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Research Article

Flat Elastic Band: A Unique Material to Develop Simulated Models for Laparoscopic Suturing

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Abstract

Objectives: During COVID -19 opportunities for surgical simulation have become slim. Undoubtedly, there are ways to develop home based platforms for laparoscopic simulation; developing clinically relevant, cheap suture models is challenging. The objective of the current study is to describe the content, face and construct validity of elastic band-based suture model.

Methods: Using flat elastic band, laparoscopic suturing model was developed to simulate four most common surgical procedures including enterotomy closure, suture cruroplasty for para-oesophageal hernia and peritoneal flap closure for right and left inguinal hernias. Every task was practiced 10 times. To document content and face validity, a short video consisting of the concept of the model, suturing tasks an actual performance on the model was shared with surgical colleagues. Responses were collected using Survey Monkey. Using recordings of 40 sessions, data was collected to document construct validity through Kruskall-Wallis and Mann-Whitney U tests.

Results: Response from 40 participants documented face and content validity of the suture model as there was 80% to 100% agreement on various characteristics of elastic material. Construct validity was documented by the fact that each task was unique (Kruskall-Wallis test: chi square=24, df 3, p-value =0.00). Moreover, there was significant difference in task completion time for the first 6 attempts and last 4 attempts (median time: 23 *vs.* 15 minutes; sum of ranks: 570 *vs.* 250; Mann-Whitney u=114; p-value=0.03)

Conclusion: Flat elastic band has potential to develop variety of cost-effective, robust, clinically relevant and constructively valid suture models.

Keywords: Laparoscopy; Suturing models; Surgical simulation; Inexpensive; Validation

Introduction

Laparoscopy has transformed the field of surgery. The superiority of this technique over its open counterpart is well recognized. However; it is technically demanding and acquiring laparoscopic skills is a strenuous job [1]. Moreover, during early phase of learning, incidence and severity of complications is significantly increased. This along with social demands for safer surgeries and lawsuits for compensations in case of complications, make it mandatory to train new surgeons in safe, stress free and simulated environment, outside of the operating room [2]. Auspiciously, there is body of evidence that laparoscopic skills can be acquired and enhanced by using a variety of simulators [3,4]. One of such skills, that are highly valuable for laparoscopic surgeons, is laparoscopic suturing. New surgical trainees have insight in to this fact and are interested acquiring this skill early in their training [5]. The most popular method is to attend laparoscopic suturing courses.

Due to COVID-19 pandemic, most of the advance laparoscopic suturing courses offered by the Royal Colleges of Surgeons have been cancelled [6]. Moreover, to comply with social distancing, on-site courses have been suspended as well. This challenging situation, along with cancellation of elective procedures, has left the surgical residents with an option of utilizing off-site, home based, low fidelity simulators [7]. The effectiveness of such simulators has been well documented through validation studies [8]. An example of such simulators is cardboard based platform with an I-pad as monitor. Developing platform for laparoscopic surgery is not that challenging as is the development of suture models. Different resources used for open or laparoscopic suturing include cadavers, animal models, commercially sold models, silicone-based models and banana skin. Cadavers and animal models are not suitable for home-based simulators for obvious reasons [9]. Commercially available models are expensive and not reusable [10]. Silicone based models are difficult to construct [11]. Banana skin has its own limitations because it cannot be used for construction of variety of models to simulate real practice [12]. Faced by these challenges, a new suture model was constructed using an elastic band to practice diverse laparoscopic surgical procedures.

The objective of the current study is to describe the content, face and construct validity of elastic band-based suture model.

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Materials and Methods

Current study was conducted during the first author's upper GI surgical rotation in a district general hospital over a period of 8 weeks starting in early April 2020. Laparoscopic suturing tasks were developed to simulate four most common surgical procedures performed by upper GI surgeons. These tasks included enterotomy closure, peritoneal flap closure for Right Inguinal Hernia (RIH), suture cruroplasty for Para-Oesophageal Hernia (PEH) and peritoneal flap closures for Left Inguinal Hernia (LIH) (Appendix A). To accomplish these tasks, laparoscopic platform and suture models were developed.

Laparoscopic platform was developed using 3 cardboard boxes as shown in Figure 1. The boxes were used to develop a base, a working top and a suture model. Base hosted the working top on the back and suture model on the front. Working top was used to place two 5 mm trocars and an I-pad which worked as camera and monitor [13,14]. For development of suture models, flat elastic band of 10 mm width (Figure 2A) was used. The size of defect was fixed in all the four models i.e., 9 cm in length. Laparoscopic suturing tasks were performed. Every task was practiced 10 times (Figure 2B). Recording was done on the same I-pad which was being used to simulate laparoscopic camera and monitor [15].

To document content and face validity, an eight-minute video, consisting of the concept of the model, suturing tasks an actual performance on the model, was created [16]. It was sent to core trainees, higher surgical trainees and consultants for their opinion on the suture model. Opinion of the surgical faculty was sought on 10 different questions using Survey Monkey link. To document construct validity, recorded videos which were also uploaded on YouTube, were used by the author to review and document the values of different variables. These variables included date of procedure, task specific attempt number, and total number of attempts, task completion time, problems identified areas to improve and overall personal satisfaction score. Overall personal satisfaction was scored on an arbitrary scale of 1-10.

Statistical Package for the Social Sciences (SPSS), (IBM, Corp., Chicago, Illinois, USA) was used for data analysis. Data were recorded on SPSS file as soon as task was completed. It was analysed using Version 20. Descriptive statistics including minimum, maximum, medians with interquartile ranges and means with Standard Deviations (SD) were calculated for numerical variables with non-normal distribution. Frequencies were determined for categorical variables. Software Excel (Microsoft, Redmond WA) was used to develop the line graph to show relationship between the task completion time and task specific attempt number. After interpretation of line graph, task specific attempt number variable was categorized into early attempts and late attempts at cut off value of 6. Early Attempt Group (EAG) included first six attempts where performance was not stable while Late Attempt Group (LAG) included the last 4 attempts where performance had become more stable.

To document the validity of the suture models, Kruskall-Wallis test and Mann-Whitney U test were performed. Kruskal-Wallis test was used to determine statistically significant difference in task completion time across the allocated tasks. While, Mann-Whitney U test was performed to determine statistically significant difference between Early Attempt Group (EAG) and Late Attempt groups across all the tasks. For all inferential statistics, p-value <0.05 was considered significant.

Results

Surgical faculty that resounded to the survey (n=40) about the suture model, consisted of 19 consultants, 17 higher surgical trainees, and 4 core trainees. Responses from the participants were very promising. Suturing model was clinically relevant, according to 92.5% (n=37) of the participants. Majority of the respondents (87.5%, n=35) perceived that variation in angles and orientation will help in learning more advanced laparoscopic suturing skills, as compared to conventional models. Regarding elastic band material itself, there was consensus on many of its alleged characteristics. These included; capability to develop a variety of simulation scenarios (92.5%, n=37); utility in learning the skill to maintain the tension across the edges (82.5%, n=33); light-weightiness (100%, n=40); and robustness (92.5%, n=37). It was quite interesting to notice that most of the respondents (92.5%, n=37) claimed that they can develop elastic band-based suture models themselves. Moreover, 87.5 % (n=35) showed interest in learning or teaching on such models. Further results are shown in Figure 3.

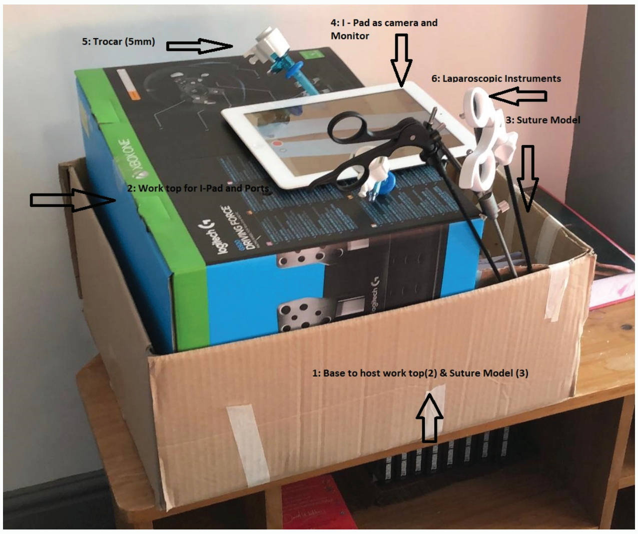


Figure 1: Home based Laparoscopic Platform.

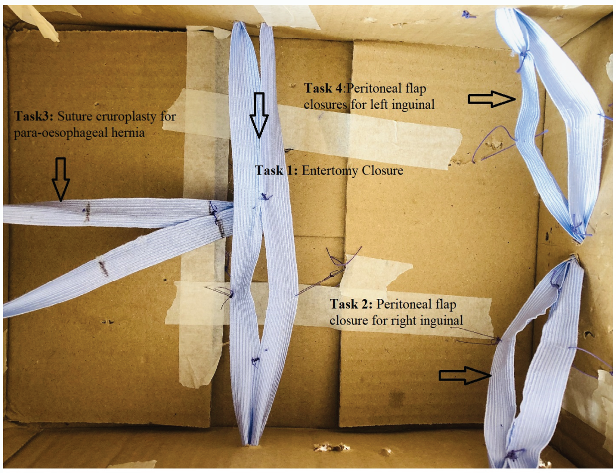


Figure 2A: Elastic Band Based Clinically Relevant Suture models.

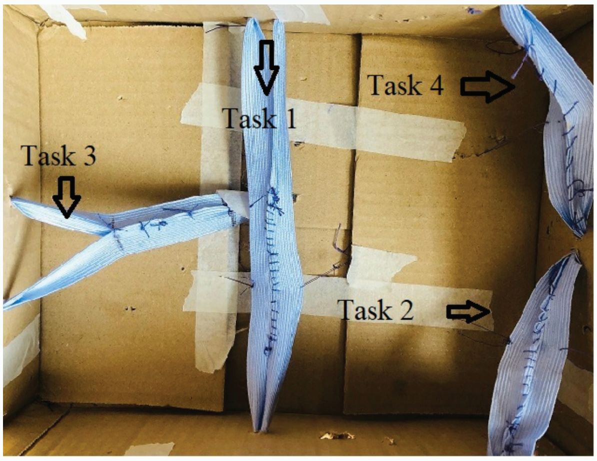


Figure 2B: Completed suturing tasks on Elastic band-based suture models.

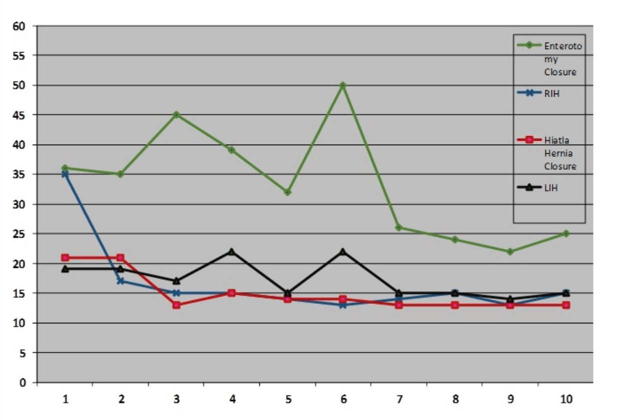
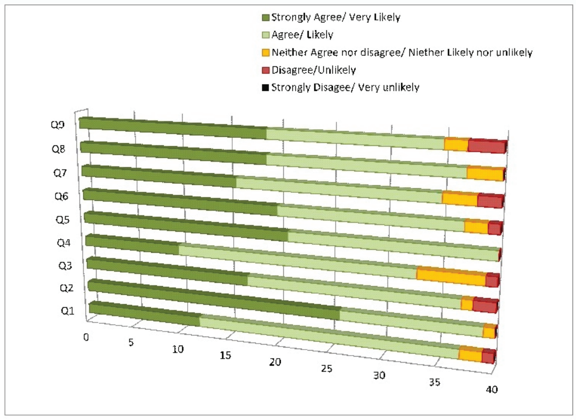


Figure 3: Line graph between task completion time and task attempt number for various tasks.



Q2	**The four scenarios presented for laparoscopic suturing are reflective of real practice.**
Q3	The flat elastic band is a cheap alternative to other materials.
Q4	The flat elastic band can be used to develop a variety of simulation scenarios.
Q5	The elastic nature of the flat band is useful in learning the skill to maintain the tension across the edges.
Q6	Elastic band-based suture models are expected to be lightweight.
Q7	I can develop suture models using a flat elastic band myself.
Q8	I would like to learn/ teach at training sessions using the above-mentioned suture models.
Q9	Once developed, the suture model can be used over and over without any major issues.
Q10	Variation in angles and orientation will help in learning more advanced laparoscopic suturing skills as compared to conventional models.

Figure 4: Results of Survey about the flat elastic band-based suture models.

Regarding the completion time for various laparoscopic suturing tasks, it ranged from 13 minutes to 50 minutes with a median of 15 minutes and IQR of 9.30 minutes. On average maximum time was spent on suturing of enterotomy model. Task completion time of the other three tasks with their descriptive is shown in Table 1.

Figure 4 describes the task completion time of all the four tasks over task specific attempt numbers. Performance was not very smooth for the first 6 attempts, especially in case of enterotomy closure and left inguinal hernia models. However, in all cases, it became consistent from 7th attempt onwards. Table 1 depicts the results of Kruskal-Wallis test, showing difference in task completion time by different tasks. There was statistically significant difference which documented Construct validity (chi square=24, df 3, p-value=0.00). Table 2 confirms that there was significant difference in task completion time for the first 6 attempts and last 4 attempts for all tasks, except for peritoneal flap closure model for RIH.

Discussion

Current study describes development of a laparoscopic platform using household utensils. It also provides an account on crafting innovative and cost-effective suture model, using a unique material. Moreover, it validates the suture model by providing evidences on content, face and construct facets. The discussion below is an attempt to link the phenomenon of acquisition of laparoscopic suturing skills, by using the described platform and suture model, with the theories of adult learning.

Reflection and feedback are the two powerful tools that enhance acquisition of skills through deliberate practice [17]. Review of recorded videos of self-performance helps in reflection and improvement in performance. Sharing these videos with mentors, helps in receiving feedback to further enhance performance. In current study, author experienced improvement in laparoscopy suturing skills by using these tools. Reflection and feedback on the recorded video have been reported very valuable by many authors [18]. The added advantage is that, the mentors like this type of feedback, as this can be done at their own ease without much stress [19]. Laparoscopic platforms described in current study provides opportunity to record videos and then utilize them to reflect and receive feedback from mentors.

According to motivational models of educational theory, besides reflection, motivation is a critical element for adult learning [20]. Sustenance of motivation requires autonomy, competence and sense of belonging or relatedness [20]. We feel that features of clinical relevance and versatility, in current suture model, increase motivation. This motivation is further enhanced by easy access to suture model due to its unique characteristics of easy constructability; transportability; affordability; and durability. Hence, current suture model provide motivation to learn with a feeling of autonomy and belonging which is perfect combination to achieve competence.

Sense of belonging and having offsite suturing model is beneficial in other ways as well. Noaparast M et al. [21] have reported that basic laparoscopic surgical skills, can be achieved in 5 attempts. In current study, the performance plateaued certainly after 6th attempt, probably

Table 1: Kruskal-Wallis Test results showing difference in completion time by various categorical variable (univariate analysis).

Task Name	N	Descriptive Statistics				Kruskal-Wallis Test			
		Minimum	Maximum	Mean ± SD	Median (IQR)	Mean Rank	Chi-Square	df	p-value
Closure of enterotomy	10	22.00	50.00	33.70 ± 9.18	33.50 (15.75)	34.85	24.03	3	0.00
Peritoneal Flap closure- RIH TAP Approach	10	13.00	35.00	16.60 ± 6.56	15.00 (1.75)	15.40			
Closure of espophageal hiatus- Hiatal hernia	10	13.00	21.00	15.00 ± 3.23	13.50 (3.50)	11.00			
Peritoneal Flap closure- LIH TAP Approach	10	14.00	22.00	17.30 ± 3.02	16.00 (4.75)	20.75			

Table 2: Comparison of completion time for various tasks by attempt group.

	Attempt Group	N	Mean Rank	Sum of Ranks	Mann-Whitney U	p-Value
Closure of enterotomy	First 6	6	7.50	45.00	.000	0.01
	Last 4	4	2.50	10.00		
Peritoneal Flap closure- RIH TAP Approach	First 6	6	6.17	37.00	8.000	0.37
	Last 4	4	4.50	18.00		
Closure of espophageal hiatus- Hiatal hernia	First 6	6	7.17	43.00	2.00	0.02
	Last 4	4	3.00	12.00		
Peritoneal Flap closure- LIH TAP Approach	First 6	6	7.25	43.50	1.500	0.02
	Last 4	4	2.88	11.50		
Overall completion time	First 6	24	23.75	570.00	114.000	0.03
	Last 4	16	15.63	250.00		

because it involved learning of more advanced laparoscopic suturing skills. However, in authors' view, skill acquisition is task specific and at least 10 attempts should be performed to make sure the skill is acquired. Moreover, it should be practiced at regular intervals to consolidate it, by applying the concept of spaced learning [22]. Having off site suturing model and platform is of a great advantage in this scenario.

Another benefit of elastic band base model is the feasibility of modification of orientation and angle of the suturing model. This can help the trainees to learn at different angles and acquire more advanced skills. Nepomnayshy D et al. [23] have demonstrated the similar concept. This concept has clinical implications as most of the suturing scenarios in clinical practice are not simple and straightforward. There has been a demand to introduce more challenging tasks in the laparoscopic suturing curricula [24]. We believe that current suture model can help to fill this gap and elastic nature of the material provides a great chance to explore further simulated scenarios, close to reality.

Although, for current study, no formal scoring systems was used. However, it is evident that essentially any scoring system can be used to gauge the performance. We have used completion time as objective measure because it has great clinical relevance. Increase in operative time increases patient morbidity and mortality [25]. The most important factor that affects the completion time is task at hand itself. This would mean that completion time is task specific and each task should be well rehearsed. The findings that total number of sessions and task specific sessions decrease the completion time, have practical implications as completion time can be improved with practice. This is also an indirect evidence of convergent validity of the laparoscopic tasks crafted by the authors [4].

Limitations

There are few limitations of the study. Firstly, current study was not aimed at investigating the transferability of the skills to the clinical environment. Secondly, laparoscopic suturing was performed by a single participant i.e. author himself. This may question authenticity and reliability of data. Moreover, observer bias may be another concern. However, completion time as a measure of performance can easily be checked by online videos consisting of all the performances. Additionally, it will also endorse the authenticity and reliability of data. These concerns can be dealt with, in future validation studies.

Conclusion

In conclusion, current study provides face, content and construct validity for clinically relevant scenarios, practiced on elastic band-based suture model. Easy access to platform and suture model, increase motivation to practice laparoscopic suturing. Video recording facility provides opportunity for reflection and feedback. Motivation, reflection and feedback all contribute to improvement in laparoscopic suturing skills that can help surgical residents to prepare for advanced laparoscopic task in real patients.

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Appendix A

Simulated Laparoscopic suturing tasks

Task 1: You are assisting your bariatric surgery consultant who has created common channel of alimentary and biliary limb of jejunum by using linear stapling device. There is 9 cm enterotomy. Your consultant has asked to close the enterotomy using continuous suturing technique. Complete the task by performing a water tight closure with an interstich distance of at least 5 mm.

Task 2: You have performed a laparoscopic repair of right inguinal hernia using TAPP technique. Your boss is against the use of tacks for peritoneal flap closure due to the risk of neurovascular injuries. Close the peritoneal flaps on suturing model using continuous suturing technique. There should be no major gaps to allow small bowel to get adherent with mesh. However, closure needs not be watertight.

Task 3: Suture cruroplasty is an important surgical procedure performed for paraesophageal hernia. Using an interrupted suturing technique perform crural approximation. There should be at least 4 stiches between the two points marked on suture model.

Task 4: Peritoneal flap closure of left inguinal hernia is difficult task due to angle created for the right-handed person. Moreover, it is recommended to start the closure from lateral to medial side which complicates the situation further. Close the defect using back of the hand technique (right/ left) in continuous fashion. Closure needs not be watertight, however there should be no major defects in the peritoneum to allow the small bowel to get adherent to mesh.

Appendix B

Survey Questions

Flat Elastic Band: A unique material to develop simulated models for laparoscopic suturing

Q1	**About yourself (Tick the highest level applicable)**				
	Core Trainee/ SHO	Higher Surgical Trainee/ Registrar	Consultant Surgeon	Program Director/ Above	
Q2	**The four scenarios presented for laparoscopic suturing are reflective of real practice.**				
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Q3	**The flat elastic band is a cheap alternative to other materials.**				
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Q4	**The flat elastic band can be used to develop a variety of simulation scenarios.**				
	Very Likely	Likely	Neither Likely nor unlikely	Unlikely	Very Unlikely
Q5	**The elastic nature of the flat band is useful in learning the skill to maintain the tension across the edges.**				
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Q6	**Elastic band-based suture models are expected to be lightweight.**				
	Very Likely	Likely	Neither Likely nor unlikely	Unlikely	Very Unlikely
Q7	**I can develop suture models using a flat elastic band myself.**				
	Very Likely	Likely	Neither Likely nor unlikely	Unlikely	Very Unlikely
Q8	**I would like to learn/ teach at training sessions using the above-mentioned suture models.**				
	Very Likely	Likely	Neither Likely nor unlikely	Unlikely	Very Unlikely
Q9	**Once developed, the suture model can be used over and over without any major issues.**				
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Q10	**Variation in angles and orientation will help in learning more advanced laparoscopic suturing skills as compared to conventional models.**				
	Very Likely	Likely	Neither Likely nor unlikely	Unlikely	Very Unlikely