ORIGINAL ARTICLE

Parotidectomy Surgical Simulation and Education with a Three-Dimensional Printed Face Model for Iraqi Surgeons

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Abstract

Purpose: Parotidectomy is usually suggested for many persons with parotid gland tumors. Facial nerve weakening is the most concerning of the potential consequences related to parotidectomy, resulting in a significantly reduced patient quality of life. With preoperative preparation and surgical training and simulation, a three-Dimensional (3D) printed human face anatomical model has just been designed and fabricated.

Materials and Methods: Fifteen surgeons from Iraqi teaching hospitals evaluated the simulator model by using a Likert scale survey. The model is composed of a silicon based human face replica with an incorporated parotid gland replica and a closed electrical circuit of the facial nerve course to show when contact is made between the surgical instrument and the nerve to provide feedback.

Results and Conclusion: All participants gave favorable feedback. Significant levels of satisfaction with the designed simulator have been relatively achieved. In comparison to experts, novice surgeons scored less for skin realism and handling. Such a difference suggests that the proposed simulator appears to have the potential to contribute to the advancement of surgical simulation, education, and planning.

Keywords: 3D Printing; Face Model; Facial Nerve; Parotidectomy; Surgical Simulation; Education.

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1. Introduction

The largest salivary gland in the human body is the parotid gland. On both sides of the mouth and in front of both ears, there are two parotid glands. These glands pass via a variety of structures, as shown in Figure 1 www.kenhub.com. Surgery is recommended for many persons with benign or malignant tumors of the parotid gland. The goal of surgery for parotid gland tumors is to remove the tumors completely and without complications [1].

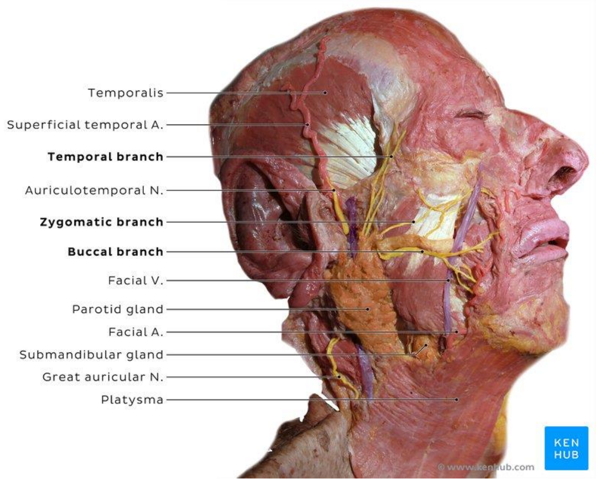

Figure 1. Facial nerve anatomy in a human cadaver. Note that the facial nerve penetrates, but does not innervate the parotid gland [1]

Because the facial nerve is close by, treating parotid gland tumors necessitates extreme precision on the side of the surgical team. Damage to any part of that nerve can result in a significant reduction in the patient's quality of life [2, 3]. Bruising causes the majority of nerve injuries since nerve preservation is so important. Repetition is required for competent parotid surgery. Surgical risks must be discussed with trainees as they are being taught. Resident duty hours may limit participation in live surgery. The use of cadavers for learning is limited due to the cost and availability [4]. The goal of this work was to design and fabricate a three-Dimensional (3D) printed surgical simulator that could be used to investigate the face anatomical model as well as the facial nerve course surrounding parotid gland tumors. For this simulator, face layers were made of soft silicone-based materials. The facial nerve in this concept was simulated as a closed electrical circuit where extended through the face layers and configured to identify any touch with surgical instruments in order to provide the user with pertinent feedback [5]. This may allow the surgeon to perform better surgical simulations, training, and/or planning interventions during parotidectomy.

To help surgeons working in settings with limited resources, Aduba *et al.* (2020) at Boston University developed a novel accurate training model with realistic tissue textures and physical characteristics that simulates parotid activities. This model enables surgeons working in environments with limited resources to practice and receive real-time feedback throughout the procedure.

3D printing has made a successful comeback in healthcare in recent years, with a variety of applications. Preoperative planning and surgical training, designing and fabrication of prosthetic implants and equipment, restoration of anatomical components, model development, and biomedical research are just a few of the fields where 3D printing has been successful in recent years [6]. Surgical simulators date back over 2,500 years when they were initially used to plan out novel procedures while keeping patients safe. They are commonly used to train medical students and surgeons in specific procedures without using animals or cadavers before dealing with live people [6]. The key capabilities of this technology in education are the ability to minimize expenses, medical errors, and lethal infection rates while also enhancing trainee management, knowledge, and confidence, regardless of the field of competence [7].

2. Materials and Methods

This study was designed to indicate whether a three-Dimensional (3D) printed human face anatomical model is potentially suitable for simulating and learning adequate parotidectomy. A silicon-based human face duplicate makes up the model. The silicone model included an incorporated parotid gland replica as well as a closed electrical circuit for the facial nerve route. Recent breakthroughs in 3D printing have made it possible to construct skin components with a variety of material qualities, ranging from flexible to rigid, in a relatively short period of time. Thus, the physical properties (such as colour and density) of the soft material of one layer were different from those of another layer of the face model, so both layers can be differentiated by the trainee. A 3D-printed skull model containing the gland silicone replica was processed using a low-cost desktop 3D printer with Polylactide filament (PLA) material. Finally, the face skin layer mold was fabricated using double silicone rubber (see Figure 2).

Figure 2. 3D-printed PLA skull model (left). 3D-printed silicone parotid gland replica and the live wire system (middle). Skin layer mold (right)

The facial nerve of the patient was simulated as a closed electrical circuit that is comprised of a conductive metallic wire extending underneath the face layers model. This circuit includes electrodes connected to a group of certain coloured LEDs that replicated the five different branches and locations of the facial nerve as follows; white for the Temporal nerve, black for the Zygomatic nerve, green for the Buccal nerve, yellow for the Mandibular nerve and red for the Cervical nerve (see Figure 3).

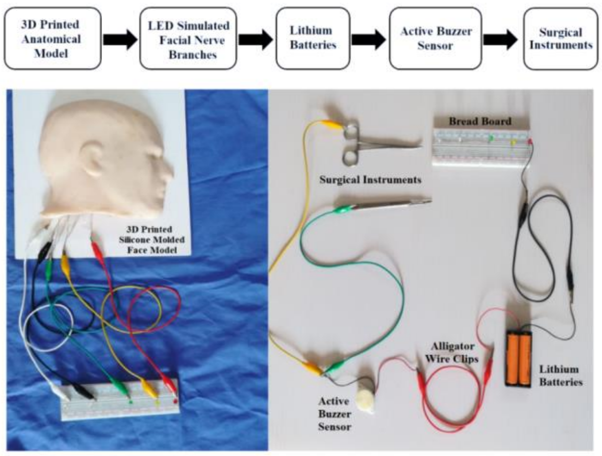

Figure 3. Block diagram of the surgical simulator components (up). The final implementation of the 3D-printed surgical simulator components (down)

Then these LEDs were connected to the anode terminal of the lithium battery source in a breadboard. The electrical circuit also utilized an alarm system that includes a light (from the five coloured LEDs) for generating a visual signal and an active buzzer sensor for generating an audio signal. A surgical knife and tissue scissors were both connected to the alarm system and via wires to facilitate an efficient surgical simulation for the model's trainee. This closed electrical circuit architecture enables the surgical simulator to notify that when contact is made between the surgical instruments and the facial nerve, the alarm will be activated, allowing the user to receive appropriate feedback.

2.1. Subject

For such a qualitative research study, fifteen surgeons from teaching Iraqi hospitals in Baghdad and Nasseriya were recruited through a purposeful sampling approach to evaluate the designed simulator model favourably and proceeded with the simulated parotidectomy procedure over a period of seven months. The participants' satisfaction with the impact of the simulation was assessed by using a survey characterized by 10 closed-answer questions after giving their written informed consents according to the approval obtained from the Research Ethics Committee of the Biomedical Engineering Department at Al-Nahrain University under the reference (version 1_02/2020). The surgeons were divided according to their practicing into two groups; 7 expert surgeons (with more than 10 years of practicing) and 8 novice surgeons with an average age of 39.07 ± 2.15 years and 26.33 ± 1.64 years, respectively. The 3D-printed model has been cut and opened by the enrolled surgeons who were practicing the parotid surgery after connecting the closed electrical circuit that represents the facial nerve locations and placing them under the lateral part of the skull 3D-printed model (see Figure 4).

Overall, surgeons participated in the initial validation of the proposed surgical simulator, then completed a specific 10 closed-answer questionnaire on a five-point Likert scale ranged with 1 indicating "strongly dissatisfied", 2 indicating "dissatisfied", 3 indicating "neutral", 4 indicating "satisfied", and 5 indicating "strongly satisfied" to evaluate participants feedback about the impact of simulation. Comparison of expert and novice participants' average response for each item was evaluated and statistically analyzed using an independent sample t-test (with a 5% significance level) by using SPSS version 22.0 (see Table 1).

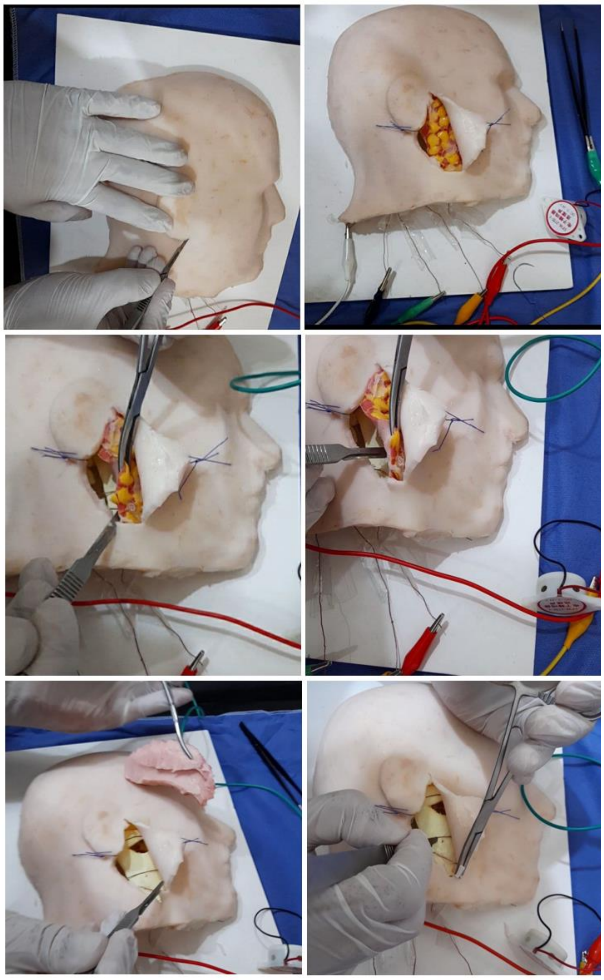

Figure 4. Surgery resident proceeds with the simulated parotidectomy procedure on the integrated model

3. Results

Figure 5 illustrates the evaluation comparison of the parotidectomy simulator regarding the use of expert and novice participants using the 5-point Likert scale.

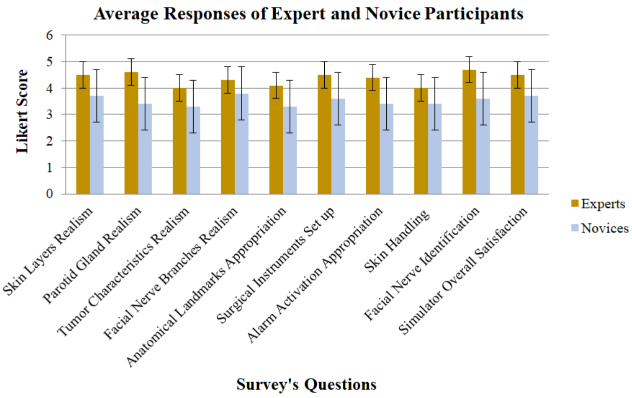

Figure 5. Comparison of average responses to 10 survey questions using the 5-point Likert scale with a difference percentage among expert and novice participants

Also, the percentage of scoring bands of overall participants' responses on the 5-point Likert scale has been analyzed for each one of the 10 survey questions (see Table 2).

As a result, significant levels of satisfaction with the parotidectomy simulator have been achieved. The response with higher levels of satisfaction (strongly and quite satisfied) was achieved about the aspects of skin layers realism (%80), facial nerve branches realism (%74), and surgical instruments setup. On the other hand, the lowest

Table 1. Summary of Responses to 10 Survey Questions using the Likert Scale

		Expert Participants n=7					Novice Participants n=8					
	Survey's Question	Strongly Dissatisfied (1)	Dissatisfied (2)	Neutral (3)	Satisfied (4)	Strongly Satisfied (5)	Strongly Disagree (1)	Dissatisfied (2)	Neutral (3)	Satisfied (4)	Strongly Satisfied (5)	p-value
1	Skin Layers Realism	-	-	-	1	6	-	2	1	3	2	> 0.05
2	Parotid Gland Realism	-	-	1	1	5	-	2	2	2	2	> 0.05
3	Tumor Characteristics Realism	-	-	2	-	5	-	3	1	2	2	> 0.05
4	Facial Nerve Branches Realism	-	-	1	1	5	-	2	1	3	2	> 0.05
5	Anatomical Landmarks Appropriation	-	-	-	1	6	1	2	3	2	-	> 0.05
6	Surgical Instruments set up	-	-	-	1	6	1	1	2	2	2	> 0.05
7	Alarm Activation Appropriation	-	-	-	2	5	-	2	2	2	2	> 0.05
8	Skin Handling	-	-	-	2	5	1	2	3	1	1	> 0.05
9	Facial Nerve identification	-	-	1	1	5	-	2	3	2	1	> 0.05
10	Simulator overall satisfaction	-	-	-	1	6	-	2	2	3	1	> 0.05

Table 2. Percentage of overall participants' responses

	Survey's Question	Participants Responses % (no.)					Total Responses
		Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	
1	Skin Layers Realism	-	%13 (2)	%7 (1)	%27 (4)	%53 (8)	15
2	Parotid Gland Realism	-	%13 (2)	%20 (3)	%20 (3)	%47 (7)	15
3	Tumor Characteristics Realism	-	%20 (3)	%20 (3)	%13 (2)	%47 (7)	15
4	Facial Nerve Branches Realism	-	%13 (2)	%13 (2)	%27 (4)	%47 (7)	15
5	Anatomical Landmarks Appropriation	%7 (1)	%13 (2)	%20 (3)	%20 (3)	%40 (6)	15
6	Surgical Instruments set up	%7 (1)	%7 (1)	%13 (2)	%20 (3)	%53 (8)	15
7	Alarm Activation Appropriation	-	%13 (2)	%13 (2)	%27 (4)	%47 (7)	15
8	Skin Handling (incision, flap elevation, closure)	%7 (1)	%13 (2)	%20 (3)	%20 (3)	%40 (6)	15
9	Facial Nerve identification	-	%13 (2)	%27 (4)	%20 (3)	%40 (6)	15
10	Simulator overall satisfaction	-	%13 (2)	%13 (2)	%27 (4)	%47 (7)	15

levels of satisfaction (strongly and quite dissatisfied) were achieved about the aspects of tumor characteristics realism, anatomical landmarks appropriation, and skin handling (20%).

Detailed analysis of the number of responses for the 10 survey questions regarding the use of the parotidectomy simulator by expert and novice participants is illustrated in Figures 6 and 7, respectively.

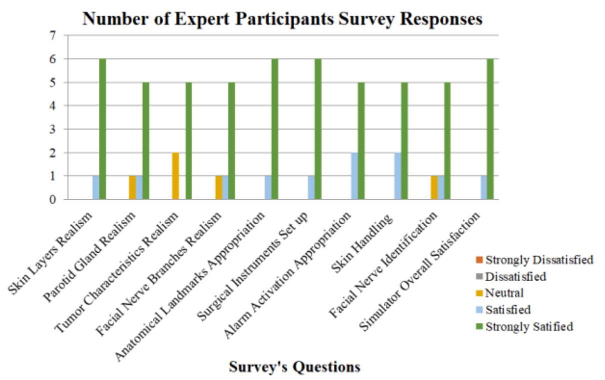

Figure 6. Frequency of expert participants' responses to 10 survey questions using the 5-point Likert scale

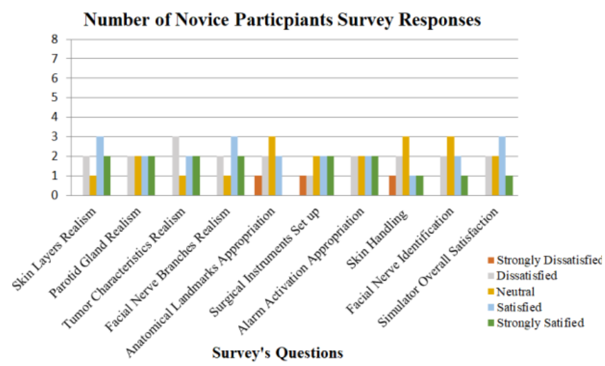

Figure 7. Frequency of novice participants' responses to 10 survey questions using the 5-point Likert scale

4. Discussion

The proposed simulator was made up of a soft material face layer model that the surgical instruments could manipulate and a closed electrical circuit with an alert indicator that would sound and light up when the surgical instrument made contact with the fictitious facial nerve wire(s).

Regarding their responses to the survey's questions, there was no significant difference between the expert and novice participants. In comparison to experts, novice participants scored less for skin realism and handling.

Regarding the alarm activation appropriation, both participant groups gave favourable feedback. A difference suggests that the simulator model can discriminate between participants' experience levels, demonstrating content validity. The results analysis supported the finding that parotidectomy surgeons tended to have better operative outcomes.

Understanding subjective viewpoints is affected by the usage of the Likert scale surveys. As a result, over the course of seven months, all participants evaluated their immediate live performance with the proposed simulator before completing the identical set of 10 closed-ended questions to assess the construct validity. Regarding gender and handedness, there was no difference between novice and expert participant groups. The results of every response show that the survey's reliability is sufficient to separate participant performance based on experience from other replies. Additionally, it seems that every participant who took part in the study identified the same benefits and drawbacks of adopting the suggested simulator model.

In comparison to the reported study conducted by Gabryaz-Forget *et al.* (2020) [4], we also present similar comparable conclusions regarding the simulation model's findings and survey scores as both pertinent and beneficial.

Contrary to our study, some of the participants recruited by Gabryaz-Forget et al. were junior residents who had not yet performed parotid surgical operations while the post-simulation survey was being conducted. No substantial differentiation was reported after that, which is probably a consequence of the participants' experiences.

This study has certain restrictions. There was a small sample size. This was anticipated, in some ways unavoidable and further impacted by incomplete surveys and missing data. Moreover, the Likert scale evaluation also carries the risk of response bias, which might lead participants to place too much significance on the predictive simulator even though it is subjective. Hazards of parotidectomy must be discussed while teaching trainees how to lower the incidence of facial paralysis and overall patient morbidity.

Experience levels, whether expert or novice, might affect what is seen to be advantageous in terms of training, planning, and simulation. Therefore, the proposed simulator model is designed to address these issues and raise the standard of surgical instruction.

For a variety of reasons, practicing and teaching surgical techniques on live patients can be dangerous. One such reason is that bodily parts could come into touch with a tool being used by a surgeon, surgical student, nurse, or other healthcare providers during the surgical operation, which might be hazardous. In particular, it would be ideal to have surgical simulation technologies that allow medical personnel to educate and practice surgical operations before performing on live patients and alert them to the risk of damaging interaction with body components. Future testing and training of medical students in developing practice and research will be made possible by this.

5. Conclusion

In conclusion, a 3D-printed surgical simulator of a face anatomical model for the parotid gland was designed and fabricated. Expert and novice surgeons from Iraqi teaching hospitals used and evaluated this simulator in terms of parotidectomy procedure according to a specific 10 closed-answer questionnaire on a five-point Likert scale. The majority of participants gave the simulator model utilized in this study a good rating, indicating that it has the potential to contribute to the progress of surgical education, simulation, and planning before carrying out actual surgery. Enhancing skin realism and collecting further validation results may be part of future development. Different feedback among participant groups suggests that the proposed simulator appears to have the potential to contribute to the advancement of surgical simulation, education, and planning.

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