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Content and Face Validity of a Novel Homemade Laparoscope and Laparoscopic Camera Navigation Model: A Pilot Study

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Rezumat

Validitatea conținutului și a formei unui nou model de navigare laparoscopică și la cameră laparoscopică fabricate acasă: un studiu pilot

Introducere: Introdusă acum puțin peste un secol, chirurgia laparoscopică a devenit mai populară decât cea deschisă. Deşi este asociată cu o curbă de învățare abruptă, o multitudine de simulatoare, evaluări şi cursuri sunt disponibile pentru a stăpâni abilitățile laparoscopice. Cu toate acestea, în ciuda expertizei chirurgului, aceasta poate fi limitată de manipulatorul camerei. Se oferă foarte puțină instruire în navigarea cu camera. Scopul acestui studiu este de a valida un laparoscop de casă de 0° şi 30° şi modele de navigare cu camera laparoscopică.
Metode: A fost creat un laparoscop de casă şi diverse modele de navigare cu camera. Au fost recrutați 18 participanți fără experiență sau instruire anterioară în manipularea camerei. A fost oferită o scurtă introducere cu privire la scopul şi sarcinile studiului. Aceştia au efectuat 3 sarcini pe laparoscopul de 0° (navigare cu camera, orientare în linie şi orientare în linie opusă) şi laparoscopul de 30° (navigare cu camera). Participanții au fost apoi rugați să răspundă la chestionare de validare a conținutului şi formei atât pentru laparoscoape, cât şi pentru modelele de navigare cu camera laparoscopică.
Rezultate: Costul laparoscopului de 0° a fost de 25 de lire sterline, iar cel al laparoscopului de 30° a fost de 20 de lire sterline. În chestionarul privind validitatea feței şi a conținutului, cel mai mic scor mediu de 7,5 a fost obținut pentru cât de realist părea. Dintre modelele concepute pentru navigarea cu camera, modelul 5 a fost utilizat cu 0°, iar modelul 7 a fost utilizat cu 30°. Din chestionar, cel mai mic scor mediu de 6,9 a fost obținut pentru cât de realiste păreau modelele. Pentru sarcina de navigare cu camera la 0°, media grupului pentru ambele încercări a fost de 267 de secunde. Aşa cum era de aşteptat, orientarea în linie (61 de secunde) a fost finalizată mai repede decât pe linia opusă (151 de secunde). Pentru navigarea cu camera la 30°, timpul mediu de lucru al grupului a fost de 134 de secunde.

Concluzii şi recomandări viitoare: Laparoscopul artizanal s-a dovedit a fi ieftin, iar din exercițiile efectuate de participanți, este evident că modelele sunt eficiente. Modelele laparoscopice au ajuns la 2760 de lire sterline. Se pot face îmbunătățiri pentru a le face mai eficiente şi mai ieftine. Evaluările subiective ar trebui analizate pentru a vedea dacă pot fi obiective. Ar fi interesant să se evalueze din nou participanții după 3-6 luni. Se recomandă un studiu de urmărire cu mai mulți participanți, precum şi o validitate constructivă cu începători, intermediari şi experți.

Cuvinte cheie: laparoscop artizanal, manipularea camerei laparoscopului, chirurgie laparoscopică, navigare cu camera laparoscopică, laparoscop

Abstract

Introduction: With being introduced just over a century ago, laparoscopic surgery has become more popular than open. Although a steep learning curve is associated, a plethora of simulators, assessments and courses are available to master laparoscopic skills. However, despite a surgeon's expertise, it can be limited by the camera handler. Very little camera navigation training is provided. The aim of this study is to validate a homemade 0 and 30° laparoscope and laparoscopic camera navigation models.
Methods: Homemade laparoscope and various camera navigation models were created. 18 participants with no previous camera handling experience or training were recruited. A brief introduction was provided on the study purpose and tasks. They performed 3 tasks on the 0° laparoscope and model (camera navigation, in line orientation and opposite line orientation) and 30° laparoscope and model (camera navigation). Participants were then asked to answer face-content validation questionnaires for both the laparoscopes and models.
Results: The cost of the 0° laparoscope came to £25 and the 30°laparoscope was £20. In the face and content validity questionnaire, the lowest average score of 7.5 was achieved for how realistic it seemed. Of the models designed for camera navigation, model 5 was used with 0° and model 7 was used with 30°. From the questionnaire, the lowest average score of 6.9 was achieved for how realistic the models seemed. For the 0° camera navigation task, the group average of both attempts was 267 seconds. As expected, in line orientation (61 seconds) was completed quicker than opposite line (151 seconds). For 30°camera navigation, the group average time taken was 134 seconds.
Conclusion and future recommendations: The homemade laparoscope has proven to be inexpensive and from the exercises carried out by the participants, it is evident the models are effective. The laparoscopic models came to £2760. Improvements can be made to make them more effective and inexpensive. Subjective assessments should be looked into to see if they can be made objective. It will be interesting to assess participants again after 3-6 months. A follow up study with more participants would be recommended and also a constructive validity with novices, intermediates and experts.

Keywords: homemade laparoscope, laparoscope camera handling, laparoscopic surgery, laparoscopic camera navigation, laparoscope

Introduction

With being introduced just over a century ago, laparoscopic surgery has become more popular than open. Although a steep learning curve is associated, a plethora of simulators, assessments and courses are available to master laparoscopic skills. However, despite a surgeon's expertise, it can be limited by the camera handler. Very little camera navigation training is provided. The aim of this study is to validate a homemade 0 and 30° laparoscope and laparoscopic camera navigation models.

Camera Handling

Camera handling is often given to junior surgeons due to its perceived simplicity, but it requires strong visuospatial and psychomotor skills. Assistants must mimic eye movements to keep the image stable, centered, and level. Tremors or abrupt movements can cause visual fatigue and impair surgical precision (1).

Studies have shown that a camera tilt between 15-30° increases complication rates, highlighting the importance of strategies like maintaining a "gravity line" (1). Navigating confined spaces requires proficiency in zooming and rotating the

camera; poor handling can lead to misidentification of anatomy, deeper dissection, or thermal injury (2-4).

Surgical training is limited, with most learning occurring under pressure during operations, offering little feedback. Mastery demands a safe space for repetition and error-based learning without risking patient safety.

Currently, only ALSGBI's LapPass formally assesses camera skills, requiring one "excellent" and two "good" scores for 0° and 30° scopes. Research by Sarker et al. supports formal training, showing improved speed and image stability (5). Validated homemade trainers offer practical alternatives.

Homemade Box Trainer

Box trainer components typically include a cavity (abdominal, urological, or gynaecological), walls, port sites, a light source, visualization, and a monitor (6). Common materials were plastic or cardboard, with transparent plastic allowing external light entry (7). However, trainers must avoid direct visual access to replicate surgical conditions. An optimal box size is 30 cm long and 15 cm high allowing instrument mobility in the cavity (8). Boxes should not be wide to ensure instruments can function in tandem.

Removing the top wall facilitates exercise setup. A two-part wall design-one for port insertion and the other for internal access was common (9). Port sites were created by piercing the wall, with or without trocars. Trocars replicate the surgical environment and prevent damage. Neoprene, a synthetic rubber, was often used to simulate skin at port sites (10).

Lighting methods varied. Some relied on external light, though sealing the box while allowing side light was challenging. Internal sources included desk lamps, torches, webcams, battery-powered strip lamps, and LED tubes. LED tubes were affordable and long-lasting, while battery-powered strip lights were compact and inexpensive but lacked laparoscope-like targeted lighting (11-13).

Most trainers used electronic visualization, excluding device costs assuming users already owned them. Common tools included smartphones, tablets, cameras, and laptops, with added benefits like performance recording (14-15). However, these lacked authenticity, requiring frequent charging and offering no camera-handling practice. Alternatives included webcams, spy cameras, or real laparoscopes. Few studies constructed a laparoscope from scratch (6).

Homemade Laparoscope

A homemade laparoscope consists of a small camera and tubing. Spy cameras, about 35 cm long, are suitable due to their compact size. These can connect to monitors via USB or RCA (13).

Commercial and Homemade Camera Models

EndoTower (£23,000) features a virtual interface with software for performance analysis (16). Compared to the Tulane trainer (17), it showed better participant outcomes. LASTT (£1200) and HYSTT (£1220), developed by the European Academy of Gynaecological Surgery, include timed tasks focused on camera navigation. Both Tulane and EndoTower include a 30° laparoscope and software tracking for accuracy, movement count, and errors. LASTT and HYSTT use a 0° scope and lack software.

Three homemade models provided detailed camera training. The Camera Handling Trainer (CHT) focused on 30° navigation for urologists and used 12 circle targets to assess orientation, navigation, and tremor control (18). However, high costs of components like the Olympus endoscopic camera and timing software limit home replication. Alam et al. developed a similar model requiring participants to align two circles while maintaining distance, horizon, and center (19). It used a Karl Storz scope and digital recording, again limiting accessibility. OpticsLT, by Daniel et al., involved matching lines on three discs to a transparent monitor overlay in a task called spatial location (20).

Impact of Camera Training

Most used a pre-training session, followed by assessments in environments such as operating rooms (OR), video trainers (VT), or virtual reality (VR) (21). Other methods included baseline testing, simulator training, and post-tests (22-24).

Overall, studies agreed training improved novice skills and helped overcome the steep learning curve. Franzeck et al. found VR more effective than OR for navigation skill development (24). However, transfer of these skills to real procedures showed mixed results, often due to environmental differences and procedure duration (25-26). While not all studies compared scopes, 0°

laparoscopes were generally easier to handle than 30°.

Aims

The primary aim is to build a novel homemade 0 and 30° laparoscopes and laparoscopic camera navigation models (LCNM). The secondary aim is to conduct a face and content validation on the laparoscopes and LCNMs.

Materials & Methods

The study took place over two days and included adults aged 18+ with no prior camera navigation training. Exclusion criteria included ineligibility, pregnancy, vertigo, or musculoskeletal issues.

Due to Covid-19, only one participant was allowed per 30-minute session. Each session began with a brief PowerPoint explaining the project and tasks, followed by a demo. Participants had 5 minutes to familiarize themselves with the equipment and received feedback on their performance. Due to the Covid pandemic, participant numbers were low. Of the 23 recruited, only 18 attended (*Fig. 1*).

Homemade Laparoscope

From the literature review, it was understood camera and tubing were required to build a laparoscope, with this information, Delphi method (*Fig. 2*) was used to identify a camera (27).

Two separate mini CMOS cameras (4.3 mm and 1.8 mm lenses, 5 megapixels, 1m wiring) were purchased for 0° and 30° laparoscopes (*Fig. 3*). The cameras were attached to 35cm bamboo sticks, with a 30° angle created using a protractor (*Fig. 4*). Foam was used to secure the cameras in a 21.6 mm PVC waterline pipe, which was cut to 35 cm. The cameras, with RCA connectors, were connected to a lab monitor for display.

Laparoscopic Camera Navigation Model

The navigation model replicates diagnostic laparoscopy and the abdomen. Jenga blocks represent organs like the oesophagus, stomach, spleen, colon, pelvis, appendix, gallbladder, and liver. The model consisted of Laprotrain box (70 x 36 x 32 cm), cardboard base (70 x 36 cm), and Jenga blocks (1.5 x 2.5 x 7.5 cm).

Model 1 For 0° Laparoscope (8 Vertical Jenga Pieces)(Fig. 5)

Model 1 was to be used for 0° laparoscope. 8 Jengas were placed, where 5 were placed in the upper half of the box whilst 3 were placed in the lower half. The model was still similar to vertices of a hexagon but with 2 extra Jengas allowing for it to replicate the abdomen. Jengas were placed so that the vertical faces were inwards to be used in conjunction with the 0°laparoscope.

Model 2 (30° Laparoscope Only)(Fig. 6)

Model 2 was created for use with 30°laparoscope. 4 Jengas were placed on the floor of the upper half all angled, two in the left upper quadrant and 2 in the

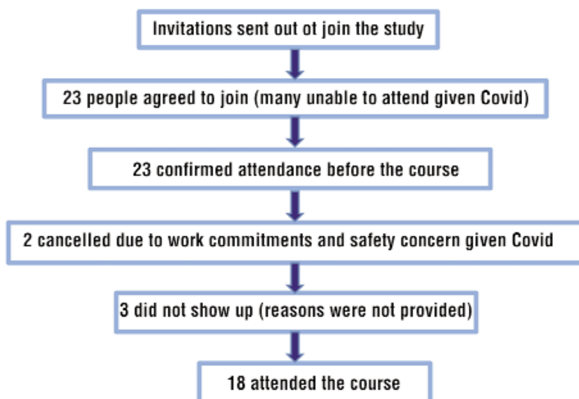


Figure 1. Summary of participant recruitment process

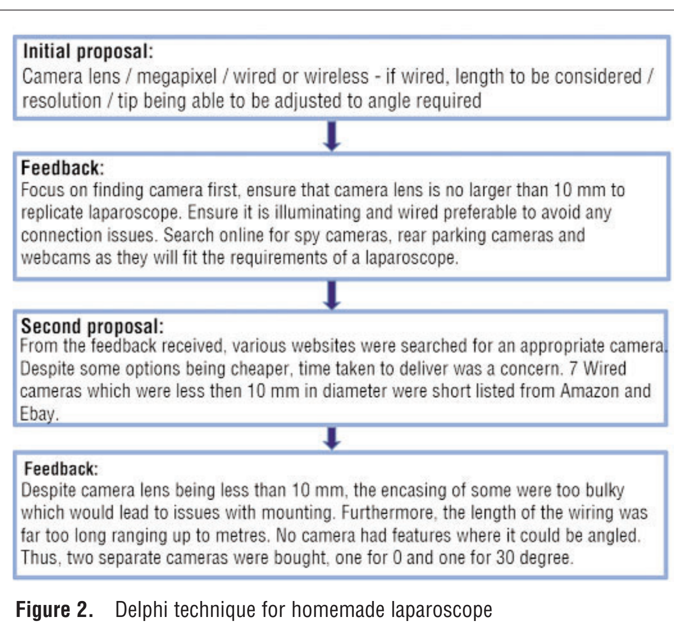


Figure 2. Delphi technique for homemade laparoscope

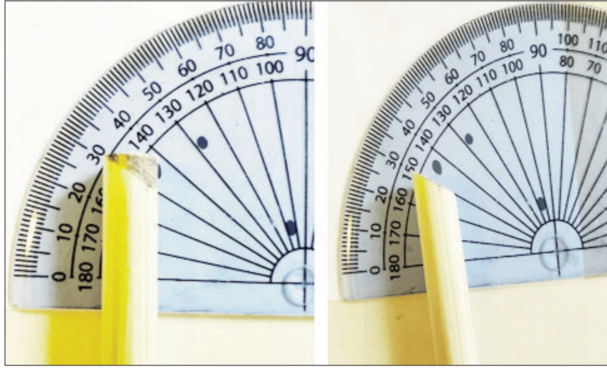


Figure 3. Construction of 300 laparoscope

Figure 4. Summary of constructing homemade laparoscope

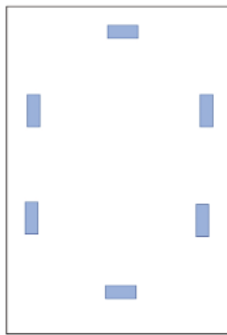


Figure 5. Model 1 bird's eye view

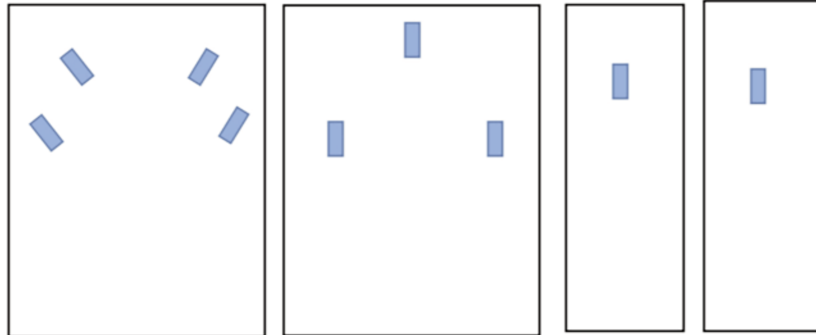


Figure 6. Model 2, from left to right: Floor, lid of box, side of box, side of box

right with the vertical in use. One was attached to the side of the box and 3 were also stuck to the underside of the lid.

Data Collection Methods

Participants were briefed on the project rationale and task summary, then asked to answer questions.

Two stations were set up, 0 and 30° laparoscopes with corresponding navigation models. Three tasks were made for 0, whilst 30 ° only had one. Each participant was given 5 minutes to familiarise themselves with the model and tasks. Participants were given one attempt and feedback for improvements.

0° Laparoscope And Model

Three tasks were set up as follows:

a) Camera Navigation

This task was set up to imitate diagnostic laparoscopy in surgery. There were two attempts where participants were required to go through a series of numbers (1-8) or letters (A-H). As seen in *Fig. 7* each sticker had a number and letter. In order to ensure they do not remember the order, they could be asked to start at any number, for example 5 and work in a clockwise (5,6….3,4) or anticlockwise cycle. Each participant was assessed using time and tremor score. The tremor score was assessed subjectively using a Likert scoring system *(Table 1)*.

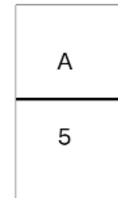


Figure 7. Example of sticker used for camera navigation

Table 1. Likert scoring system for tremor

Description	Score
No tremor present, image on screen always easy to follow	5
Little tremor present, image on screen almost always easy to follow	4
Some tremor present, image on screen mostly easy to follow	3
Moderate tremor present, image on screen can just about be followed	2
Substantial tremor present, image on screen difficult to follow	1
Tremor present consistently, image on screen very difficult to follow	0

b) Horizontal orientation (in line with camera)

Participants completed two attempts. As shown in *Fig. 8*, each Jenga block had a black line at its center for alignment with the two black lines on the monitor, shown in *Fig. 9*. The task required aligning the black line on the sticker between the monitor's lines for three seconds, repeating if unable to hold. Participants were timed, and tremor scores were recorded for each attempt. Error scores were also measured, with participants receiving a rating of 0, minor, or major error per attempt.

0 is defined as no error present. Minor is indicated by the dotted line drawn on at 30°on the plastic wallet. As it lines with the base of the box, it is classed as a minor error (*Fig. 10*). A major error on the other hand is indicated by the black line, measured at 60° (*Fig. 11*).

c) Horizontal orientation (opposite line of camera)

Participants were asked to align with the lines present in the lower half of the box and hold at each line for three seconds. Measurements were taken against time (*Table 2*) and tremor scores (*Table 1*) for each attempt. Error scores were also measured objectively per attempt where participants were again given 0, minor or major error.

30° Laparoscope And Model

The camera navigation task consisted of two attempts where participants were required to work through a series of numbers, from 1 to 9. They could be asked to start at any number, for example 5 and work in a clockwise (5,6….3,4) or anticlockwise cycle. Each participant was assessed using time and tremor score. The tremor score was assessed subjectively using a Likert scoring system as described in *Table 1*. An error score (0, minor or major) was also subjectively given based on their ability to maintain a horizontal, central view which is very important in surgery.

Table 2. Example of data collection

1	2	3
Attempt 1		
Horizontal Line alignment: yes/no		
0/Major/minor		
Tremor score		
Attempt 2		
Horizontal Line alignment: yes/no		
0/Major/minor		
Tremor score		
Attempt 3		
Horizontal Line alignment: yes/no		
0/Major/minor		
Tremor Score		

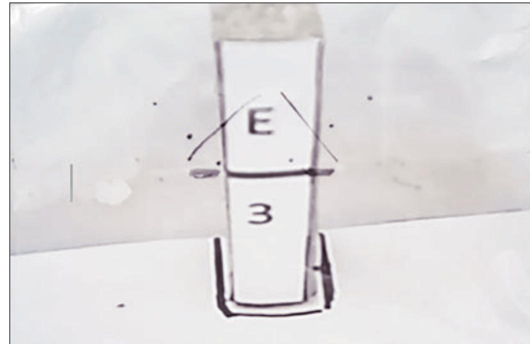


Figure 8. Alignment of line on wallet with line on sticker

Figure 9. Plastic wallet with black lines (indicated by red lines) to align with line on sticker

Figure 10. Minor error indicated by the dotted line matching with the box base (indicated by the 2 red arrows)

Figure 11. Major error indicated by the dotted line matching with the box base (indicated by the 2 red arrows)

Finally, participants were asked to fill a validity questionnaire on completion. After using the laparoscope and models, participants were asked to answer face-content questions. These questions were deemed appropriate based on previous validated questionnaires present in literature from Chertoff et al and Mc Doughal et al (28-29).

Results

Demographic Data

18 participants attended the study, 12 females and 6 males respectively with a mean age of 22.9 with 67% of participants being medical students. All participants were not aware of homemade laparoscopes or camera navigation models. *Table 3* and *4* summarises participant's demographic data.

Table 3. Demographic data results

	Number	%
Male	6	33
Female	12	67
Medic	12	67
Non-medic	6	33
Aware of homemade Laparoscopes?		
Yes	0	0
No	18	100
Aware of camera navigation training models?		
Yes	0	0
No	18	100
Aware of current camera handling training?		
Yes	1	6
No	17	95
Any previous training?		
Yes	0	0
No	18	100
Any gaming experience?		
Yes	6	33
No	12	67

Table 4. Age of participants

	Age
Mean	22.9
Median	23
Standard deviation	2.47

Homemade Laparoscope

The expenses involved in building the laparoscopes came from the mini CMOS camera, wood to attach it to and the PVC water pipeline tubing. The cost of the 0° laparoscope came to £25 and the 30°laparoscope was £20.

Upon using the laparoscopes, participants were asked to fill in the questionnaire used for face and content validation. Using a 10 point Likert scale, participants were asked about how easy it was to use, realistic, appropriate, fun and its use in training. *Table 5* indicates the participant's views.

The lowest mean value was 7.5 for how realistic the laparoscope appeared. Some expressed image quality needed improvement and taller participants felt the laparoscope length was shorter than expected. In terms of ease of use, appropriateness and fun, equal mean of 8.07 was obtained. Males in particular found the experience more enjoyable which may be due to all of them being gamers. The highest mean score, 8.8 was obtained for its use in laparoscopic training.

Another suggestion for improvement of laparoscopes was to provide a ridge instead of looking down for the neutral position to reorientate.

Laparoscopic Camera Navigation Model

No participant was aware of any camera navigation training models. Upon task completion, participants were asked to fill in the questionnaire used for face validation of the models. *Table 6*

Table 5. Questionnaire scores on homemade laparoscope

	Easy to use	Realistic	Appropriate	Fun/enjoyable	Used in training
Mean	8.1	7.5	8.1	8.1	8.8
Median	8	7	9	7	8
Standard Deviation	1.62	1.06	1.10	1.28	0.86

Table 6. Questionnaire scores on LCNM

	Easy to use	Realistic	Appropriate	Fun/enjoyable	Used in training
Mean	8.6	6.7	8.9	9.2	9.6
Median	9	6.5	9	10	10
Standard Deviation	1.69	2	1.00	1.35	0.51

indicates participant views. The lowest mean value was 6.7 for how realistic the models appeared. Additionally, the height at which the model was challenging for taller participants. Although the model received an average score of 9.2 for how fun/enjoyable the model seemed, unfortunately 3 of the participants suffered motion sickness. Especially with the 30° laparoscopic task which required them to take breaks in between or going outside.

In terms of ease of use and appropriateness, similar means were obtained. Although males did not perform better than females, they found the experience more enjoyable which may be due to all of them being gamers. The highest mean score 9.6 was obtained for its use in laparoscopic training.

Camera Navigation Tasks

0°Camera Navigation

As seen in *Table 7*, 17 participants completed the 0° navigation task. The quickest time was 122 seconds and the longest was 486 seconds. Participant 1 had the lowest average between the two attempts while participant 3 had the highest average. The mean time taken to complete the task improved by 72 seconds from attempt 1 (291) to attempt 2 (219). The tremor score had improved very slightly from 3.1 to 3.2. Majority of the participants maintained their tremor score between the two attempts.

0° Inline Orientation

Only 16 subjects were able to complete this task as seen in *Table 8*. The minimum time taken to complete the task was 41 seconds and the maximum was 97 seconds. Participant 2 had the lowest average between the two attempts while participant 10 had the highest. The mean time taken to complete the task increased by 1 second from attempt 1 (63) to attempt 2 (64). The tremor score improved slightly from 3.3 to 3.6. Most participants either maintained or improved their tremor score between the two attempts. Only 3 minor errors were present with attempt 1 and no errors with attempt 2.

0° Opposite Line Orientation

The minimum time taken to complete the task was 60 seconds and the maximum was 316 seconds as seen in *Table 9*. Participant 8 had the lowest average between the two attempts while participant 3 had the highest average. The mean time taken to complete the task improved by 37 seconds from attempt 1 (170) to attempt 2 (133). The tremor score had improved very slightly from 3.4 to 3.8. Majority of the participants had either maintained or improved their tremor score between the two attempts. 3 minor errors were recorded in attempt 1 but only 2 in attempt 2.

Fig. 12 compares the average time for inline and opposite line of horizontal orientation. The

Table 7. 0° camera navigation task results

Participant No	Attempt 1 (s)	Tremor Score 1	Attempt 2 (s)	Tremor Score 2	Average of attempt 1&2 (s)	Average of Tremor 1&2
1	130	4	122	5	126	4.5
2	203	3	152	3	178	3
3	397	2	221	3	508	2.5
4	303	4	271	4	287	4
5	180	4	179	4	180	4
6	424	3	291	3	358	3
7	250	2	333	2	292	2
8	311	3	136	3	224	3
9	360	2	241	2	301	2
10	355	2	266	2	311	2
11	138	4	122	4	130	4
12	186	4	181	4	184	4
13	274	3	188	3	231	3
14	296	3	233	4	265	3.5
15	486	2	301	1	394	1.5
16	445	3	355	3	400	3
17	206	4	127	4	167	4
Mean	291	3.1	219	3.2	267	3.7

Table 8. Inline orientation task results

Participant	Attempt 1	Tremor Score 1	Error:0/ Minor (m)/ Major(M)	Attempt 2	Tremor Score 2	Error:0/ Minor (m)/ Major(M)	Average of attempt 1&2	Average of Tremor 1&2
1	56	5	o	45	5	0	51	5
2	41	0	m	47	2	0	44	1
3	63	3	m	65	4	0	64	3.5
4	37	4	o	55	4	0	46	4
5	46	3	m	67	3	0	57	3
6	68	4	o	61	4	0	65	4
7	82	3	o	81	3	0	82	3
8	56	3	o	65	3	0	61	3
9	87	2	o	81	3	0	84	2.5
10	94	3	o	97	3	0	96	3
11	54	4	o	56	3	0	55	3.5
12	49	5	o	42	5	0	46	5
13	50	3	o	62	3	0	56	3
14	64	3	o	61	4	0	63	3.5
15	83	4	o	56	4	0	70	4
16	74	3	o	79	4	0	77	3.5
Mean	63	3.3		64	3.6		63	3.4

Table 9. 0° opposite line orientation task results

Participant	Attempt 1	Tremor Score 1	Error:0/ Minor (m)/ Major(M)	Attempt 2	Tremor Score 2	Error:0/ Minor (m)/ Major(M)	Average of attempt 1&2	Average of Tremor 1&2
1	56	5	o	45	5	0	51	5
1	115	4	o	118	4	0	116.5	4
2	165	3	m	221	4	m	193	3.5
3	316	3	o	175	4	0	245.5	3.5
4	141	4	o	162	4	0	151.5	4
5	183	4	o	139	4	0	161	4
6	177	4	o	116	4	0	146.5	4
7	160	3	o	173	3	0	166.5	3
8	60	3	o	76	3	0	68	3
9	199	3	m	201	3	0	200	3
10	130	3	o	60	3	0	95	3
11	102	4	o	57	4	0	79.5	4
12	74	4	o	104	4	0	89	4
13	189	4	o	132	4	0	160.5	4
14	227	3	o	102	4	0	164.5	3.5
15	280	3	m	110	4	m	195	3.5
16	200	3	o	180	4	0	190	3.5
Mean	170	3.4		133	3.8		151	3.6

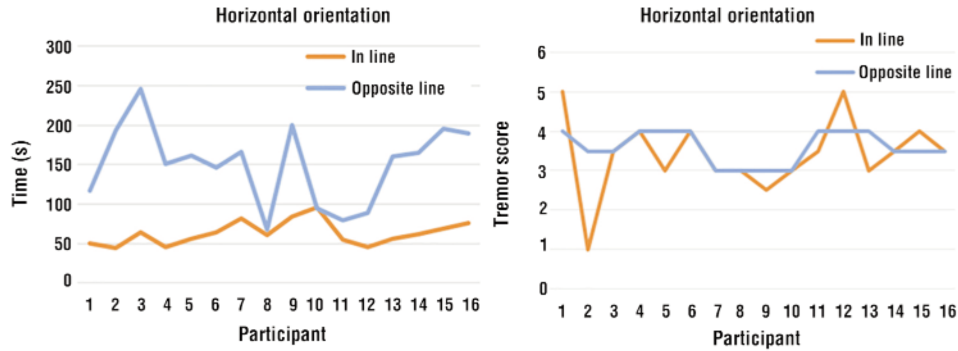
general trend indicates the time taken for completing the task in opposite is greater than in line. Participant 10 however is an anomaly which does not follow the general trend. The inline orientation is longer than opposite by 0.5 seconds.

It also compares the average tremor score for inline and opposite line of horizontal orientation. Whilst there is no general trend, the tremor score fluctuates far more for inline than opposite. Opposite line maintains a tremor score within the range of 3 to 4. Having said this, 10 participants achieved the same tremor score for both tasks.

30° Camera Navigation

The minimum time taken was 59 seconds and the maximum 320 seconds as seen on *Table 10*. Participant 17 had the lowest average between the two attempts while participant 15 had the highest average. The mean time taken to complete the task improved very slightly by 5 seconds from attempt 1

Figure 12. Comparison of time (left) and tremor (right) between inline and opposite line orientation



(137) to attempt 2 (132). The tremor score improved very slightly from 3.5 to 3.7. Majority of the participants maintained their tremor score between the two attempts. Error score had either stayed the same or improved from attempt 1 to 2. As seen in *Fig. 13*, from attempt 1 to 2, the number of major errors had decreased to 0 and minor errors decreased by one. This in turn resulted in a decrease in the number of errors from attempt 1 to 2.

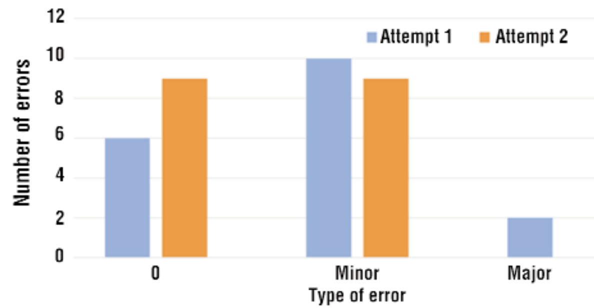


Figure 13. 30° camera navigation error results

Discussion

This project aimed to create 0° and 30° homemade laparoscopes, design a camera navigation model, and conduct face and content validation using navigation tasks.

Homemade Laparoscope

The 0° model cost £25 and the 30° model £20. Face

Table 10. 30˚ camera navigation task results

Participant	Attempt 1	Tremor Score 1	Error:0/ Minor (m)/ Major(M)	Attempt 2	Tremor Score 2	Error:0/ Minor (m)/ Major(M)	Average of attempt 1&2	Average of Tremor 1&2
1	91	5	o	92	4	o	92	4.5
2	111	3	m	113	4	m	112	3.5
3	118	3	m	113	3	m	116	3
4	134	4	m	78	4	o	106	4
5	97	3	m	71	4	m	84	3.5
6	100	4	m	120	5	o	110	4.5
7	158	3	M	140	3	m	149	3
8	82	3	m	82	4	o	82	3.5
9	274	3	M	223	3	m	249	3
10	138	3	m	193	3	m	166	3
11	115	4	m	59	4	m	87	4
12	82	4	o	73	4	o	78	4
13	205	3	m	311	3	m	258	3
14	136	4	o	82	4	o	109	4
15	320	3	m	276	3	m	298	3
16	120	3	o	202	3	o	161	3
17	78	4	o	72	4	o	75	4
18	100	4	o	68	4	o	84	4
Mean	136.6	3.5		131.6	3.7		134	3.6

validity scores were positive, with all aspects averaging at least 7.5. The lowest score (7.5) was for realism.

Participants found the 35 cm laparoscope short, though it reflects standard dimensions. In clinical use, zoom and focus features improve usability. For homemade models, adding zoom may be a better solution than adjusting length, despite higher cost. A tactile ridge to indicate the neutral position was also suggested for better orientation.

While zoom suffices for a 0° scope, the 30° model needs more functionality to replicate real instruments. A standard 30° laparoscope can rotate in four planes and allows independent movement of optical fibers. The homemade version lacks this, limiting realism.

Participants raised concerns about image quality. Despite a 5MP camera with 5 lux lighting, it could not match the clarity of fiber optic laparoscopes. Upgrading to a higher-quality camera could improve this.

Despite laparoscopes being in use since the 1930s, few homemade versions exist. A review of four databases found only four studies creating laparoscopes-none validated (see *Table 11*).

- Pokorny et al. used a CMOS sensor for NZ$170 (£88), allowing angle adjustment between 0° and 90° (30).
- Daniel et al. built a similar 0-30° adjustable model for US$170 (£135), which included a trainer box (20).
- Al-Abed et al. created a 0° scope using a webcam and separate light source, costing £40 with the model included (31).
- Rivas et al. used a micro-CMOS camera for a 30° scope but lacked price data and the paper was not in English (32).

While hinges in Pokorny and Daniel's models offered more movement, they also made the camera external, reducing realism. Al-Abed's design mimicked a separate light source but was bulky and loosely assembled (30-32).

Laparoscopic Camera Navigation Model

The Laprotrain box (£2748) can be substituted with a cardboard or plastic box, and Jenga blocks can be replicated using wood. While foam was a low-cost option for simulating skin, it proved flimsy-neoprene is preferred.

Despite high scores for ease of use (8.6) and enjoyment (9.2), three participants experienced motion sickness. Future studies should inform participants of this risk.

Most camera navigation models, except VBLaST, don't involve 360° movement or off-axis navigation (33). Though advanced surgeries rarely require such skills, they are essential in diagnostic laparoscopy or procedures like colorectal surgery, where the camera may need to operate opposite the body's orientation.

Despite the risk of motion sickness, early exposure before surgery is beneficial. The low-cost Jenga-based setup replicates virtual simulators at a fraction of the cost, something even validated models like LASTT and HYSTT lack. The model scored 6.7 for realism, but both medical and non-medical users struggled with realism without anatomical knowledge. A brief overview could help. Additionally, model height impacted posture and performance, suggesting a height-adjustable table could enhance usability.

Camera Navigation Tasks

Camera Navigation

Navigation times improved by an average of 72 seconds between attempts. While familiarity with positions could influence results, participants navigated in different directions, and Jenga blocks can be rearranged to reduce bias. Some found letters easier than numbers, likely because they were printed on the upper half, requiring less navigation. Future designs could mix letters and numbers to balance difficulty. The LASTT model's sequential combination (e.g: A5 → 5B → B7)

Table 11. Summary of homemade laparoscopes in research

	Camera	Price (£)	Angle (˚)
Pokorny et al (59)	CMOS sensor	88	0-90
Daniel et al (60)	CMOS sensor	135 (including training model)	0-30
Al-abed et al (61)	webcam	40 (including training model)	0
Rivas et al (62)	CMOS sensor	n/a	30
Homemade laparoscope 1	CMOS sensor	25	0
Homemade laparoscope 2	CMOS sensor	20	30

may confuse users and limit variation. Most participants showed stable or improved tremor scores, likely due to increased familiarity with the task.

Inline/Opposite Orientation

Inline orientation was completed faster, even with two more blocks to align. Opposite orientation had a steeper learning curve, though two participants performed better in this mode, suggesting individual variation worth exploring.

Inline tremors fluctuated more, possibly due to overconfidence, while opposite orientation saw greater focus and control due to increased difficulty.

30° Task

Only a 5-second improvement was observed, suggesting participants didn't rely on memory. Varying completion times (59-230 seconds) highlight task difficulty and individual differences in overcoming the learning curve. Tremor scores improved between attempts, indicating growing comfort.

Most participants struggled with maintaining a horizontal view-expected due to the angled scope. However, performance improved with training, showing this challenge can be overcome. Maintaining horizon is essential for surgical performance and avoiding motion sickness.

Conclusions

Inexpensive homemade laparoscopes and LCNM offer a viable alternative to commercial models, allowing surgical trainees to practice at home. However, further modifications are needed to improve the designs. More research is required, as existing studies are limited. The next step is to recruit more experienced participants to assess construct validity.

Recommendation and Future Proposal:

- Create homemade angled laparoscope to replicate the 360° rotation provided by the optical fiber;
- Ensure LCNM is fully homemade and make amendments to improve model quality;
- Change positions of letter/number combinations to prevent memorising of order;
- Avoid subjectively measuring tremor and error scores, objective measurements using technology would be more accurate;
- Follow up study upon these improvements;
- Re-examine same participants on the tasks 3 months after to assess skill retention and skill improvement;
- Construct validation with novices, intermediates and experts of the laparoscopes and models.

Author's Contributions

All the authors have read and approved the final version of the manuscript. Kayaththery Varathan, Adele Zacken and Havil Stephen Alexander Bakka have contributed equally to the paper and should be considered joint first authors.
Kayaththery Varathan: Drafting of manuscript, acquisition, analysis or interpretation of data, concept and design and critical review of the manuscript for important intellectual content.
Adele Zacken: Drafting of manuscript, acquisition, analysis or interpretation of data, concept and design and critical review of the manuscript for important intellectual content.
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Tharaga Kirupakaran: Drafting of manuscript, acquisition, analysis or interpretation of data, concept and design.
Mustafa Albayati: Drafting of manuscript, acquisition, analysis or interpretation of data, concept and design.
Uzair Khan: Drafting of manuscript, acquisition, analysis or interpretation of data.
Sanjeevi Bharadwaj: Drafting of manuscript, acquisition, analysis or interpretation of data.

Conflicts of Interest

The authors declare no conflicts of interests.

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