in vitro Tube Model System

Analytical Task Assignment-Casting Methods

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Introduction:

Team 23 is producing an *in vitro* modeling system for aneurysm treatment. Common treatments for aneurysms include coils, clipping, other forms of embolization, and other methods of diversion of flow via a catheter system inserted through the femoral artery. Dr. Tim Becker has developed an alginate hydrogel than can utilized to embolize an aneurysm without the safety risks that are included in other treatments. Additionally, the hydrogel is bioinert and will not induce a negative reaction by the human body. The *in vitro* model will provide Dr. Tim Becker with the availability to test his product outside of a biological system. The primary goals of the model are to be anatomically correct and reusable. Current models primarily use glass vasculature and deionized (DI) water in place of blood. Team 23's *in vitro* model will provide a more accurate testing environment because of its biological accuracy to the human body.

Within the system, there are numerous components requiring analytical analysis in order to optimize the model's performance. Anne Marie Holter will give a detailed analysis of the different casting methods available for creating the model. The various casting methods include a wax vasculature with a rubber cast, a 3D printed cast, and a CNC machined cast-3D printed vasculature-hydrogel/silicone vessel. The biological accuracy of the model will be analyzed by other team members, therefore calculated comparisons to the human body are not necessary for this analysis. As a result, the various casting methods will be compared to each other based on their maintenance and manufacturing time and tolerances due to manufacturing. The lifespan time of the model, its maintenance and manufacturing times, are evaluated in order for the model to be reusable, and the tolerance must be minimized to optimize the anatomical accuracy of the vasculature measurements.

Assumptions and Analysis:

As stated previously, the different casting methods for the *in vitro* model include a wax vasculature with a rubber cast, a 3D printed cast, and a CNC machined cast with a 3D printed vasculature and a hydrogel or silicone vessel. These models will be analyzed based on their lifespan based on manufacturing time and usage and their manufacturing tolerances.

Lifespan and Manufacturing Analysis

The lifespan of each casting method will be evaluated by observing the time it takes to fabricate each model and the maintenance, based number of usages it can withstand. The manufacturing times will be analyzed with the following equation:

$$T = (100/N)*t$$

Where:

T: Total time for manufacturing and life span
t: Time for manufacturing
N: Number of uses before need for new cast
100 was assumed as the total number of cycle

For the wax model with rubber cast, Team 23 has created previous prototypes in Dr. Becker's Bioengineering Devices Lab (BDL). The fabrication process includes making the wax mold by hand and creating the two-part rubber mold. The wax mold takes approximately 45 minutes to create. The two-part mold requires a total of 48 hours to fully cure, 24 hours for the first half and another 24 hours for the second. After ample testing, Team 23 believes this model could withstand 50 trials. Therefore, the equation listed above would provide a total time of 5,850 minutes.

The 3D printed cast would only require 3d printing for its manufacturing processes. Due to the complexity in the vessel curves, the 3D printing could take up to four hours. Additionally, Team 23 assumes that this cast, due to its rigidity, will withstand all 100 trials. As a result, the total time is 240 minutes.

The final option requires 3 stages to the manufacturing process. First, the mold material would be cut to the correct vasculature measurements, based on the outside diameter of the vessel walls) with a Control Numerical Control machine (CNC). Due to Team 23's experience in Northern Arizona University's (NAU) Machine Shop, it can be assumed that the CNC process will take 120 minutes. This includes the time to write the code and to run the machine. The second stage involves creating a 3D printed (solid) vasculature, which can take up to 240 minutes. Finally, the cast would be created from silicone, which would take up to 24 hours to create and cure [1]. Team 23 believes the silicone vasculature will withstand 100 trials. Thus, the total time for this process would be 1,800 minutes.

In contrast to the silicone, Team 23 could use their Polyacrylamide-Alginate hydrogel composite as the casting material. The total time it takes to make this material is approximately 240 minutes. Team 23 believes this model could last 20 trials. However, only the hydrogel composite would have to be fabricated again. As a result, the total time for this process is 1,560 minutes. The equations stated above becomes:

$$T=(100/N)*h + (t-h)$$

Where:

T: Total time for manufacturing and life span
t: Time for manufacturing
N: Number of uses before need for new cast
h: Time for hydrogel manufacturing
100 was assumed as the total number of cycle

Manufacturing Tolerances

In addition to the time required for manufacturing and maintenance, the casting methods are also analyzed by their manufacturing tolerances. As shown below, Figure 1 displays the structure, shape, and scaled measurements of the desired vasculature.

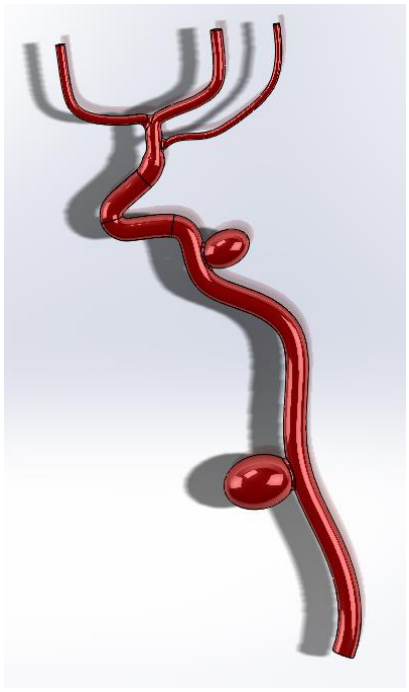

Figure 1: 3D model of vasculature

The handmade wax cast and rubber mold are made directly by Team 23, not machines, causing a large discretion in vasculature lengths, diameters, and curvature. Due to this human error, Team 23 estimated the tolerance to be +/- 1.0mm. The next casting method, 3D casting, would be completed with NAU's Fortus 400mc 3D printer. With the specifications of this printer, the tolerance for this casting method is +/- 0.127 [2]. Finally, the CNC machined mold, with 3D printed vasculature, and a hydrogel/silicone cast will have multiple tolerances. The CNC machined mold would be manufactured with Tormac 700 that has a tolerance of 0.0156 mm [3]. While the 3D printed vasculature would have a similar tolerance as the 3D printed cast, Team 23 plans to utilize an acid bath in NAU's art department to smooth the printer layers. However, the acid bath may increase the tolerance because the bath may remove material off of the printed dimensions. Therefore, this tolerance is estimated to increase to 0.15.

Results

The *in vitro* model casting methods doe not require extensive calculations, only a comparison of required times and tolerances. Among the different calculations for maintenance and manufacturing times, the 3D printed cast required the least amount of time, followed by both CNC machined molds-3D printed vasculature-hydrogel/silicone casts, and the wax cast with two-part rubber mold. For tolerances, the casting methods were ranked in the same order. However, Team 23 will not proceed with the 3D printed cast due to its inaccuracy in other anatomical aspects as analyzed by other members of the team. Therefore, Team 23 plans to proceed to optimize the CNC machined-3D printed vasculature-hydrogel/silicone cast model. This model will also provide further optimization in other analytical analysis.

References

[1]E. J. McCormick, "All You Need To Know About Making Silicone Molds," *Art Molds*, pp. 1–5.

[2]P. 3000 Inc, "Fortus 400mc production 3D printer | production-grade Thermoplastics, high Repeatability, high accuracy," 2016. [Online]. Available: http://proto3000.com/fortus-400mc.php#Fortus-400-Tabs:Product-Specifications. Accessed: Nov. 19, 2016.

[3]T. Inc, "PCNC performance expectations," 2016. [Online]. Available: http://www.tormach.com/product_pcnc_performance.html. Accessed: Nov. 19, 2016.