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Validation of a simulator for cranial graft lift training: Face, content, and construct validity

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SUMMARY

Purpose: Surgical skills can be improved through practical exercise. The use of specimens, human as well as animal, or live animals for surgical training is limited due to ethical concerns. Drawbacks of simulators are costs, fidelity and creditibility. Thus, simulators must be evaluated objectively to determine their validity before they can be used as teaching modalities. The aim of this study was to verify the face content and construct validity of a novel model-based simulator for lifting tabula externa transplants from the parietal skull.

Materials and methods: Participants were invited to perform a tabula externa graft lift during a training session on the simulator. Task performance was analyzed with a standardized assessment tool evaluating realism and appropriateness. Specialist ratings were used to evaluate the performance of the participants. This was an exploratory study using a questionnaire, at Kepler University Hospital, Linz, Austria, a university hospital. According to their expertise in craniomaxillofacial surgery, 17 participants were subdivided into 3 groups: 8 novices, 7 experts and 2 raters.

Results: The face validity (realism) obtained an average score of 4.2 of a maximum of 5 points. Likewise, the content validity (appropriateness as a teaching modality) obtained an average score of 4.8 of maximum 5 points. No differences were found between experts and novices concerning the recorded surgery completion times ($p = 0.418$) or the sizes of the lifted grafts ($p = 0.110$). During the evaluation of task performance, the expert surgeons (46.9 ± 3.7) were graded significantly better than the novices (36.4 ± 8.5), which proved the construct validity of the simulator ($p = 0.001$).

Conclusion: All investigated validities were confirmed and approved the simulator as a valid training tool for parietal graft lift.

1. Introduction

Cranial split thickness grafts are popular for the reconstruction of skeletal defects due to the easy access, less complaints following the harvesting surgery, and for the large amounts of available cortical bone from the outer cortex (Schortinghuis et al., 2012). During a split thickness graft lift procedure, the parietal skull is exposed and an outer table cortical graft is contoured with fast rotating drills and millheads (Fig. 1). Then, the graft is split in situ with an oscillating saw, and remaining diploic connections are cut with a flexible osteotom (Frodel et al., 1993). Advantages like a minor donor site pain, short surgery times, shorter hospitalization times and a hidden scar below the hairline are reported (Bruno and Gustafson, 1994). On the contrary, possible complications include dural exposure or tear, intracranial haemorrhage, brain injury and even the death of the patients due to the entry of the fast rotating and oscillating tools into the brain (Strong and Moulthrop, 2000). Those complications are minimized by proper surgical education and training, targeting precise dosage of speed of rotations and forces (Diaz et al., 2013). Traditionally, novice surgeons are educated directly in the operating room during their first experiences under

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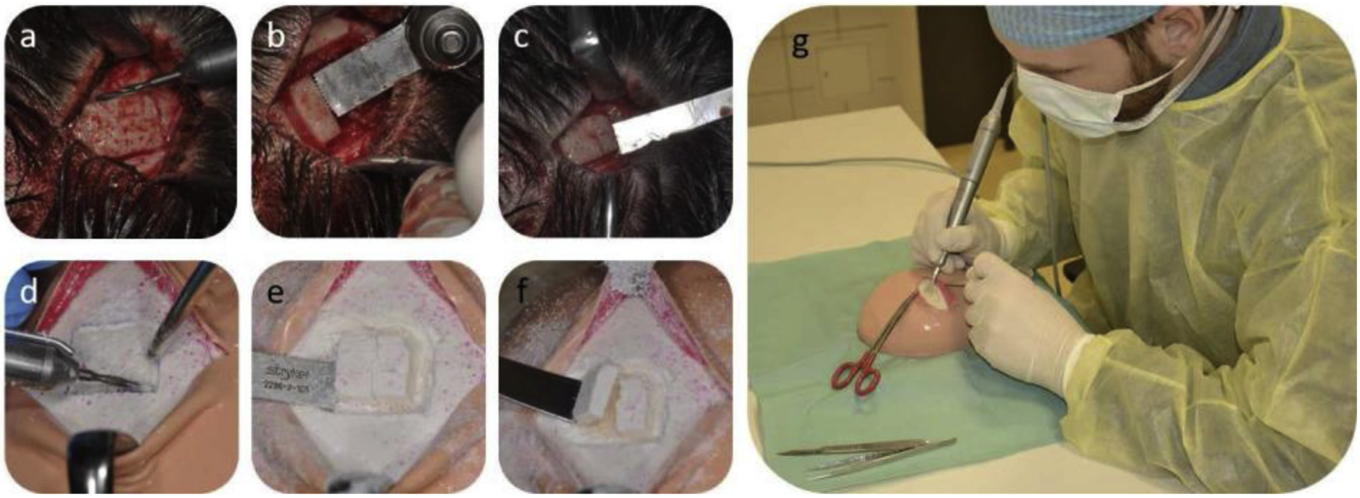

Fig. 1. Parietal graft lift (a–c: real surgery, d–f: simulated surgery, g: training with TabSIM).

supervision by an experienced surgeon. Other training approaches include surgical courses where procedures are taught with fixed human specimens, animal specimens or live animals. These teaching approaches are expensive and the use of human specimens or live animals may be limited due to ethical concerns (Okada et al., 2010). Therefore, simulation environments are rapidly expanding across the majority of professional domains. Simulators, which can be distinguished into virtual reality, model-based or augmented reality simulators (Kneebone, 2003), provide the opportunity to perform surgical tasks safely with the additional advantage of simultaneous documentation of the learning process (Fuerst and Schrempf, 2012). Simulators are able to reduce risks for both the patient and the operator (Singh et al., 2013). With simulators, trainees have almost unlimited training opportunities (Abolhassani et al., 2007), and the need for live animals or human specimens is reduced. Although several studies demonstrated that haptic feedback in surgical training with simulators consistently improves learning (Aggarwal et al., 2004), there are still drawbacks, like the cost of simulator equipment or validity issues (Bradley, 2006). The authors have developed a model-based simulator (TabSIM) for the aforementioned cranial graft lift procedure (Hollensteiner et al., 2017). However, prior to introducing this simulator as a teaching tool, its validity has to be established (McDougall, 2007). The aim of this study was the assessment of three forms of validity: face, content, and construct validity of a graft lift procedure on the TabSIM simulator. Face validity demonstrates the realism of a simulator, content validity demonstrates whether the simulator is appropriate as a teaching modality, and construct validity shows whether the simulator is able to distinguish between experienced and inexperienced surgeons (McDougall, 2007).

2. Materials and Methods

2.1. TabSIM Simulator Development

In the context of this study, a model-based simulator of the parietal skull named TabSIM was developed (Fig. 2). This is a model-based simulator for tabula externa graft lifting (Fig. 2a: skid-proof base plate with brain, Fig. 2b: artificial skull cap, Fig. 2c: skull cap covered with artificial muscles and skin, Fig. 2d: whole assembly).

Key feature of this simulator is a physical phantom with validated artificial parietal bones for drilling, milling and sawing covered with artificial soft tissues (Hollensteiner et al., 2017). The artificial materials were assembled to a model of a skullcap, placed on a skid-proof silicone brain plate. The system weighs about 1 kg and due to its small size, it can be transported to any training place very easily. Training on this artificial bone can be performed with authentic surgical machining instruments.

2.2. Subjects

The simulator was brought to the Kepler University Clinic in Linz, Austria. Craniomaxillofacial (CMF) specialists, novices and other medical staff were invited to perform surgical tasks on the model-based simulator during their routine working day. According to their clinical experience, the participants were divided into two groups: an experienced group (EG, n = 7, 6 male/1 female, 31 ± 11 yr) including participants who have performed more than 30 cranial graft lift procedures, and a novice group (NG, n = 7, 4 male/3 female, 33 ± 9 yr), consisting of surgical residents and other medical staff, who had not performed any surgical CMF interventions but had solid anatomical knowledge. All participants provided informed consent after having a general explanation of the surgical procedure, the simulator and the study design. Two experienced surgeons (both male), who did not perform any training on the TabSIM, acted as rater group (RG) and assessed the performance of the participants.

2.3. Tasks

Prior to the training task, the participants completed questionnaires on demographics and medical experiences. Then, experts and novices were invited to perform lifts of a 1.5 × 2 cm graft split in three equal proportions from the parietal tabula externa using the TabSIM. The full surgical procedure was divided into 15 procedural tasks, listed in Table 1. During the training task, the performance of the participants was recorded with a video camera. After completing the simulation tasks, the participants were asked to complete questionnaires concerning the face (NG only) and the content validity (EG only). The video was rated by the RG.

2.4. Assessment

2.4.1. Face Validity

The face validity evaluates whether the surgical simulator has a high degree of reality (McDougall, 2007) and encourages surgical novices to train more often, since a high degree of realism leads to a

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