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Feasibility of 3D Printed Temporal Bone for Surgical Simulation and Practice

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Abstract

Temporal bone (Ear Bone) has the most complex anatomical structure in body. ENT Surgeons need lot of practice before doing any surgery. Dissecting cadaver temporal bone is best teaching aid available with ENT surgeons, but have several constrains like legal, ethical, religious ground etc., restricts the hands-on dissection training. Availability of cadaver temporal bone is also very limited; it also houses many infectious agents and viruses. With recent advancement in 3D printing, it is possible to fabricate accurate 3D printed temporal bone with all the intricate anatomical details. Internal and external anatomical structures and landmarks can be easily identified in the 3D printed temporal bone. 3D printed temporal bone is validated by a group of ENT surgeons comprises of post graduate students and senior surgeons (No of participants = 30). 3D printed temporal bone is validated based on usefulness of the model for surgical simulation and tasked based usefulness (surgeries that can be practiced). Results shows that the 3D printed temporal bone model is highly accepted by the validating group for the hands-on surgical simulation and practice and can be used as substitute of cadaveric temporal bone for enhancing surgical skills of ENT surgeons.

Keywords: 3D Printed Temporal Bone, Artificial Temporal Bone, Surgical Training Model, Surgical Simulation, Dissection Training Mode.

INTRODUCTION

The complex neurovascular nature of the temporal bone (ear bone) makes it difficult for ENT to carry out ear procedures without experience. Complex surgery requires very trained surgeons. Dissection training is the most effective way for an ENT's to improve their skills. Lack of anatomical understanding can cause complications during surgery. Temporal bone laboratories are being built up in several locations for dissection training on cadaver temporal bones [1]. However, availability of cadaveric temporal bone is extremely rare and include infectious agents and viruses. Few countries have banned the use of cadaveric temporal bone on legal, religious, and ethical grounds. The cost of cadaveric temporal bone is similarly significant, and one can only obtain the cadaver temporal bone if the body is donated to a medical research center, or it is unclaimed [2]. 3D printed temporal bone has a significant potential to overcome difficulties faced while dissecting cadaver temporal bone[3][4]. Studies on the influence of surgical simulation training have been conducted at a different scenario, with a focus on the positive outcome of participant's competence and confidence in completing surgical tasks.

Researchers have studies and reported the use of surgical simulation can reduce the duration of surgical training to junior surgeons/ resident surgeons, but many trainees are yet to be exposed to the surgical simulation training. Junior surgeons/ resident surgeons performing the

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surgical procedure itself needed a higher level of trust from the mentoring surgeon, and takes some time to build the trust and confidence. Many crucial factors have yet not been evaluated extensively on how surgical training. [5][6][7].

Coronavirus pandemic (COVID-19) have caused an adverse effect on operative experience of surgical training, especially with some elective surgical cases. While acknowledging the possibility of longer training times, leading ENT institutes highlights the possible benefit of simulation to address this difficulty [8].

Optimizing factors to maximize active surgical involvement is crucial, especially in consideration of the decreasing firm-based structure of working and the fact that juniors often work with several consultants with shorter training rotations[9]. Exposure of top-notch simulation experience is one way to enhance the operating experience, with primary benefits of task based training simulation is the early adoption of surgical opportunities, reducing the time to participate actively in surgery [10]**.**

We aimed to investigate the potential influence of simulation training on surgical opportunity for Resident surgeons and junior surgeons under the supervision of cohort of experienced ENT surgeons. In this article we tried to quantify how simulation increased surgical involvement from passive observation to active participation or indeed if it would affect the trainee's ability to complete the entire procedure or not.

Materials and Method

A Standardize questionnaire was provided to 30 Senior ENT surgeons and PG medical student, validating the usefulness of this bone as surgical simulation tool. Standard surgical procedures such as mastoidectomy, cortical atticotomy, facial recess dissection, cochleostomy, canal wall down mastoidectomy, labrynthectomy were validated.

Parameters such as bone drilling with respect to cadaver bone, drilling experience (haptic feel, visual experience, sound), ease of use (setup in bone holder., preparing to drill etc.), safety and toxicity in comparison with cadaver bones were also evaluated.

30 surgeons across leading institutes across India have participated for the evaluation study of 3D Printed temporal bone. All the surgeons had some surgical experience from 2 Years to 35+ Years at the time of study. 30 3D Printed bones were validated by the esteemed cohort of ENT surgeons consisting of senior surgeons, practicing surgeons, resident surgeons and post graduate student of age group ranging from 27 years to 67 years. The 3D printed temporal bone were designed and 3D printed at NuOssa Mediquip Pvt Ltd, Nagpur. Out of 30 surgeons 44% were female surgeons and 56% were male surgeons. Qualification, 86% were MS ENT qualified, 6% were MS ENT and DNB qualified, 6% were DNB qualified. Evaluating group consists of 16% Senior surgeons, 50% Practicing surgeons, 23% Resident Surgeons and 10% Post Graduate Students. Demo graph of the evaluating group is described in Table 1.

Table 1: Demo-graph of evaluating surgeons

Age Group	**61+**	**41 Years – 60 Years**	**25 Years – 40 Years**	**Not Disclosed**
	3	12	11	4
Gender	***Male***	***Female***		
	17	13		
Qualification	***MS***	***MS DNB***	***DNB***	
	26	2	2	
Surgeons Demograph	***Senior Surgeons (>20+ Yrs***	***Practicing Surgeons (> 10+ Yrs Exp)***	***Resident Surgeons (>5+ Yrs Exp)***	***Post Graduate Students***

	Exp)			
	5	15	7	3
No of cadaver bones dissected	***More than 10***	***5 – 10***	***Less than 5***	***Never***
	15	5	4	6

Questionnaire has been floated along with the bones to evaluating surgeons to validate the 3D Printed Temporal Bone consisting of 30 questions divided into four domains: basic questions and current surgical simulation scenario, usefulness of this model for surgical simulation, task-based usefulness, and overall reaction.

Surgical tasked-based validation, these bones were validated for standard surgical procedures such as cortical mastoid, cortical atticotomy, facial recess dissection, cochleostomy, canal wall down mastoidectomy, labrynyhectomy. Figure 1 shows 3D Printed Temporal Bone.

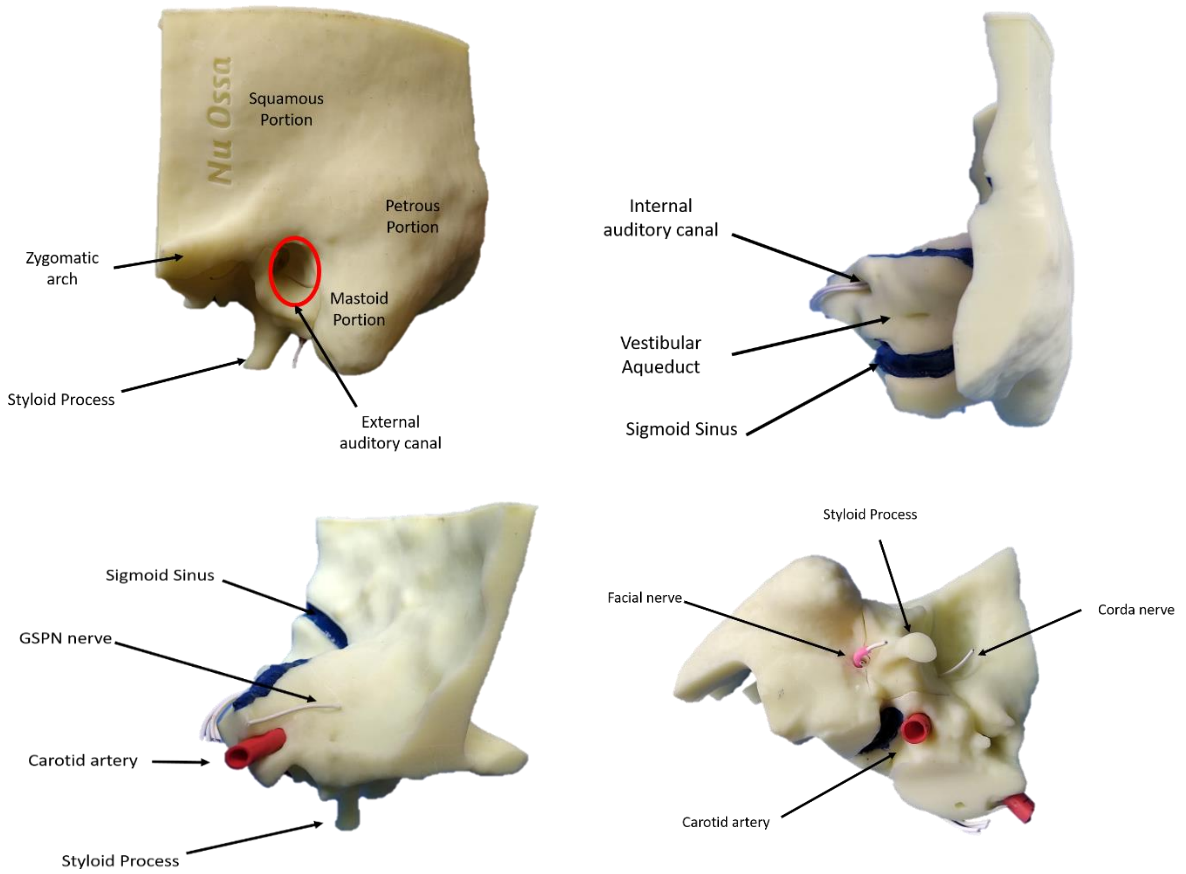

Figure 1. 3D Printed Temporal Bone

RESULTS AND DISCUSSION

Immediately after dissecting the 3D Printed Temporal Bone: Dissection Training Tool, surgeons were asked to complete the validation form, which consisted of 30 questions divided into four domains: basic questions and current surgical simulation scenario, usefulness of this model for surgical simulation, task-based usefulness, and overall reaction. The responses were recorded using a five-point system, with 5 = identical, 4-very similar, 3 =similar, 2 =very different, 1=unlike. A score of 3 indicates that this 3D Printed temporal bone model as dissection training tool can be used as a substitute for cadaver; a score less than 3 indicates that the 3D Printed model is a poor substitute for cadaver and should not be used; A score of 4 or above suggests that 3D Printed bone is a superior substitute for human cadaver temporal bones in surgical practice.

Prior to testing the models for effectiveness as a dissection training tool. Some basic questions were posed to the evaluating panel, such as the current surgical training scenario, the availability of cadaver bones for surgical practice, the necessity for ethical or legal approval prior acquiring cadaver bones, etc. The response to these questions is given in Table 2.

Table 2. Response recorded on basic questions and current surgical simulation scenario

Evaluation Factors	**Responses**		
Practice of temporal bone dissection enhances the learning of anatomy of this bone	Yes	No	
	50 (100%)	0 (0%)	
Practice of temporal bone dissection is essential before doing ear surgery	Yes	No	Maybe
	50 (100%)	0 (0%)	0 (0%)
Temporal bone dissection should be mandatory for PG course	Yes	No	Maybe
	50 (100%)	0 (0%)	0 (0%)
Acquiring the cadaveric bones has ethical, legal, health-hazardous, institutional issues	True	False	Maybe
	40 (80%)	5 (10%)	5 (10%)
Cadaveric temporal bones are easily available	Yes	No	Maybe
	2 (4%)	40 (80%)	8 (16%)
What stops you from temporal bone dissection	Cadaver temporal bone unavailability	Other	Reason (others)
	42 (84%)	8 (16%)	We are doing regular cadaveric temporal bone dissections at our center, however due to formalin the dissections have to be spaced.
			Time constrains.

On evaluating this 3D Printed bone in comparison to drilling cadaver, surgeons felt the model is excellent as compared to cadaver bones with mean value of 4.18, external anatomical details are also realistic and anatomically accurate with mean value of 4.42 as compared to cadaveric temporal bone. In terms of haptic feel and drilling sound, this 3D Printed bone behaves as good as cadaver temporal bone. Surgeons also concluded that this 3D Printed model will add value in surgical experience and is ease to use for surgical simulation (can be easily mounted on temporal bone holder, no need of any chemical preservations etc.), in term of safety to use this bone, surgeons have given highest rating of 4.6 as compared to rest of the response.

In terms of surgical tasked based validation, these bones were validated for surgical procedures such as cortical mastoid, cortical atticotomy, facial recess dissection, cochleostomy, canal wall down mastoidectomy, labrynyhectomy, highest score is recorded by cortical mastoidectomy, followed by cortical atticotomy. Surgeons response in terms of usefulness of these bones is shown in Table 3 and Figure 2

Overall impression of using this bone as substitute to cadaver temporal bone is very positive. Post graduate students feel that the techniques which they learned while dissecting 3D Printed temporal bone can be transferrable to operation room. Dissecting 3D Printed temporal bone helped them to boost their confidence to perform ENT procedures in operating room. Figure 3 shows the surgeons responses on the tasked based usefulness for using this 3D Printed temporal bone as substitute of cadavers for surgical practice.

Table 3: Response recorded for validation of 3D Printed Temporal Bone

Evaluating Factor	**Responses (n)**	**Mean**	**Std. Deviation**	**Upper Bound**	**Lower Bound**

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Current surgical simulation scenario and usefulness of this model for surgical simulation	Please rate the bony anatomy detail in comparison to drilling a cadaveric temporal bone	30	4.18	0.72	4.38	3.98
	Please rate the external anatomy you encountered in comparison to a cadaveric temporal bone	30	4.42	0.67	4.61	4.23
	Please rate the similarity of drilling experience (haptic feel, visual experience, sound) in comparison to a cadaveric temporal bone for the cortical bone	30	4.18	0.83	4.41	3.95
	Please rate the similarity of drilling experience (haptic feel, visual experience, sound) in comparison to a cadaveric temporal bone for the trabecular bone	30	4.14	0.76	4.35	3.93
	Please rate the printed temporal bone for its value in surgical experience and training in comparison to a cadaveric temporal bone	30	4.32	0.82	4.55	4.09
	Please rate the printed temporal bone for "ease of use" (setup in holder, preparing to drill, etc.) in the temporal bone laboratory in comparison to a cadaveric temporal bone	30	4.54	0.76	4.75	4.33
	Please rate the printed temporal bone for "safety" in the temporal bone laboratory in comparison to a cadaveric temporal bone	30	4.6	0.64	4.78	4.42
	Please rate the printed temporal bone for its overall value as a surgical simulation, in preparation for cases in the OR	30	4.52	0.79	4.74	4.30
	Please rate the printed temporal bone material, in terms of drilling, bone dust etc.	30	4.24	0.74	4.45	4.03

Tasked based usefulness	Use of this 3D Printed temporal bone for teaching cortical mastoidectomy	30	4.54	0.68	4.73	4.35
	Use of this 3D Printed temporal bone for teaching cortical atticotomy	30	4.44	0.84	4.67	4.21
	Use of this 3D Printed temporal bone for teaching facial recess dissection	30	4.28	0.86	4.52	4.04
	Use of this 3D Printed temporal bone for teaching cochleostomy	30	4.16	0.87	4.40	3.92
	Use of this 3D Printed temporal bone for teaching canal wall down mastoidectomy	30	4.44	0.76	4.65	4.23
	Use of this 3D Printed temporal bone for teaching labyrinthectomy	30	4	1.11	4.31	3.69

Figure 2: current surgical simulation scenario and usefulness of this model for surgical simulation

Q1	Bony anatomy detail in comparison to drilling a cadaveric temporal bone
Q2	External anatomy you encountered in comparison to a cadaveric temporal bone
Q3	Similarity of drilling experience (haptic feel, visual experience, sound) in comparison to a cadaveric temporal bone for the cortical bone
Q4	Similarity of drilling experience (haptic feel, visual experience, sound) in comparison to a cadaveric temporal bone for the trabecular bone
Q5	Printed temporal bone for its value in surgical experience and training in comparison to a cadaveric temporal bone
Q6	Printed temporal bone for “ease of use” (setup in holder, preparing to drill, etc.) in the temporal bone laboratory in comparison to a cadaveric temporal bone
Q7	Printed temporal bone for “safety” in the temporal bone laboratory in comparison to a cadaveric temporal bone
Q8	Printed temporal bone for its overall value as a surgical simulation, in preparation for cases in the OR
Q9	Printed temporal bone material, in terms of drilling, bone dust etc.

Figure2. Current surgical simulation scenario and usefulness of this model for surgical simulation

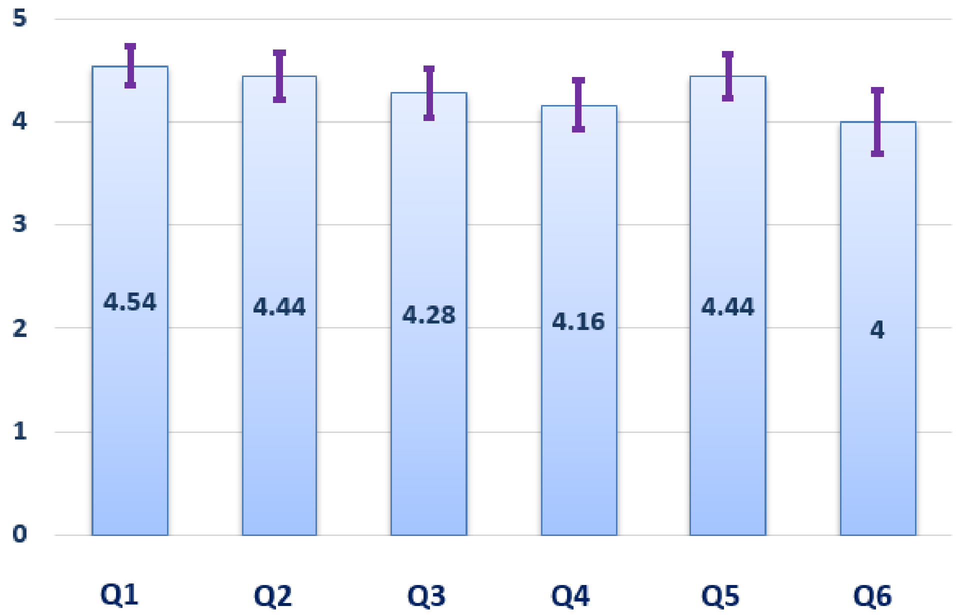

Figure 3: Tasked based usefulness

Q1 Use of this 3D Printed temporal bone for teaching cortical mastoidectomy
Q2 Use of this 3D Printed temporal bone for teaching cortical atticotomy
Q3 Use of this 3D Printed temporal bone for teaching facial recess dissection
Q4 Use of this 3D Printed temporal bone for teaching cochleostomy
Q5 Use of this 3D Printed temporal bone for teaching canal wall down mastoidectomy
Q6 Use of this 3D Printed temporal bone for teaching labyrinthectomy

Figure3. Task based usefulness

CONCLUSION

Printed 3D Printed temporal bone has good potential in surgical simulation, can be used as substitute of cadavers. Results shows the excellent usefulness of this model for surgical simulation and for practicing surgical tasks. More than 6+ surgeries can be practiced on the models. Model is being validated by senior surgeons and post graduate students. Can be used by otologist to hone their surgical skills.

Declaration of Interest

Authors should reveal any possible conflict of interest in their submitted manuscripts. A competing interest exists when professional judgment concerning the validity of work is influenced by a secondary interest, such as financial gain. The author(s) declare(s) that there is no conflict of interest regarding the publication of this manuscript.

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