. The purpose of the study was to assess the suitability of each material in the benchtop model.

The purpose of timing participants is to determine the ability of the model to distinguish experts from novices. Participants were asked to consider the suitability of each material as a simulator, and asked to consider the material's diameter, texture, appearance and tissue hold during the task. Participants provided informed consent verbally.

Participants

Four consultants agreed to participate in the study, three of whom were plastic surgery-trained hand consultants and one orthopaedic-trained hand consultant. These four participants were included in the 'Expert' group for the purpose of construct validity. Four speciality registrars in plastic surgery participated, ranging from ST3 to ST8. A further four participants made up the 'Novice' group for the purpose of construct validity, including two CSTs (CST2), a clinical development fellow (CDF) and a foundation year doctor (FY2).

Equipment

All participants were provided the same equipment (Fig. 1) of a 4-0 round bodied suture, needle holders, scissors, toothed and non-toothed forceps. The benchtop model

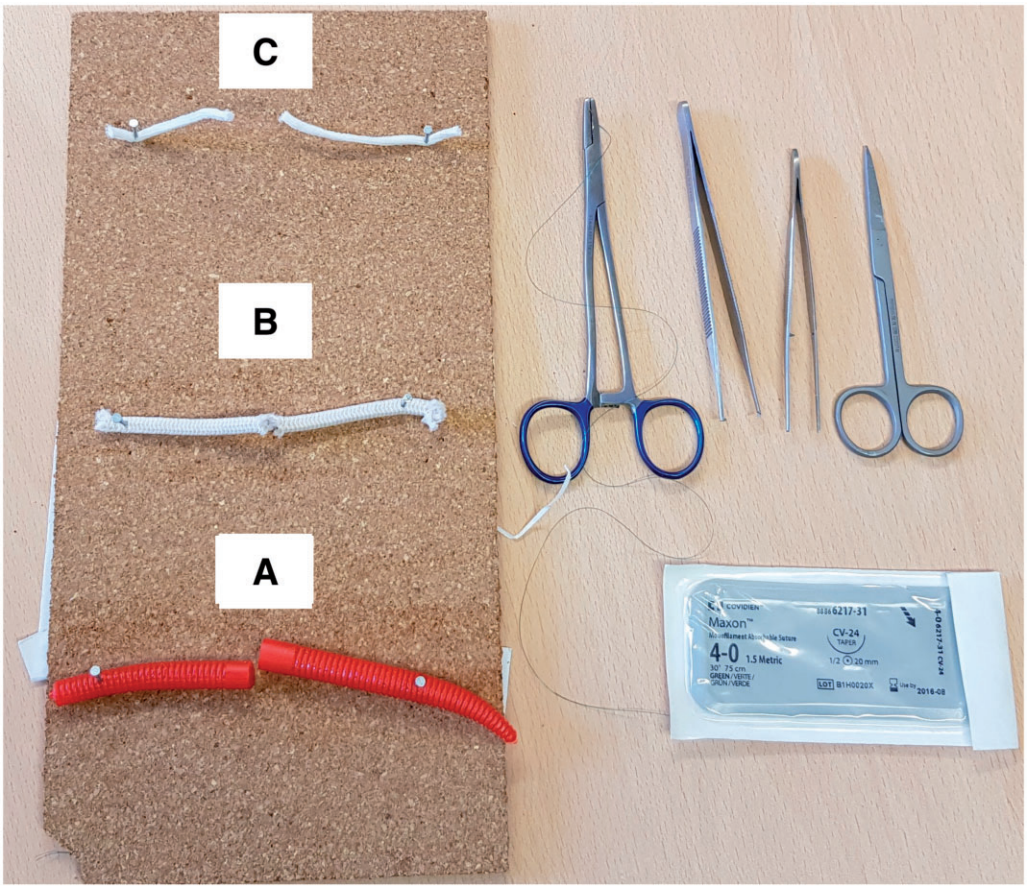

Figure 1. Benchtop model with equipment provided. (A) Artificial worm fishing bait; (B) 6 mm elastic bungee cord rope; (C) 3 mm elastic cord used for face masks.

was set up as demonstrated in Fig. 1, with the three materials secured to an adhesive backed cork board with nails. The materials were replenished between participants. All participants started on Material A, followed by Material B and finally Material C. The three materials are low-cost and easily replenishable: (A) Artificial worm fishing bait (cost £4.44/m), (B) 6 mm elastic bungee cord rope (cost £2.20/m) and (C) 3 mm elastic cord used for face masks (cost £0.80/m).

Task training

Participants were asked to perform a two-strand modified Kessler core suture and epitendinous running suture, on the three potential simulation materials. A demonstration of the task was offered to participants by the researcher prior to initiation of the task.

Validation tool questionnaire

The participants were timed in their ability to complete the task on each individual material. They were then asked to complete a questionnaire based on validated surveys found in the literature.[21–23] A template of the constructed questionnaire can be seen in Fig. 2, which can easily be adapted to other simulation benchtop models.

The survey gathered data on the participants' basic demographics, such as hand dominance, seniority and speciality. Validation of the content, face and acceptability were assessed using a 5-point Likert scale in which participants rated the statements listed in Fig. 2. This was established by asking the participant to state to what degree they agree with the statements, using a continuous line visual analogue scale which translates to a 5-point Likert scale from Strongly Disagree, Disagree, Neutral, Agree and Strongly Agree.[38]

Content validity is the degree to which a simulator represents the problem; in this case, the problem is the task of performing a 'flexor tendon repair'. Participants are asked to consider to what degree the model is an accurate representation of the procedure, teaches the relevant anatomy, trains hand–eye coordination, uses accurately represented surgical

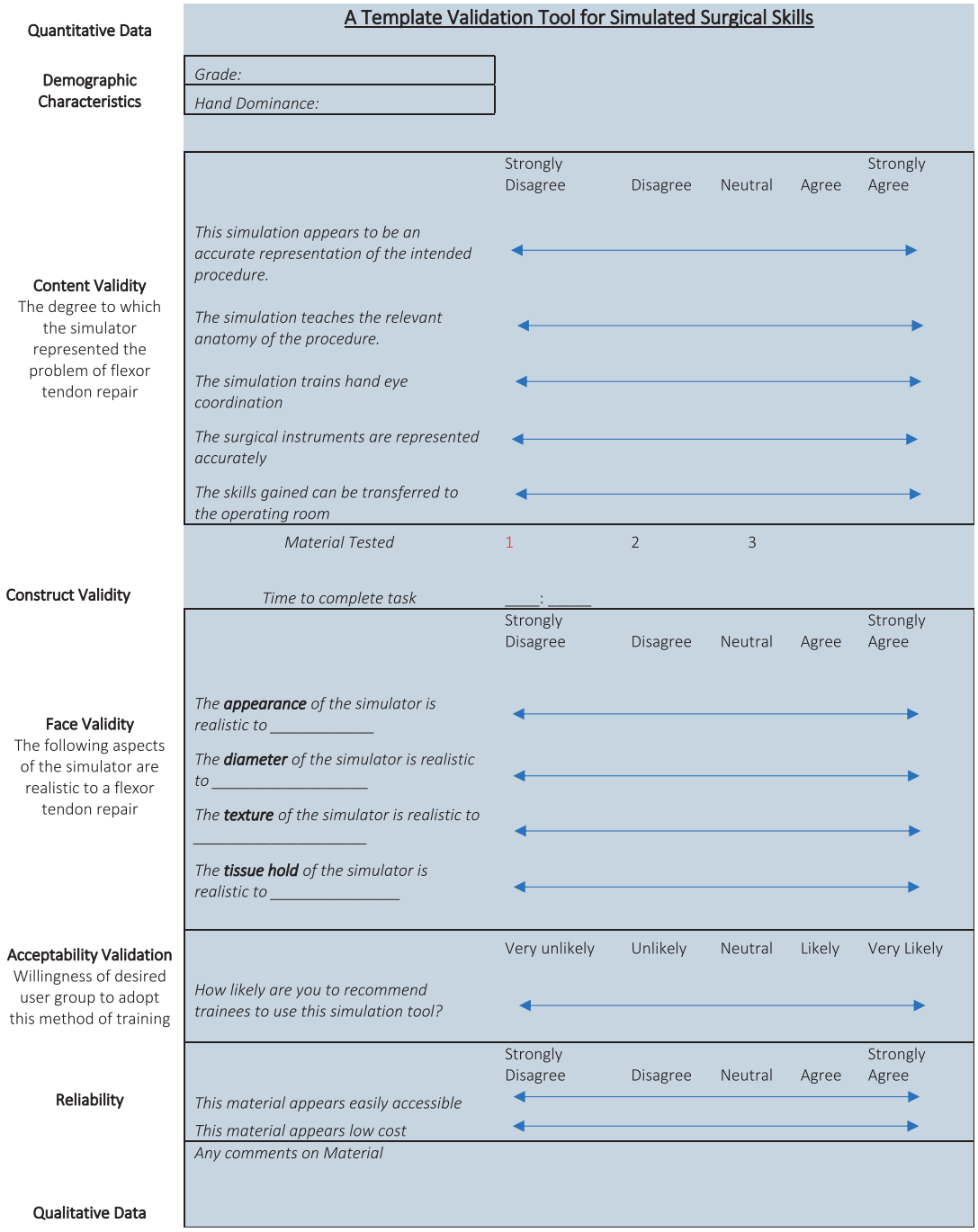

Figure 2. A template validation tool for simulated surgical skills, showing the questions used in this study. This tool was repeated for each material used in this study.

instruments and the skills gained can be transferred to the operating room.

Construct validity is the ability of the benchtop model to distinguish an experienced from inexperienced surgeon, in this case between the 'Expert' and 'Novice' groups. This was gathered by noting the time for the participant to complete each of the materials. The material with a higher construct validity can be viewed as being a helpful model, as it demonstrates the ability to improve a trainee's skills, such

as tissue handling, tensioning and suture placement. If a material has a poor construct validity, it could be argued that no pre-existing experience or skill is required to complete the task, thereby limiting learning potential provided by the benchtop simulator.

Face validity is how realistic the simulator is to the task of a 'flexor tendon repair'. This was gathered by exploring attributes of the materials which are important to the task, including the appearance, diameter, texture and tissue hold.

Acceptability validation is the willingness of the desired user group to adopt this method of training. This was assessed by asking participants to state how likely they are to recommend trainees to use this simulation tool, again on a visual analogue scale which can be translated to a 5-point Likert scale of Very Unlikely, Unlikely, Neutral, Likely and Very Likely.

The participants' perception of the reliability of this model was assessed by using the visual analogue score of Strongly Disagree to Strongly Agree as above. Participants were asked to state their perception of each material's apparent accessibility and cost.

Finally, participants were offered the option to provide qualitative data through a general free text box to provide any comments on the materials used on the benchtop model.

Ethics

Participation in the study was voluntary with no incentives. Participants were asked only identifiable information of their hand dominance and grade. Questionnaires were completed as hard copies, the results of which were transcribed into a database with participant identifiers known only to the researcher. The hard copies were then destroyed. According to NHS Health Research Authority, this study does not require ethical approval through the NHS Research and Ethics Committee in Scotland where this study was carried out. Written informed consent was not obtained because completion of the questionnaire was taken as written acceptance of participation in the study. This study was completed in accordance with the Helsinki Declaration as revised in 2013.[39]

Results

Of the 12 participants, there were seven males and five females, with 92% right-hand dominant. The only participants to offer comments in the free text comments box for gathering qualitative data were three of the most junior members of the plastic surgery team.

Content validity

The overall content validity was positive for the benchtop simulation model. The median response being Agree to the simulation being an accurate representation of the intended procedure, with 75% answering Agree or Strongly Agree. Participants reported a mean Strongly Agree for the simulation model teaching hand–eye coordination, the instruments were accurately represented and the skills being transferred to the operating room. However, 67% of participants responded Disagree or Strongly Disagree on 'the simulation teaches the relevant anatomy of the procedure'.

Construct validity

All participants began on Material A which was closest to them on the benchtop model. This may explain why this material had the longest median time to complete the task at 162.9 s. Material C had a median completion time of 130.2 s, and Material B of 129.6 s. For determination of the construct validity of the model, the time to complete the task must be compared between the Expert and Novice groups. The average time to complete the task in the novice group on Material A was 172.8 s; Material B, 148.5 s; and Material C, 186.6 s (see Fig. 3). The results for the Expert group on the other hand were Material A, 164.8 s; Material B, 92.5 s; and Material C, 98.2 s (see Fig. 3). The difference between the Expert and Novice groups was found to be 7.9 s for Material A, 55.9 s for Material B and 88.3 s for Material C, meaning the most discriminatory material was Material C, holding the highest construct validity.

Face validity

All three of the materials were found to have overall neutral face validity, with all materials returning answers of the face validity aspect of the questionnaire being 'Neutral'. However, there appeared to be some variation in responses between the groups of participants (Fig. 4).

The group of junior trainees (CST, CDF and FY2) generated answers to suggest Material C as the highest face validity with median answers in this section of 'Strongly Agree', followed by B with median of 'Agree' and lastly A 'Neutral'. Registrars felt Materials B and C to have the highest face validity of the three with median answers of 'Neutral', as opposed to 'Disagree' for Material A. Consultants felt Materials A and B had the highest face validity with median answers of 'Agree' for these materials, in comparison to 'Neutral' for Material C.

Acceptability

Acceptability of the materials used in the benchtop models was measured through participants' likelihood to recommend trainees to use this tool. The overall median for

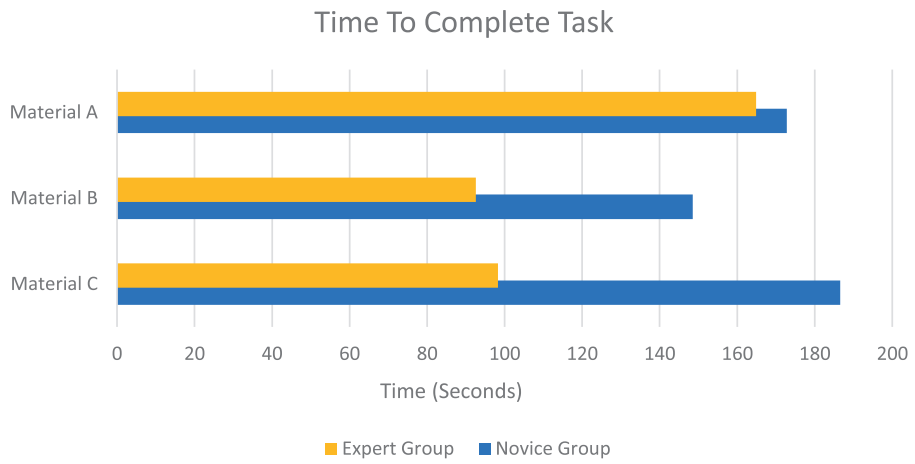

Figure 3. Construct validity: time to complete task on Materials A, B and C for Expert and Novice groups.

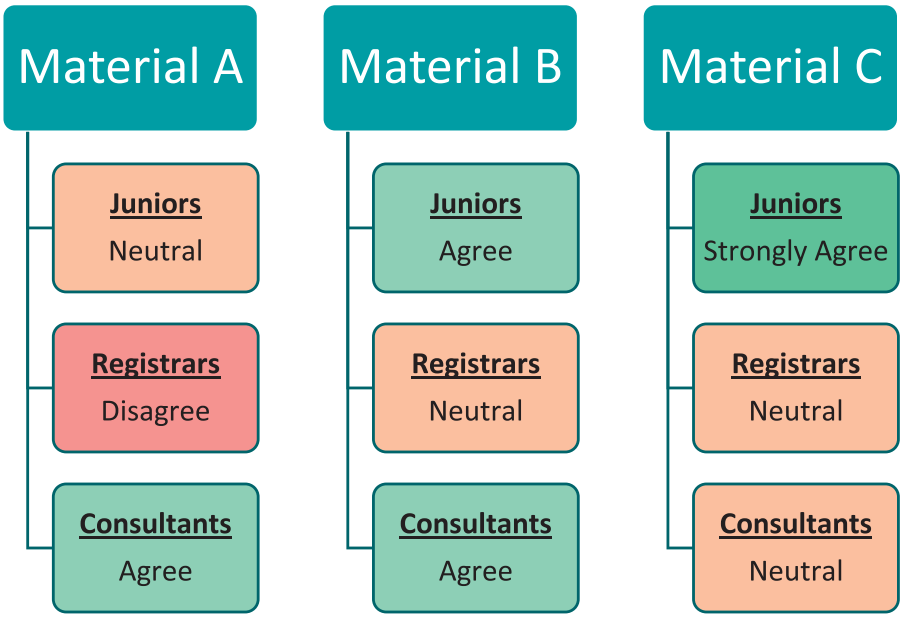

Figure 4. Face validity: median answers to four face validity questions for Materials A, B and C. Participants chose responses on a scale from Strongly Disagree to Strongly Agree.

each of the three materials was 'Agree', meaning all participants would recommend the materials equally. Analysing the response of each participant group found that both the junior trainees and consultant groups would recommend the materials equally with a median response of 'Likely' to recommend all materials. The registrar group, on the other hand, was 'Neutral' with Materials A and C, and the median response for Material B was 'Unlikely' to recommend trainees to use this material (see Fig. 5).

Reliability

Reliability was measured by the participants' perception of the accessibility and cost of each of the materials. The overall responses from participants accurately reflected the depreciating value of materials. Material A was recognised unanimously as appearing to be the most expensive and the least accessible, in comparison to Material C which was recognised as lowest cost and most accessible.

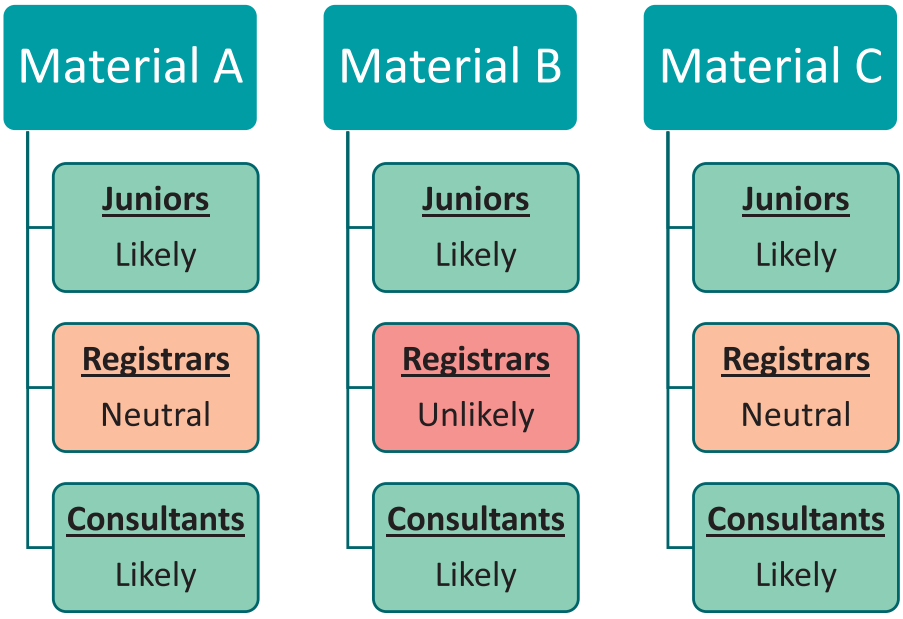

Figure 5. Acceptability: median answers to the question: 'how likely are you to recommend this material to trainees?' Participants chose responses on a Likert scale from Very Unlikely to Very Likely.

Qualitative data

The only qualitative comments offered in writing were from the junior trainee group. Material A comments included: 'Rips easily, too wide, flexible', 'Most realistic, good for beginners', 'Least favourite'. Material B comments included: 'Good texture, good feel', 'Least realistic, although would be useful to train the difficult non mobile tendons', 'Second favourite'. Material C comments included: 'Good diameter, quite lax', 'Good for practicing smaller more difficult tendons', 'First favourite'.

Limitations

The design of the benchtop model aimed to use low-cost easily accessible materials, including the construct of the model itself. The small sample size of participants is a limitation to this study, and a larger scale study would be required for future research.

Practice

The orientation of the materials on the cork board may allow for bias on a certain material or create some variance between participants. One could criticise the vertical orientation of the model, allowing participants to progress from Materials A, B then C working away from them. An alternative orientation could be a horizontal layout where participants could work from left to right. However, regardless of the orientation of the materials, participants would have to initiate the task on one material, and finish on another. This holds potential for bias on the material participants complete the task on, as they have practised the technique on the prior two materials.

Techniques

To standardise the assessment of all three materials, the participants were requested to use a defined suture technique. This may have been an unfamiliar suture technique to some participants; therefore, they may not feel comfortable performing this in such a setting. This could be the case for seniors using an alternative technique as their own standard, or trainees participating being new to the technique. However, this has been addressed by offering a demonstration of the technique prior to initiation.

Bias potential

There is potential for bias within this methodology which must be acknowledged. All trainees and trainers participating in the study were colleagues of the author, working in the same department. Therefore, their answers or judgements could be influenced by their relationship with the authors.

There is a further potential for bias depending on the trainer's or trainee's prior experience with similar benchtop models. This was not explored within the questionnaire to address this area of bias for any one material over another.

Discussion

This study aimed to assess the validity of the three materials for use in this benchtop simulation model. The validation tool in the form of the post-simulation questionnaire assessment tool has allowed achievement of this aim.

The use of the locally designed questionnaire allowed for comparison of the validity of each material, which can be easily adapted for future simulation models. Trainees require guidance on how to optimise their training through simulation and should be encouraged to explore new and innovative ideas to achieve this. Several studies have shown that training on low-fidelity models improves performance in the theatre setting.[40] Using a validated benchtop model will aid skill acquisition by ensuring deliberate practice on appropriate simulation models.

Construct validity

The construct validity was found to be most valid in Material C which, interestingly, was the final material to be completed by all participants. This could be the explanation as to why it has been demonstrated as the most discriminatory material. Novices were found to have a significantly slower time to complete the tasks than the Expert group; however, this was less apparent on the 'starting' material (A), implying that all participants required a warmup to improve their time to complete the task, and the true discriminatory abilities are demonstrated once participants were warmed up. Construct validity is considered desirable when used as a training tool; however, it is considered to be essential when used as an assessment tool.[41] Perhaps an area for improvement in this study is allowing participants a practice round on all the materials before the timed round to eliminate this variable of a warmup period.

Face validity

The three materials were found to have overall similar face validity, with each of the materials benefitting in either texture, tissue hold, diameter and appearance, each offering strengths in different fields. Many comments were made during the study, including Material A being too prone to 'cheese wire' (suture material cutting through tendon) and too large in diameter, whereas Material B was too firm and unable to replicate tensioning the tendon, and finally Material C being too small in diameter, but provided the strongest repair. Many participants identified individual benefits of all materials, with none being the perfect simulator but all being representative of the real-life task.[20,42]

Content validity

For future work on the content validity, this simulation model could be advanced to address the deficiencies in the benchtop model for teaching the relevant anatomy. This could be improved through the addition of a simple instructional information sheet to use alongside the model, including anatomy of the flexor tendons, the classification of flexor tendon injury zones, with bullet points of key points, and further inclusion of step-by-step instructions of how to perform a flexor tendon repair with diagrams, including different techniques available and the evidence to support them. This has potential to improve the overall construct validity by providing context of both clinical and anatomical relevance through creation of a relevant training protocol.[43]

Acceptability

The general acceptability of all the simulation materials used in this benchtop model may suggest that there is no perfect inorganic material that replicates a true flexor tendon. It may, on the other hand, reflect the unimportance of the material itself, in that many may view all the tools as adequate materials to practise the technique, which is the most valuable aspect to the simulation rather than the texture, appearance, diameter or tissue hold. Similar studies have demonstrated similar acceptability of low-fidelity simulation resources.[44–46]

Next steps

The next steps for this benchtop model are to design a training protocol for use with the materials and equipment. The training protocol should incorporate an introduction to the clinical and surgical relevance, an adequate briefing on the task, explanation of the equipment and evaluation of the performance tool.[43,47] Creation of this training protocol will allow the release of this self-led training model to units with minimal cost.

Conclusion

This study found all three of the prototypes to be beneficial in the simple benchtop model. Participants, overall, did not have a clear preference on the material used in the benchtop model, suggesting the material itself is inconsequential. The model can be introduced into local skills labs for self-led and facilitated learning opportunities in the department, with all three materials available for use.

The skill acquisition of a flexor tendon repair is gained through repeated deliberate practice, as with all procedural skills as demonstrated in simulation literature,[48,49] which may be the true advantage of this benchtop model, through its ability to provide trainees with the tools and opportunity

to practice. Providing a vessel for practice appears to be more important than the simulation material replicating the biological tissue.

Conflict of interest

None declared.

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