Design of a 3D Printed Tagging System to Improve Accessibility in Medical Education

Yasmin Carter (yasmin.carter@umassmed.edu)
University of Massachusetts Medical School https://orcid.org/0000-0003-1369-6636
Daniel J. Mangiameli
University of Massachusetts Medical School

Technical Note

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Abstract

Anatomy, one of the cornerstones of medical education is often subject to testing in a practical manner utilizing tagged specimen-based exams. The design and production of 3D printed tags described here offers a unique ability to design in factors that support students with visual and learning disabilities. The lack of commercially available tags that can withstand the rigors and chemical exposure within this specific environment make the creation of this novel intervention vital to a great number of facilities. This report outlines the iterative process in creating a successful tag and the specifications needed to repeat the project. The success of these tags will impact students for years to come.

Introduction

Anatomical education is the study of the human body and is a foundational topic in medical school curricula and other health professions including physical therapy, nursing, and other medical applications [1]. For the majority of anatomy departments, education involves the use of cadaveric specimens, defined as a person who donates their body to science. The most common format for anatomy laboratory exams is the bell-ringer or spotter exam [2] which, involves the identification of specific structures at a station on the cadaveric specimens within an allotted time period.

Students may experience high stress with examinations, but with this particular examination style, this stress can be compounded by the unique environment [3]. Additionally, an increasing number of medical students are presenting with disabilities that can make this type of exam more difficult [4]. These factors can lead to common exam errors including visual field processing, running out of time at the station, recording an answer incorrectly, or simply misunderstanding of what structure is being tested. Traditionally the specimens at each station are marked with a pin or a string. Currently, no better options are available commercially. Therefore, most schools use handwritten tags with numbers or letters to identify the structure and the accompanying question.

Design Challenge

3D printing has been well demonstrated as a useful tool in the medical education setting for creating models of human structures in addition to more general uses in producing lab equipment [5, 6]. The goal of this project was to create an advanced 3D tagging system to replace the currently utilized hand-written versions. The 3D printed solution would address the requirement that the intervention be more inclusive of students with disabilities including color vision deficiency (color blindness), learning-disabilities, and exam-based stress.

The objective was to create a dual-color solution, incorporating a pair of non-identical shaped 3D tags that could be used in conjunction with a commercially available metal T-pin or string in order to label anatomical structures on a specimen for both the review and examination purposes. It was hypothesized that a difference in shape and color would increase visibility and increase student awareness and identification of structures with greater accuracy. These tags needed to be low cost, readily fitted and removed, easily cleansed, and highly adaptable to the unique needs of the medical education sector.

Materials And Methods

Multiple design iterations were required to achieve a 3D tagging system that repeatedly and easily, snapped onto the head of a t-pin. The 3D tagging system needed to be easily removable to facilitate the frequent replacement of the T-pin necessitated by corrosion created by the exposure to embalming fluid.

Autodesk Fusion 360® (Autodesk, San Rafael, CA, US) three-dimensional modeling software was used to design the prototypes. Given the design requirement easy visual differentiation of the 3D tagging system, a contrast color palette of white lettering on a black background, and red lettering on a white background were selected.

T-Pin Design

Design 1 - Annular Snap Joint

The first design iteration, featured a two-part tag, consisting of a top and bottom, where the pin would be inserted from above (Fig 1: A.1). The lid would then be placed on the top, snapping into place, trapping the pin in position (Fig 1: A.2). A raised surface on the outside of the lid provided a level of friction to aid in removal of the top. This model failed as the annular design, with small ridges inside made it difficult to snap the lid into place, without simply snapping off the ridges. In addition, the longevity of this design was doubtful (Fig 1: A.3). Design 1 was eliminated for the reasons given above.

Design 2 - Flanged Annular Snap Joint

A modified version of Design 1 was created to reduce the force needed to snap the lid into place (Fig 1: B.1). This featured cutout flanges (Fig 1: B.2) to allow the lid to flex while snapping into place. Due to the small size of the tags, printing these flanges proved structurally unreliable and resulted in a high breakage rate under the pressure of lid placement (Fig 1: B.3). Design 2 was eliminated for the reasons given above.

Design 3 - Press Fit Tag

A complete redesign of the prototype incorporated a press-fit design, with paired projections on the top section (Fig 2: A.1) and two matching indentations to receive them on the base (Fig 2: A.2). Due to the print tolerance, specifically the XY-axis resolution, of the desktop printer, it proved unreliable to 3D print a top section that remained in place, whilst still being easily removable (Fig 2: A.3). Design 3 was eliminated for the reasons given above.

Design 4 - Toothed Pin Tag

It was determined that a single-piece design would be an ideal solution and allow for a thinner, lighter pin tag (Fig 2: B.1). In this iteration, the pin is inserted from below into a small channel on the tag (Fig 1: B.2). Small teeth snap into place between the bent portion of the metal structure of the T-pin. Challenges involved in reliably printing such small features, led to variance in the teeth and not every pin fitting securely into the channel (Fig 2: B.3). Design 4 was eliminated for the reasons given above.

Design 5 - Final Tapered Design

To minimize 3D print tolerance issues with small features, a tapered design was modeled. This solution featured a narrow opening on the bottom of the tag, that gradually widened to allow the pin to snap in place (Fig 3: A). This feature was easily printed and did not require any support material. Additionally, it allowed the tag to have smaller dimensions allowing unobstructed viewing of the anatomical structures below the pin. Printing of this design proved reliable for large batch printing. The circular section was created for the “A” tag (Fig 3: B) while a square section was used for the alternative “B” tag (Fig 3: C). The 3D printed tagging system requirements of the black & white vs red & white tags were then applied in the modeling software.

Non-Pin Version

A pin type tag is not always the best labeling method for anatomical structures. When labeling very small, or thin and long structures such as nerves and vessels, the common practice is to tie a small string around the structure and attach a label to this string. To accommodate this, a design was needed for a very light tag that could be tied to a string. The finalized tapered design was adapted to create a thin tag incorporating a hole to allow a string to pass though the tag, while maintaining the shapes and color schemes of the original 3D tagging system requirements (Fig. 4).

3D Printing Workflow

Model Placement

Due to the high production numbers of tags required, large batch printing became a necessity. The first step in the 3D printing process was to export the CAD files from Fusion 360 into the .STL file format. The next step was to import the .STL files into ideaMaker (v3.1.7.1850) slicing software from Raise3D and orient them to the printing surface. Parts were oriented flat with the letters facing up. In addition, to achieve optimal print surface quality with dual extrusion, a single vertical row was used (Fig. 5). This helps prevent the admixture of multiple colors, which can result from the idle extruder ‘oozing’ material onto the tag as the nozzle travels over it. Due to the fact that printer results vary largely by printer type and settings, printing multiple rows simultaneously may also be feasible depending on the equipment used. Thus, with the right equipment, higher volume production of the 3D tagging system may well be achievable.

Print Settings

After a series of test prints to determine the optimal print parameters, the following settings were chosen for consistent printing of the 3D tagging system; however, these settings can only be recommended as a guide as numerous factors affect print quality and these differ between 3D printer technologies and manufacturers. The prototype 3D tagging system was printed on a heated bed utilizing a raft. Table 1 shows the ideal print settings for a Raise3D N2 Dual extruder printer with Acrylonitrile Butadiene Styrene (ABS) plastic. A “wipe wall” and “wipe tower” were both used to ensure proper material flow when changing between colors. The same settings were able to be used for both the T-pin system and the adapted system to be used with a string.

Table 1
Primary Print Settings for a Raise3D N2 Dual extruder printer with ABS plastic

Setting	Value
Layer Height	0.15 mm
Left Nozzle Temperature	230 °C
Right Nozzle Temperature	230 °C
Bed Temperature	110 °C
Infill Density	20%
Shells	2
Platform Adhesion	Raft
Support	No
Wipe Wall # of Lines	2
Default Printing Speed	50 mm/s

Adaptation for Alternative Uses

The two-tag system was designed specific to our purposes due to the double nature of our anatomy exam station set up, this could easily be expanded with the addition of other shapes and colors. The design itself can be changed from text “A” and “B” to other numbers or symbols as required. These tags could be used within a large number of medical programs that use specimen-based examinations including but not limited to nursing, physical therapy and veterinary schools.

Conclusion

Like all relatively simple interventions, the practicality of this 3D tagging system design lies in its ability to provide a stable yet adaptable solution, fulfilling all of the requirements of those who find it difficult to work within the currently available, simplistic anatomical structure tagging situation. This is evident by their ease of use, ability to be disinfected, and practicality for highly specific tasks. By designing a 3D tagging system to solve the multiple challenges of specimen labeling in the anatomy laboratory, the 3D tagging system presents an opportunity to expand visual markers to be more inclusive of student color blindness, pattern recognition-based learning disabilities, and even braille for visually challenged students.

Abbreviations

3D: Three-Dimensional

CAD: Computer-aided Design

.STL: Stereolithography File Format

ABS: Acrylonitrile Butadiene Styrene

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The tag model created during the current study and their associated advanced print settings are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

YC identified the challenge, created the project, helped to design the style of the model, tested the tags, performed the analysis and wrote up the project. DM designed and printed the model iterations. All authors read and approved the final manuscript.

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Authors' information:

YASMIN CARTER, PhD., is an assistant professor in the Division of Translational Anatomy, Department of Radiology at the University of Massachusetts Medical School. She is also Founding Director of the Innovations Lab @UMMS.

DANIEL (Clay) MANGIAMELI, BS., is a device engineer and the manager of the 3D Printing Core at the University of Massachusetts Medical School. His role focuses on providing engineering design support and rapid prototyping to UMMS and the local community.

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Figures

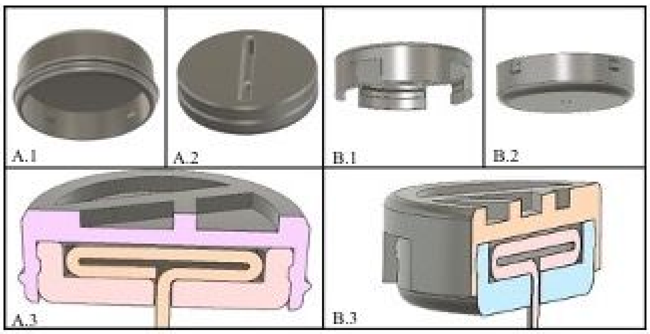

Figure 1

A. Design 1 - Annular snap joint (1. Bottom Isometric view; 2. Top Isometric view; 3. Cross-section); B. Design 2 - Flanged annular snap joint (1. Lid Bottom Isometric view; 2. Base Bottom Isometric view; 3. Cross-section).

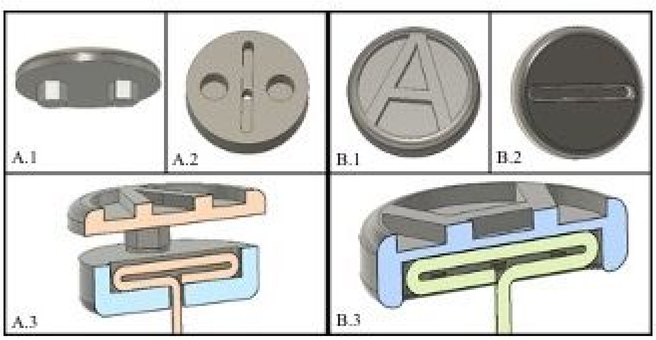

Figure 2

A. C. Design 3 - Press fit tag (1. Bottom Isometric view; 2. Top Isometric view; 3. Cross-section); B. Design 4 - Toothed pin tag (1. Top view; 2. Bottom view; 3. Cross-section).

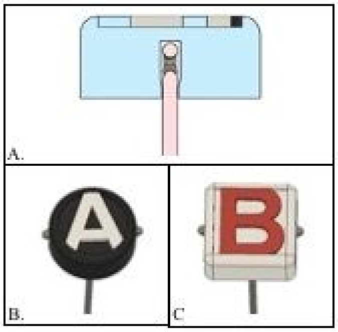

Figure 3

Design 5 - Final tapered design (A. Cross-section; B. Round style “A”; C. Square style “B”).

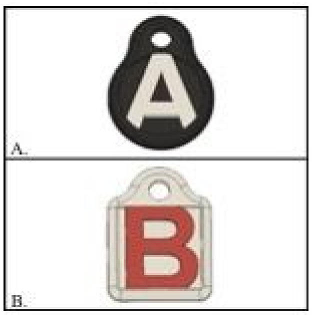

Figure 4

String-style tag design maintaining shape and color differences

Figure 5

Batch printed in single vertical column