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A systematic review of facial plastic surgery simulation training models

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Review Article

Dr M A Mohd Slim takes responsibility for the integrity of the content of the paper

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Abstract

Objectives. The coronavirus disease 2019 pandemic has led to a need for alternative teaching methods in facial plastics. This systematic review aimed to identify facial plastics simulation models, and assess their validity and efficacy as training tools.

Methods. Literature searches were performed. The Beckman scale was used for validity. The McGaghie Modified Translational Outcomes of Simulation-Based Mastery Learning score was used to evaluate effectiveness.

Results. Overall, 29 studies were selected. These simulated local skin flaps ($n = 9$), microtia frameworks ($n = 5$), pinnaplasty ($n = 1$), facial nerve anastomosis ($n = 1$), oculoplastic procedures ($n = 5$), and endoscopic septoplasty and septorhinoplasty simulators ($n = 10$). Of these models, 14 were deemed to be high-fidelity, 13 low-fidelity and 2 mixed-fidelity. None of the studies published common outcome measures.

Conclusion. Simulators in facial plastic surgical training are important. These models may have some training benefits, but most could benefit from further assessment of validity.

Introduction

In traditional surgical training, the trainee acts as an apprentice to a senior surgeon. In the UK, surgical training competencies are now more explicitly laid out. Working hours are also limited by the European Working Time Directive,[1] potentially leading to reduced exposure to surgical procedures.

The coronavirus disease 2019 (Covid-19) pandemic has led to a reduction in operative exposure, particularly for facial plastics. In the UK, all non-essential elective surgery stopped, and most facial plastic surgery has ceased. Indeed, only skin cancer operations are regarded as sufficiently high priority.[2] Following commencement of elective activity, facial plastics operative numbers are likely to be reduced because of extra precautions in the operating theatre and patients wishing to avoid elective surgery in a 'high Covid risk' environment. In addition, workforce mobilisation and redeployment are likely to continue, impacting surgical training.[3]

The concept of the 'learning curve' in surgery is familiar to every practising surgeon.[4,5] For example, Yeolekar and Qadri reported a mean of 76.66 open septorhinoplasties required to achieve proficiency.[6] Surgical performance improves with experience.

Human cadaveric dissection offers the most effective method of training without real patient exposure; however, this is not always available. Surgical simulation is a way to help address this skills gap, particularly in the context of reduced operative numbers. In view of this, we conducted a systematic review to evaluate current facial plastics themed simulation models by assessing their validity and level of effectiveness. Human cadaveric dissection was outside the scope of this review. It is hoped that this systematic review will assist readers to choose simulators to ensure skill maintenance and provide alternative training.

Methods

Protocol

A review protocol was developed (available online at the following website: https://osf.io/qyvkf/?view_only=a1436d90c8b94b16a875aa5c5e45f93c).

Literature search

Literature searches were conducted independently by two authors (MAMS and RH), using PubMed, Embase, Cochrane, Google Scholar and Web of Science databases, between 1 April 2020 and 10 May 2020. Searches were performed using the combination of Boolean logic 'AND' and 'OR' with the following key word search terms: 'simulation', 'simulations', 'reconstruction', 'auricle', 'pinna', 'ear', 'blepharoplasty', 'facial nerve', 'facial', 'nerve', 'resurfacing', 'plastic', 'facial plastic', 'animation', 'reanimation', 're-animation', 'lip', 'malar', 'augmentation', 'chin', 'mentoplasty', 'nose', 'pinnaplasty',

Table 1. Beckman validation rating scale[7]

Beckman scale		Description of validity method applied in this systematic review		
Rating	Description	Face	Content	Construct
N	No evidence of source validity discussion	No evidence of source validity discussion	No evidence of source validity discussion	No evidence of source validity discussion
0	Source validity discussed, but no data presented	No formal evaluation of face validity	No formal evaluation of content validity	No formal evaluation of construct validity
1	Weak or limited supportive data	Questionnaire evaluation of face validity	Questionnaire evaluation of content validity	Single method used to evaluate construct validity
2	Data strongly support source of validity	Comprehensive face validity assessment (e.g. application of a threshold, comparison to alternative model or 'gold standard')	Comprehensive content validity assessment (e.g. application of a threshold, comparison to alternative model or 'gold standard')	>1 method used to evaluate construct validity

Table demonstrates the method by which the authors evaluated studies using the Beckman validation rating scale. Face validity reflects the extent of a model's realism; content validity represents the extent to which the steps undertaken on the model reflect the real environment; and construct validity signifies the extent to which the model discriminates between different levels of expertise.

'otoplasty', 'rhinoplasty', 'septoplasty', 'septorhinoplasty', 'rhytidoplasty', 'rhytidectomy', 'lift', 'flap' and 'flaps'. References were also reviewed.

Article selection

Titles and abstracts were screened by two authors (MAMS and RH) independently based on the agreed criteria. Non-English-language studies, conference posters and presentations, results with no abstract, and non-facial plastics themed training simulator studies were excluded. Articles reviewing free flap simulation models were also excluded from this review. No limits were applied regarding publication year, publication status or type of study for the data synthesis in this systematic review. Any disagreement regarding selection status was resolved by discussion. If consensus could not be reached, a third and final opinion from the senior author (TDM) was obtained.

Data synthesis and extraction

Data from the selected studies were extracted by one author (MAMS) and revalidated by the others (RH, ML, SO and TDM). The model type, material used, procedure simulated, simulator fidelity, simulator cost, model validation, and information regarding progress assessment, comparative assessment and reliability assessment were obtained.

Progress assessment evaluates evidence of skills progression with the simulator (measured by either the user or the assessor). Comparative assessment assesses performance across different sessions or between different simulators. Reliability assessment evaluates the impact on the user's skills according to their experience.

Table 2. McGaghie Modified Translational Outcomes of Simulation-Based Mastery Learning score[8]

Parameter	Definition	Level of effectiveness
Internal acceptability	Trainee's satisfaction with using simulator	1
Contained effects	Changes in performance in simulation context	2
Downstream effects	Behaviour changes in clinical context	3
Target effects	Direct changes to patient outcomes	4
Collateral effects	Changes on wider, systemic level	5

Face validity (the extent of a model's realism), content validity (the extent to which the steps undertaken on the model represent the real environment) and construct validity (the extent to which the model discriminates between different levels of expertise) were assessed using the Beckman rating scale (Table 1).[7]

The McGaghie Modified Translational Outcomes of Simulation-Based Mastery Learning score was used to evaluate the level of effectiveness of each model in simulating the intended task (Table 2).[8]

Traditionally, fidelity has been classified as high (high technology requirement with conformity to human anatomy) or low (low technology requirement with less conformity to human anatomy), and we adopted this assessment in our study.[9]

The study was designed as a descriptive systematic review, aiming to provide a qualitative assessment of facial plastic surgery models. Because of the nature of the studies analysed, no quantitative analysis (e.g. meta-analysis) was feasible.

Risk of bias for eligible studies was assessed independently by two senior authors (TDM and SO) using the Joanna Brigg's Institute critical appraisal checklist for quasi-experimental studies.[10]

Results

A total of 749 unique studies were identified (Figure 1).[11] Of these, 29 studies[12–40] were selected (Tables 3 and 4), which simulated local skin flaps ($n = 9$), microtia framework ($n = 5$), pinnaplasty ($n = 1$), oculoplastic procedures ($n = 5$), facial nerve re-animation ($n = 1$), and endoscopic septoplasty and septorhinoplasty ($n = 10$). The simulation model fidelity was classified as low in 13 studies, high in 14 studies, and there were 2 mixed-fidelity simulators (Table 3). The materials used included animal tissue ($n = 19$), synthetic materials ($n = 10$), vegetables ($n = 1$) and pastry sheets ($n = 1$).

Risk of bias assessment

Of the studies that performed analysis of model suitability,[12,15,17,21,23,31,38,40] five studies had a low risk of bias, one

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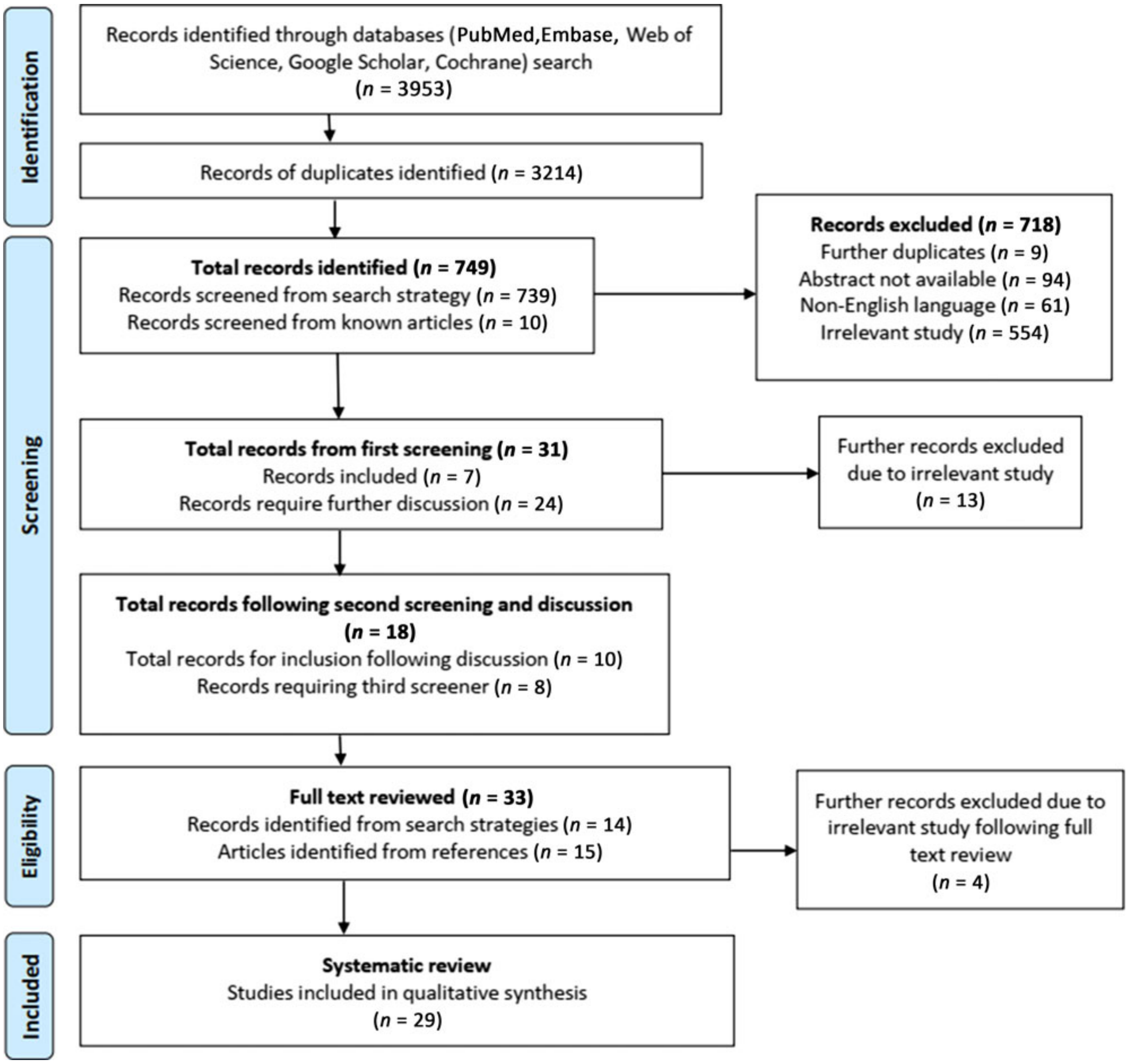

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses ('PRISMA') flow chart.[11]

had a medium risk of bias, and two studies had a high risk of bias (Table 5). Because of the nature of this systematic review's aims, all studies were included for analysis despite some being ineligible for risk of bias assessment.[10]

Local flaps

Nine studies[12–20] (Table 3) were identified as training simulators for local random-pattern flaps. Most of the simulated transposition flaps were Z-plasty[14–20] and rhomboid flaps.[12,13,15,16] Advancement flaps were simulated in three studies[13,16,20] and rotational flaps in four studies.[15–17,20] Seven studies were judged to have clear instructions to enable replication,[13–17,19,20] with four disclosing costs[14–16,18] (Table 3). Denadai *et al.* assessed a mix of high- and low-fidelity models based on the traditional definitions, and identified no difference in post-test outcomes between models of different fidelity.[12]

Three of the studies[12,15,17] measured their model's validity, each demonstrating a Beckman score of 1 for face and content validity. Only two studies[12,17] demonstrated a Beckman score of 1 for construct validity (Table 3). Only three studies were suitable for assessment according to the McGaghie's translational outcome assessment scale; two of these studies[12,17] scored 2 (measuring changes in performance in a simulation context) and one study[15] achieved a score of 1 (participant satisfaction). Only one simulator[15] was validated by expert-level users; meanwhile, five other studies[12,16–18,20] were validated by novice users (medical students to surgical residents). Amongst the studies assessing local flaps, four provided outcome assessments. Two studies[15,19] performed progress assessments alone, while two studies[12,17] analysed progress, reliability and comparative outcomes (Table 4).

Microtia framework

Five simulators (Table 3) for microtia framework[21–25] were identified. Three simulate Brent's framework,[22,24,25] one Nagata's framework,[23] and one simulates both Brent's and Tanzer's frameworks.[21] Models utilised either animal by-products,[21,24] synthetic material[22,23] or vegetable matter[25] (Table 3). Two simulators[21,23] were deemed high-fidelity

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Table 3. Types of facial plastic surgery simulator studies

Study (year)	Procedure simulated	Model type	Tissue or material used	Fidelity	Cost (GBP)	Construct information available?
Denadai *et al.* (2014)[12]	Local flap: rhomboid flap	Synthetic & animal (chicken or pig)	5 groups: (1) didactic teaching, (2) rubberised line, (3) ethylene vinyl acetate, (4) chicken leg skin & (5) pig's trotter skin	Mix	Not available	Not available
Chawdhary & Herdman (2015)[13]	Local flap: bilobed, O–Z, A–T, rhomboid flap	Pastry sheets	Ready rolled pastry sheets	Low	Not available	Yes
Sillitoe & Platt (2004)[14]	Local flap: Z-plasty	Synthetic	Thermoplastic frame, attached to wooden base with 5 screws, with neoprene sheet attached	Low	£4.61	Yes
Kite *et al.* (2018)[15]	Local flaps: rhomboid flap, bilobed, rotational, Z-plasty, forehead flap, nasolabial flap	Synthetic	Foam core with multilayer silicone layers	Low	£108–144	Yes
Denadai & Kirylko (2013)[16]	Local flaps: rhomboid flap, Z-plasty, W-plasty, banner flap, bilobed flap, rotational flap, V–Y plasty, A–T plasty	Synthetic	2.5 mm thick laminated plates composed of rubber (flattened pure polyvinyl chloride) reinforced with mesh (polyester & cotton)	Low	£4.71 per m^2	Yes
Altinyazar *et al.* (2003)[17]	Local flaps: Z-plasty & rotational flap	Animal – rat	Rat skin with cotton material underneath, anchored on different shape of wooden plates	High	Not available	Yes
Kuwahara & Rasberry (2000)[18]	Local flaps: Z-plasty, bilobed flap, transposition flap	Animal – pig	Pig head	High	£7.96	Not available
Loh & Athanassopoulos (2014)[19]	Local flaps: Z-plasty	Animal – chicken	Chicken foot webspace	High	Not available	Yes
Camelo-Nunes (2005)[20]	Local flaps: advancement, transposition, rotational & interpolation flaps	Animal – ox	Ox tongue	High	Not available	Yes
Agrawal (2015)[21]	Microtia reconstruction – Brent framework	Animal – ox	Ox scapula	High	Not available	Yes
Erdogan *et al.* (2018)[22]	Microtia reconstruction – Brent framework	Synthetic	Plastic eraser	Low	£2.90	Yes
Murabit *et al.* (2010)[23]	Microtia reconstruction – Nagata framework	Synthetic	Silicone	High	Not available	Not available
Shin & Hong (2013)[24]	Microtia reconstruction – Tanzer & Brent framework	Animal – pig	Pig rib	Low	£7.24–10.86	Yes
Vadodaria *et al.* (2005)[25]	Microtia reconstruction – Brent framework	Vegetable – sweet potato	Sweet potato	Low	Current market price	Yes
Uygur *et al.* (2013)[26]	Pinnaplasty, oculoplastic procedure	Animal – sheep	Sheep head	Low	Not available	Yes
Zou *et al.* (2012)[27]	Oculoplastic procedure	Animal – pig	Pig's eyelid	Low	Not available	Alive animal

Pfaff (2004)[28]	Oculoplastic procedure	Animal – pig	Pig eyelid above rubber ball anchored with screws on cutting board	Low	Not available	Yes
Kersey (2009)[29]	Oculoplastic procedure	Animal – pig	Pig head	Low	Not available	Yes
Ianacone *et al.* (2016)[30]	Oculoplastic (OP) procedure & facial nerve anastomosis (FN)	Animal – sheep	Sheep head	Low for OP; high for FN	Not available	Yes
Oh *et al.* (2019)[31]	Septorhinoplasty	Synthetic (3D printed) & animal (pig)	Pig costal cartilage mounted on 3D printed septal cartilage with human plastic skull	Low	Not available	Yes
Zammit *et al.* (2020)[32]	Septorhinoplasty	Synthetic – 3D printed	CT-based 3D printed mould using polyvinyl acetate dissolvable support for bone, mixture of Rigur 450 & Tango plus PolyJet material for cartilage, & Smooth-On Dragon Skin for skin	High	£40.55	Yes
Zabaneh *et al.* (2009)[33]	Septorhinoplasty	Synthetic – 3D printed	Silicone cast using CT-based 3D mould	High	Not available	Yes
Dini *et al.* (2012)[34]	Septorhinoplasty	Animal – sheep	Sheep head	High	Not available	Yes
Weinfeld (2010)[35]	Septorhinoplasty	Animal – chicken	Chicken sternal cartilage	Low	Not available	Yes
Dini *et al.* (2012)[36]	Septorhinoplasty	Animal – sheep	Sheep head	High	Not available	Yes
Touska *et al.* (2013)[37]	Endoscopic septoplasty	Animal – lamb	Lamb head	High	£13.76	Yes
Mallmann *et al.* (2016)[38]	Endoscopic septoplasty	Animal – lamb	Lamb head	High	Not available	Yes
Gardiner *et al.* (1996)[39]	Endoscopic septoplasty	Animal – sheep	Sheep head	High	£4.34	Yes
AlReefi *et al.* (2017)[40]	Endoscopic septoplasty	Synthetic – 3D printed	CT-based 3D printed mould, VeroWhitePlus RGD835 material for bony structures, TangoPlus FLX930 material for skin & mucous membrane	High	£101.37	Yes

3D = three-dimensional; CT = computed tomography
GBP = British pound;

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Table 4. Validation evaluation of facial plastic surgery simulator studies

	Validation assessment							
Study (year)	Validity parameter	Beckman score for parameter	Comparative assessment?	Number of participants	Type of participants	Progress assessment	Reliability assessment	McGaghie modified translational outcomes of simulation-based mastery learning score
Denadai *et al.* (2014)[12]	Face	1	Yes	60	Novices: 1st & 2nd-year medical students	Pre- & post-study self-perceived confidence (Likert scale 1–5). Objective assessment using Global Rating Scale between initial & final simulation dissection	Comparing didactic teaching against 2 models. No assessments based on level of surgical experience	2
	Content	1						
	Construct	1						
Chawdhary & Herdman (2015)[13]	Face	0	No	Not available	Not available	None	Not available	0
	Content	N						
	Construct	0						
Sillitoe & Platt (2004)[14]	Face	0	No	Not available	Not available	None	Not available	0
	Content	N						
	Construct	0						
Kite *et al.* (2017)[15]	Face	1	No	13	Experts & novices: 9 plastic surgery residents, 2 attendings, 1 general surgery trained burn fellow, & 1 plastic surgery nurse practitioner	7 pre- & post-questionnaires; Likert scale 1–10	Not available	1
	Content	1						
	Construct	0						
Denadai & Kirylko (2013)[16]	Face	0	No	Not available	Novices: medical students	None	Not available	0
	Content	N						
	Construct	0						
Altinyazar *et al.* (2003)[17]	Face	1	Yes	33	Novices: interns & 1st-year residents	Subjective expert scoring system; ranked 1–5 between 2 sessions	Comparing residents to interns	2
	Content	1						
	Construct	1						
Kuwahara *et al.* (2000)[18]	Face	0	No	Not available	Novices: surgical trainees	None	Not available	0
	Content	N						
	Construct	0						
Loh & Athanassopoulos (2014)[19]	Face	0	No	Not available	Not available	Against other toes webspace depth	Not available	0
	Content	N						
	Construct	0						
Camelo-Nunes (2014)[20]	Face	0	No	Not available	Novices: medical students	None	Not available	0
	Content	N						
	Construct	0						

Agrawal (2015)[21]	Face	0	No	22	Novices: surgical trainees	None	Not available	1
	Content	N						
	Construct	0						
Erdogan *et al.* (2018)[22]	Face	0	No	5 (co-authors)	Experts: established surgeons	None	Not available	0
	Content	N						
	Construct	0						
Murabit *et al.* (2010)[23]	Face	0	Yes	12	Novices to experts: 1st-year resident to fellows	Likert score & VAS (score 0–10) evaluation by 3 experienced ear reconstructive surgeons, from 2 centres, over 3 consecutive assessments	Comparing workshop training *vs* self-directed learning	2
	Content	N						
	Construct	1						
Shin *et al.* (2013)[24]	Face	0	No	12	Not available	None	Not available	0
	Content	N						
	Construct	0						
Vadodaria *et al.* (2005)[25]	Face	0	No	10	Novices: plastic surgical trainees	None	Not available	0
	Content	N						
	Construct	0						
Uygur *et al.* (2013)[26]	Face	0	No	Not available	Not available	None	Not available	0
	Content	0						
	Construct	0						
Zou *et al.* (2012)[27]	Face	0	No	Not available	Not available	None	Not available	0
	Content	0						
	Construct	0						
Pfaff (2004)[28]	Face	0	No	Not available	Not available	None	Not available	0
	Content	N						
	Construct	0						
Kersey (2009)[29]	Face	0	No	Not available	Not available	None	Not available	0
	Content	N						
	Construct	0						
Ianacone *et al.* (2016)[30]	Face	0	No	Not available	Not available	None	Not available	0
	Content	0						
	Construct	0						
Oh *et al.* (2019)[31]	Face	1	No	22	Experts & novices: 10 ENT residents & 12 practising facial plastic surgeons	None	Time to complete task, path length travelled & hand movements	1
	Content	1						
	Construct	2						

(*Continued*)

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Table 4. (*Continued.*)

Study (year)	Validation assessment							McGaghie modified translational outcomes of simulation-based mastery learning score
	Validity parameter	Beckman score for parameter	Comparative assessment?	Number of participants	Type of participants	Progress assessment	Reliability assessment	
Zammit *et al.* (2020)[32]	Face	0	No	2	Experts: senior author & anatomist	None	Not available	0
	Content	0						
	Construct	0						
Zabaneh *et al.* (2009)[33]	Face	0	No	Not available	Not available	None	Not available	0
	Content	0						
	Construct	0						
Dini *et al.* (2012)[34]	Face	0	No	Not available	Not available	None	Not available	0
	Content	0						
	Construct	0						
Weinfeld (2010)[35]	Face	0	No	Not available	Not available	None	Not available	0
	Content	0						
	Construct	0						
Dini *et al.* (2012)[36]	Face	0	No	Not available	Not available	None	Not available	0
	Content	0						
	Construct	0						
Touska *et al.* (2013)[37]	Face	0	No	Not available	Not available	None	Not available	0
	Content	0						
	Construct	0						
Mallmann *et al.* (2016)[38]	Face	1	Yes	10	Experts & novices: 4 1st-year ENT residents, 4 2nd-year ENT residents & 2 consultants	Perceived median satisfaction score & difficulty performing each procedure. 3 sequential model dissections	Analysis between different grades	1
	Content	1						
	Construct	1						
Gardiner *et al.* (1996)[39]	Face	0	No	Not available	Not available	None	Not available	0
	Content	0						
	Construct	0						
AlReefi *et al.* (2017)[40]	Face	1	No	20	8 experts, 6 senior trainees, & 6 junior trainees	None	Analysis between grades for performance metrics, time spent, & post-simulation performance	1
	Content	1						
	Construct	2						

VAS = visual analogue scale

Table 5. Joanna Briggs Institute checklist for quasi-experimental studies' risk of bias[10]

Study (year)	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Overall judgement of risk of bias
Denadai *et al.* (2014)[12]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low
Kite *et al.* (2018)[15]	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	High
Altinyazar *et al.* (2003)[17]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low
Agrawal (2015)[21]	Yes	Unclear	Yes	No	No	Yes	Unclear	No	No	High
Murabit *et al.* (2010)[23]	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Medium
Oh *et al.* (2019)[31]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low
Mallmann *et al.* (2016)[38]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low
AlReefi *et al.* (2017)[40]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low

while the other three[22,24,25] were low-fidelity (Table 3). All studies disclosed sufficient reproducible construct methods to enable replication, except Murabit *et al.*[23]

Two of the simulators were evaluated by expert-level users.[22,23] Two studies[21,23] included translational assessments according to the McGaghie's assessment scale (Table 4). Validation assessment amongst the studies was limited, with only Murabit *et al.*[23] attempting to assess construct validity of the models (Beckman score of 1). None of the studies attempted face or content validation of their models. Similarly, only Murabit *et al.*[23] performed progress, reliability and comparative assessments.

Pinnaplasty

One low-fidelity, animal-based model for pinnaplasty[26] was identified (Tables 3 and 4). This study utilised a sheep's head and described the simulated procedure; however, there were no assessments of the model's effectiveness.[26]

Oculoplastic techniques

Simulators addressing oculoplastic techniques such as eyelid laceration repair, eyelid reconstruction, ptosis repair, tarsorrhaphy, blepharoplasty and lateral tarsal strip were identified in five studies[26–30] (Table 3). All studies utilised animal models: three porcine[27–29] and two ovine[26,30] (Table 3). All models were deemed to be low-fidelity. The porcine models did not have a lower eyelid or a lateral bony orbital wall. However, histological assessment did demonstrate a high degree of similarity to human tissue.[28,29] Similarly, the sheep model has a more angulated orbital floor and low orbital fat pad volume.[30] None of the five studies performed any evaluation of translational outcomes, effectiveness or validity.

Facial nerve anastomosis

Only one model simulated the techniques required for facial nerve dissection and anastomosis.[30] This sheep model was deemed to be high-fidelity because of the close resemblance of the sheep facial nerve to the human facial nerve. No assessments of effectiveness, translational outcomes or validity were performed in this study.

Endoscopic septoplasty and septorhinoplasty

Six animal simulators,[34–39] three synthetic three-dimensional (3D)-printed simulators,[32,33,40] and one mixed synthetic and animal simulator[31] were identified for endoscopic septoplasty and septorhinoplasty (Table 3). All synthetic 3D-printed simulators[31–33,40] were based on computed tomography scans of human facial skeletons. Of the animal models studied, five were ovine[34,36–39] and one study utilised chicken sternal cartilage for cartilage grafting.[35] The mixed model[31] utilised porcine cartilage mounted on plastic. Four models simulated endoscopic septoplasty.[37–40] All studies disclosed detailed instructions on construction to enable replication, but only four studies[32,37,39,40] disclosed the costs involved (Table 4).

Of the 10 studies evaluated, only 3 (2 endoscopic septoplasty simulators[38,40] and 1 septorhinoplasty simulator[31]) performed outcome assessments (Table 4). Mallmann *et al.*[38] performed comparative, progress and reliability assessments while evaluating an endoscopic septoplasty simulator; the remaining two studies[31,40] performed only a reliability assessment. A comprehensive assessment of construct validity (Beckman score 2) was performed in two studies,[31,40] which used multiple assessment parameters. Face and content validity assessments were less robust, with all three studies that performed analyses[31,38,40] achieving Beckman scores of 1. Translational outcomes scores of 1 were achieved by all three of these studies.[31,38,40] Eight studies[32–34,36–40] were deemed high-fidelity, while the other two[31,35] were low-fidelity (Table 3).

Discussion

This review has identified a broad range of facial plastics simulators. Most described the construction or design of simulators without formal assessment or validation of models. Only seven training simulator models[12,15,17,23,31,38,40] show acceptable face, content and/or construct validity. Two demonstrated robust validation assessments (Beckman score of 2), but this was solely in the evaluation of construct validity.[31,40] Translational outcomes evaluation was similarly limited, being performed in only eight studies.[12,15,17,21,23,31,38,40] Three studies[12,17,23] demonstrated progressive development of simulation skills, amounting to a McGaghie score of 2 (Table 4). While a wide range of models are being developed, few are validated or adequately assessed, or can be confirmed to result in translational outcomes.

Simulation training is widely used across all surgical specialties to augment clinical training. It allows trainees to practise in a safe environment, improve skill acquisition and receive objective feedback.[41] In order to justify an increased investment in simulation in the surgical training curriculum, new models need to be fully evaluated and demonstrate their efficacy as a training tool. At present, simulation training is

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important because of a reduction in elective operating during the Covid-19 pandemic. The next generation of surgeons may be able to address some of this training deficit with access to effective simulation models.

The limited objective evaluation demonstrated in this systematic review reflected a missed opportunity in simulation development. Objective and subjective parameters should be used to provide feedback and assess the trainees' progression, enabling self-directed learning. For example, the evaluation of hand movements may allow the trainee to evaluate their own economy of movement. The evaluation of technical proficiency has been poor historically.[42] Feedback from expert surgeons should still be the primary method of evaluation and incorporated into simulation training.

Many materials are used in surgical simulation.[43] These vary in terms of fidelity (Table 4). While high-fidelity models are generally preferred because of their realism,[44] low-fidelity models can be effective when used in an appropriate setting. For example, in the development of basic surgical skills, the low-fidelity simulators were as equally effective as the high-fidelity models.[8] Therefore, the model material and its fidelity can be customised to the specific task.

Animal models were used in 19 studies and are advantageous for several reasons. They provide realistic tissue handling and are relatively low cost. For example, pig trotters are widely used in skin flap simulation, although the evidence for their use is limited.[12] The use of animal tissue requires a dedicated training environment, and the use of animals requires ethical consideration.[45] For example, the use of live animals here would not conform to Animal Research: Reporting of In Vivo Experiments guidelines for animal research.[27,46] The authors of this study would suggest the use of animal waste products, avoiding unnecessary *in vivo* experimentation on animals. This is important, as the data in support of live animals are poor.[28–30,47]

Most synthetic models in this review were low-fidelity. However, the use of 3D-printed models, as described by AlReefi *et al.*,[40] allows the creation of high-fidelity models without the logistical challenges presented by animal models. Synthetic models can be stored, transported and disposed of with greater ease, and simulation can be conducted in any environment. The main disadvantage is that they are relatively expensive to produce.

The main aim of any simulator is to ensure the delivery of translational outcomes. Integration of clinical outcomes into a simulation training model assessment is important to enable the cascade of knowledge from the simulated to the real environment.[48] While it will always be challenging to assess the benefit of simulation in improving clinical care, future facial plastic surgery simulation training should consider the feasibility of evaluating models according to their ability to improve clinical outcomes.

The limitations of this study largely relate to the nature of systematic reviews. Literature searches can lead to inherent biases because of the incomplete capture of all relevant articles. The authors attempted to mitigate this by using multiple terms for each procedure and to exclude studies that did not exclusively relate to facial plastic surgery. Furthermore, this systematic review is a qualitative evaluation of the literature and therefore has the potential to display subjective bias. However, the authors utilised existing simulation effectiveness evaluation tools to reduce this risk, and highlighted the bias risk of studies incorporated into this review.

Conclusion

Simulation in facial plastics training could have a key role in ensuring the maintenance and development of surgical skills. This systematic review highlights a wide range of models to simulate various facial plastics procedures. These models may have some training benefits, but most could benefit from further validity assessment. It is important to ensure the efficacy of any simulation model developed. It is hoped that this systematic review will encourage the development of validated training models with demonstrable efficacy in improving both surgical training and clinical care.

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References

1 European Commission. Working Conditions - Working Time Directive. In: https://ec.europa.eu/social/main.jsp?catId=706&langId=en&intPageId=205 [27 May 2020]

2 ENT UK. A Graduated Return to Elective ENT Within the COVID-19 Pandemic. In: https://www.entuk.org/sites/default/files/A%20Graduated%20Return%20to%20Elective%20ENT%20Within%20the%20COVID-19%20Pandemic.pdf [27 May 2020]

3 Søreide K, Hallet J, Matthews JB, Schnitzbauer AA, Line PD, Lai PBS *et al.* Immediate and long-term impact of the COVID-19 pandemic on delivery of surgical services. *Br J Surg* 2020;**107**:1250–61

4 Hasan A, Pozzi M, Hamilton JR. New surgical procedures: can we minimise the learning curve? *BMJ* 2000;**320**:171–3

5 Hopper AN, Jamison MH, Lewis WG. Learning curves in surgical practice. *Postgrad Med J* 2007;**83**:777–9

6 Yeolekar A, Qadri H. The learning curve in surgical practice and its applicability to rhinoplasty. *Indian J Otolaryngol Head Neck Surg* 2018;**70**:38–42

7 Beckman TJ, Cook DA, Mandrekar JN. What is the validity evidence for assessments of clinical teaching? *J Gen Intern Med* 2005;**20**:1159–64

8 McGaghie WC, Issenberg SB, Barsuk JH, Wayne DB. A critical review of simulation-based mastery learning with translational outcomes. *Med Educ* 2014;**48**:375–85

9 Ker J, Bradley P. Simulation in medical education. In: Swanwick T, eds. *Understanding Medical Education: Evidence, Theory and Practice*, 2nd edn. Chichester: Wiley-Blackwell, 2013;175–92

10 The Joanna Brigg's Institute. Checklist for Quasi-Experimental Studies (non-randomized experimental studies). In: https://jbi.global/sites/default/files/2019-05/JBI_Quasi-Experimental_Appraisal_Tool2017_0.pdf [01 July 2021]

11 Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009;**6**:e1000097

12 Denadai R, Saad-Hossne R, Raposo-Amaral CE. Simulation-based rhomboid flap skills training during medical education: comparing low- and high-fidelity bench models. *J Craniofac Surg* 2014;**25**:2134–8

13 Chawdhary G, Herdman R. Pastry flaps for facial plastics. *Clin Otolaryngol* 2015;**40**:509–10

14 Sillitoe AT, Platt A. The Z-plasty simulator. *Ann R Coll Surg Engl* 2004;**86**:304–5

15 Kite AC, Yacoe M, Rhodes JL. The use of a novel local flap trainer in plastic surgery education. *Plast Reconstr Surg Glob Open* 2018;**6**:e1786

16 Denadai R, Kirylko L. Teaching basic plastic surgical skills on an alternative synthetic bench model. *Aesthet Surg J* 2013;**33**:458–61

17 Altinyazar HC, Hosnuter M, Unalacak M, Koca R, Babuçcu O. A training model for cutaneous surgery. *Dermatol Surg* 2003;**29**:1122–4

18 Kuwahara RT, Rasberry R. Pig head model for practice cutaneous surgery. *Dermatol Surg* 2000;**26**:401–2

19 Loh CY, Athanassopoulos T. Understanding Z plasties - deepening of web-space on chicken foot model. *Hand Surg* 2014;**19**:323–4

20 Camelo-Nunes JM, Hiratsuka J, Yoshida MM, Beltrani-Filho CA, Oliveira LS, Nagae AC. Ox tongue: an alternative model for surgical training. *Plast Reconstr Surg* 2005;**116**:352–4

21 Agrawal K. Bovine cartilage: a near perfect training tool for carving ear cartilage framework. *Cleft Palate Craniofac J* 2015;**52**:758–60

22 Erdogan B, Morioka D, Hamada T, Kusano T, Win KM. Use of a plastic eraser for ear reconstruction training. *Indian J Plast Surg* 2018;**51**:66–9

23 Murabit A, Anzarut A, Kasrai L, Fisher D, Wilkes G. Teaching ear reconstruction using an alloplastic carving model. *J Craniofac Surg* 2010;**21**:1719–21
24 Shin HS, Hong SC. A porcine rib cartilage model for practicing ear-framework fabrication. *J Craniofac Surg* 2013;**24**:1756–7
25 Vadodaria S, Mowatt D, Giblin V, Gault D. Mastering ear cartilage sculpture: the vegetarian option. *Plast Reconstr Surg* 2005;**116**:2043–4
26 Uygur S, Ozturk C, Kwiecien G, Siemionow MZ. Sheep head model for plastic surgery training. *Plast Reconstr Surg* 2013;**132**:895–6
27 Zou C, Wang JQ, Guo X, Wang TL. Pig eyelid as a teaching model for severe ptosis repair. *Ophthalmic Plast Reconstr Surg* 2012;**28**:472–4
28 Pfaff AJ. Pig eyelid as a teaching model for eyelid margin repair. *Ophthalmic Plast Reconstr Surg* 2004;**20**:383–4
29 Kersey TL. Split pig head as a teaching model for basic oculoplastic procedures. *Ophthalmic Plast Reconstr Surg* 2009;**25**:253
30 Ianacone DC, Gnadt BJ, Isaacson G. Ex vivo ovine model for head and neck surgical simulation. *Am J Otolaryngol* 2016;**37**:272–8
31 Oh CJ, Tripathi PB, Gu JT, Borden P, Wong BJ. Development and evaluation of rhinoplasty spreader graft suture simulator for novice surgeons. *Laryngoscope* 2019;**129**:344–50
32 Zammit D, Safran T, Ponnudurai N, Jaberi M, Chen L, Noel G *et al.* Step-specific simulation: the utility of 3D printing for the fabrication of a low-cost, learning needs-based rhinoplasty simulator. *Aesthet Surg J* 2020;**40**:340–5
33 Zabaneh G, Lederer R, Grosvenor A, Wilkes G. Rhinoplasty: a hands-on training module. *Plast Reconstr Surg* 2009;**124**:952–4
34 Dini GM, Gonella HA, Fregadolli L, Nunes B, Gozzano R. A new animal model for training rhinoplasty [in Portguese]. *Rev Bras Cir Plást* 2012;**27**:201–5
35 Weinfeld AB. Chicken sternal cartilage for simulated septal cartilage graft carving: a rhinoplasty educational model. *Aesthet Surg J* 2010;**30**:810–13
36 Dini GM, Gonella HA, Fregadolli L, Nunes B, Gozzano R. Training rhinoseptoplasty, sinusectomy, and turbinectomy in an animal model. *Plast Reconstr Surg* 2012;**130**:224–6
37 Touska P, Awad Z, Tolley NS. Suitability of the ovine model for simulation training in rhinology. *Laryngoscope* 2013;**123**:1598–601
38 Mallmann LB, Piltcher OB, Isolan GR. The lamb's head as a model for surgical skills development in endonasal surgery. *J Neurol Surg B Skull Base* 2016;**77**:466–72
39 Gardiner Q, Oluwole M, Tan L, White PS. An animal model for training in endoscopic nasal and sinus surgery. *J Laryngol Otol* 1996;**110**:425–8
40 AlReefi MA, Nguyen LH, Mongeau LG, Haq BU, Boyanapalli S, Hafeez N *et al.* Development and validation of a septoplasty training model using 3-dimensional printing technology. *Int Forum Allergy Rhinol* 2017;**7**:399–404
41 Tan SS, Sarker SK. Simulation in surgery: a review. *Scott Med J* 2011;**56**:104–9
42 Shaharan S, Neary P. Evaluation of surgical training in the era of simulation. *World J Gastrointest Endosc* 2014;**6**:436–47
43 Gaba DM. The future vision of simulation in health care. *Qual Saf Health Care* 2004;**13(**suppl 1):2–10
44 Munshi F, Lababidi H, Alyousef S. Low- versus high-fidelity simulations in teaching and assessing clinical skills. *J Taibah Univ Medical Sci* 2015;**10**:12–15
45 Lateef F. Simulation-based learning: just like the real thing. *J Emerg Trauma Shock* 2010;**3**:348–52
46 Kilkenny C, Browne WJ, Cuthill IC, Emerson M, Altman DG. Improving bioscience research reporting: the ARRIVE guidelines for reporting animal research. *PLoS Biol* 2010;**8**:1000412
47 Martić-Kehl MI, Schibli R, Schubiger PA. Can animal data predict human outcome? Problems and pitfalls of translational animal research. *Eur J Nucl Med Mol Imaging* 2012;**39**:1492–6
48 Rall M, Dieckmann P. Simulation and patient safety: the use of simulation to enhance patient safety on a systems level. *Curr Anaesth Crit Care* 2005;**16**:273–81