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Investigating the Use of 3D-Printing in the Medical Education Curriculum in Otolaryngology: A Protocol Paper

Gareth Leung [1]*, Arthur Travis Pickett [2], Michael Bartellas [2], Ariana Milin [3], Matthew Bromwich [2], Risa Shorr [4], Lisa Caulley [5,6]

[1] University of Ottawa, Faculty of Medicine, Ottawa, Canada K1H 8M5
[2] University of Ottawa, Department of Otolaryngology, Ottawa, Canada K1H 8L6
[3] McGill University, Montreal, Canada H3A 0G4
[4] The Ottawa Hospital, Ottawa, Canada K1Y 4E9
[5] Ottawa Hospital Research Institute, Department of Clinical Epidemiology, The Ottawa Hospital, Ottawa, Canada K1H 8L6
[6] Erasmus University Medical Center Rotterdam, Department of Epidemiology, Rotterdam, Netherlands 2040 3000 CA

*Corresponding Author: grthlng8@gmail.com

Abstract
Three-dimensional (3D) printing has been used in recent years to produce educational materials in medicine. Recent studies have found that fields such as otolaryngology may benefit from the use of 3D printing in teaching medical students and residents. Our team will conduct a systematic review to survey the current uses of 3D printing interventions in otolaryngology. We aim to assess how similar the 3D printed models are to human anatomy, their surgical utility, and educational uses.

Keywords: medical education; otolaryngology; systematic review

Introduction

Three-dimensional (3D) printing refers to the production of a physical object by depositing heated materials in successive layers [1]. The use of 3D-printing has tremendous promise in advancing the quality and precision of health care and medical education [2]. In recent years, there has been exponential growth in 3D-printing in the field of otolaryngology - head and neck surgery [3,4]. Current evidence suggests that 3D-printed models can improve understanding of procedures such as endoscopic airway management [5]. As well, 3D-printed temporal bones have been created to help improve surgical techniques in otolaryngology [6]. Surgical teams have also used 3D-printing in pre-operative planning of surgeries that have yielded successful outcomes [7,8].

There are many advantages to using 3D-printing in otolaryngology to improve surgical skills. There is emerging evidence that simulation experiences have distinct advantages over lecture-based teaching methods and improves safety for learners [9]. 3D-printing has advantages over traditional methods such as cadavers and porcine models that have biohazard risks and are limited in supply [4,10]. The reproducible nature of 3D-printing can allow anyone with a 3D-printer and materials to learn skills relevant to otolaryngology. In institutions with less resources, the use of 3D-printing may provide them with an opportunity to reach more learners. Moreover, 3D-printing can be implemented in distance education and self-directed learning that has become more of a trend in recent years [9].

Although the use of 3D-printing is increasing, it has not yet been widely incorporated into the mainstream medical curriculum. Barriers to implementation have been reported, such as concern over initial costs, time, and expertise required to generate 3D-printed models [11]. In a previous systematic review, Hong and colleagues found that of 87 articles on 3D-printing in otolaryngology in until 2016, only six articles focused on the use of 3D-printing in medical education [4]. This highlights the fact that although there is research that has been done around this topic, there is still much to be learned with regards to its use specifically in the educational setting.

To our knowledge, none of the previous systematic reviews reporting on 3D-printing have quantitatively summarized the literature. This study aims to provide quantitative evidence regarding the use of current 3D-printing models for use in otolaryngology. This study will focus on the applicability of such technology from the perspective of medical learners, including medical students, residents, fellows, and attending physicians. Additionally, we will also investigate how the 3D-printing interventions were implemented. To achieve this goal, we will assess the materials used, the extent and duration of interventions, and methods of generating 3D-printed models. This information will be used to inform medical education curricula in otolaryngology to inspire future learners and help to raise awareness of limitations encountered when implementing programs.

Methods

Population

This systematic review will include observational studies examining the use of 3D printing within the field of otolaryngology education. Eligible studies will involve either medical students, residents, and/or attending physicians. These medical learners will be evaluating the usability of 3D-printing. Pilot/feasibility studies will be included, but studies that do not quantitatively evaluate the use of 3D-printing will be excluded. This study will be conducted in accordance with the Cochrane Handbook for Systematic Reviews of Interventions [12] and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [13].

Study Design

This is a proposed protocol for a systematic review and meta-analysis of the evidence for the use of 3D-printing as an educational tool in the speciality of otolaryngology

Search Strategy

Firstly, a search of the electronic database MEDLINE and EMBASE will be conducted using the OVID platform. Following this, the search strategy will be adapted to the Web of Science database format. Lastly, the grey literature and reference lists of included articles will be searched. This search strategy will be generated by a medical librarian and include terms relevant to 3D printing, otolaryngology, and education. There will be no restrictions with regards to the language of included articles and translations of articles will be conducted as needed. We will include articles from the inception of the databases until the date of the search conducted in 2021. The PRISMA format will be followed for this systematic review.

The following search terms will be used:

1. Intervention: Three-Dimensional Printing OR Bioprinting OR Additive manufacturing,
2. Discipline: Otolaryngology, Otorhinolaryngologic, Head and Neck Neoplasms
3. Education: education, medical students

Study Selection

Titles and abstracts of relevant studies will be assessed by two independent reviewers. Following this, the full text of relevant articles will be retrieved for further review. Any discrepancies will be resolved by a third reviewer and determined by consensus.

Inclusion criteria: articles in English, used 3D-printing in otolaryngology, and involved medical learners. Studies needed to report quantitative effect estimates for the primary outcomes.

Quality Assessment

The National Institute of Health Quality Assessment Tool (Pre-Post Studies) with No Control Group will be utilized to assess the risk of bias within studies [14]. Two reviewers will assess studies and classify them using the tool as either “good”, “fair”, or “poor” [14].

Data Extraction

The data will be extracted according to a piloted extraction form developed to include study characteristics (institution, number of trainees, level of qualification, surgical procedures, statistical comparisons) and relevant study outcomes (primary outcomes, printer costs, time to print) and reviewers will extract data according to a piloted data extraction form. Data extraction will be conducted independently by two reviewers and study authors will be contacted if any questions arise.

Outcomes

This study will classify outcomes into one of three domains: (1) anatomical realism, (2) functional/surgical outcomes, (3) overall educational utility. Though these domains represent distinct categories, several study outcomes may need to be combined or approximated to best classify their outcomes into one of the three domains.

1. Anatomic realism refers only to the appearance or visual likeness of the 3D-model in relation to the references used in the study, such as porcine or cadaveric anatomy. The anatomic realism outcome excludes the any tactile physical properties experienced b the users when the model is rotated, moved, or touched in response to the user.
2. Surgical utility refers to the use of the 3D-printed model's physical properties and how similar they are to the typical educational tools. This will evaluate the task-based use of surgical skills, whereby the evaluator is interacting with the model in some way. For example, when the evaluator is drilling holes into the model, or performing a training exercise to improve skill development.
3. Educational utility will assess the self-rated efficacy of the 3D-printed model in terms of its overall educational value. This will be reported by evaluators as the utility of the model for future trainees and the educational curriculum.

The secondary outcomes that will be investigated in this study pertain to the broader context of 3D-printing. Firstly, we will assess the scope of implementation by understanding how many trainees were involved in the 3D-printing intervention and their level of medical training. Secondly, we will evaluate the duration of the 3D-printing exercises and the duration of the study to assess the length of exposure the learners had to the intervention. Thirdly, we will assess whether certain surgical procedures have been explored more than others and whether there are any aspects of training that could benefit from more investments in 3D-printing. Finally, we will understand whether certain institutions or countries have published widely on 3D-printing and this information will help inform where potential collaborators and medical centres advancing 3D-printing may be found. Information on the resources used, such as the 3D-printers, the materials, costs, and time will be included for further analysis. Study characteristics will be presented in a tabular format, while the meta-analysis will be presented in a forest plot.

Results

Statistical Analysis

For continuous data, the mean and median values, range, and standard deviation will be extracted as data permits. For ordinal data, outcomes will be converted to a continuous scale as applicable, and data harmonized to improve consistency. For studies that report on the outcomes using separate survey questions or within different trainee subgroups, the outcomes will be combined using weighted means.

Discussion

As data permits, a quantitative meta-analysis will be conducted on the three primary outcomes (anatomic realism, surgical utility, educational utility). We will include studies that have sufficient quality and similarity for this analysis. This meta-analysis will be conducted in RevMan 5.4 software. The random effects model will be used to account for variance in study outcomes. In terms of the quality of studies, we will report those data qualitatively in summary tables by study.

For publication bias of the primary outcomes, we will use RevMan 5.4. If there is asymmetry within the funnel plot or evident, we will report that there may be publication bias with regards to the outcomes in 3D-printing studies. Some potential limitations to the study would be a lack of quantitative effect estimates or poor reporting on outcomes.

Conclusions

Our systematic review will help to improve the understanding of 3D-printing in the field of otolaryngology education. This study will be one of the first to quantitatively summarize the literature on the anatomic, surgical, and educational uses of 3D-printed models in otolaryngology. We will furthermore contribute to the literature by determining the centres where 3D-printing interventions are conducted, the level of training of learners, and assess costs of the intervention. Additionally, this review will help to inform medical education programs regarding the materials and equipment used to help institutions begin programs of their own if they choose. The review will help to identify knowledge gaps where further research into 3D-printing in otolaryngology is needed and help to encourage future studies and innovation by summarizing the current utility of 3D-printing in medical education.

This research paper has been registered in PROSPERO with ID: CRD42021262306

List of Abbreviations Used

3D: three-dimensional
PRISMA: preferred reporting items for systematic reviews and meta-analyses

Conflicts of Interest

The author(s) declare that they have no conflict of interests.

Ethics Approval and/or Participant Consent

This systematic review protocol did not require ethics approval.

Authors' Contributions

All authors made contributions to the design of the study, collected and analysed data, drafted the manuscript, and gave final approval of the version to be published.

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