Design of 3D Printed Molds for Tablet Formation

Miss Yazmine Berenice Rincon, Louis Stokes Alliances for Minority Participation

I am a Chemical Engineering Undergraduate Researcher, who helps innovate, design, print and manufacture 3D printed molds. I follow a belief that “Education is the most powerful weapon which you can use to change the world” by Nelson Mandela.

In the past 7 years, I was the President of National English Honor Society (Sigma Kappa Delta), received an Associates of Science degree in Lone Star College, completed more than 60hrs of community service, and received 8 certifications in programming. I have a passion of researching, developing solutions, overcoming challenges, and innovating, but on the side, I also enjoy bird watching, painting, and hiking.

As a Hispanic and a woman, coming from a low-income family, it is my mission to inspire, educate and bring awareness to those who have not considered an opportunity to pursue stem related dreams. I am devoted to becoming a model for those who can not represent themselves and showcase endless of possibilities. Most of all, my goal is to demonstrate potential being found everywhere, it is matter of mining the cave and finding the gold and having that special source of light to lead.

Dr. Sheena M. Reeves, Prairie View A&M University

Dr. Sheena M. Reeves is an associate professor in the Chemical Engineering Department at Prairie View A&M University and has been a faculty member at PVAMU for ten years. She serves as freshmen advisor and the primary advisor of Omega Chi Epsilon honor society.
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Abstract

Within the fast-growing pharmaceutical industry, the design and development of continuous manufacturing processes are under investigation. For this research, 3D printed molds were designed to improve the tablet qualities. Different 3D mold prototypes were designed using computer-aided design (CAD) software. The printer filaments selected include acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA). The 3D printed molds were designed to hold 325 mg of the active pharmaceutical ingredient, paracetamol (APAP) and minimize the spreading of the liquid binding material. Overall, the quality and performance of the tablets improved significantly over the previous powder bed method due to the uniformity of the tablets. The design is expected to contribute to the creation of an ideal model that will make a continuous tableting process feasible, effective, and economical. The design will also enable tailoring of new drug formulations.

Introduction

It is well-known within the pharmaceutical industry\textsuperscript{1,2} that oral tablets have been manufactured in batch processes since the early stages of drug development. Although the industry continues to produce a vast array of medicine, the literature reports\textsuperscript{1} that there is an urge to become more efficient, less time consuming, and more cost effective. Some authors\textsuperscript{2,3} list areas of improvement as processes that tailor medical formulations to the patient, the usage of natural excipients to reduce possible side effects with synthetic excipients, and the creation of continuous manufacturing processes. Previous research in the Solids and Particulate Systems Laboratory\textsuperscript{3} has yielded APAP tablets via natural liquid drops added to a powder bed. Unfortunately, this method resulted in a product that did not resemble a common pill or tablet. Based on a study by Emady et al.\textsuperscript{4}, the culprit was uncontained liquid spreading in the bed. Overall, the shape of the final product heavily depended upon the type of excipient utilized. Based on these results, the research group decided to create 3D molds to mimic actual 325 mg tablets. This method has been used in the past\textsuperscript{2}; however, actual mold designs vary based on usage. The objectives of creating the molds are to: 1) increase the production of APAP tablets for additional analysis, 2) reduce the amount of raw material required to form the tablets, and 3) create APAP tablets that are consistent in terms of physical and chemical characteristics.
Materials and Methods

The molds were created using 2 different 3D printers – a MakerBot Replicator + or a Flashforge Guider II. TinkerCAD software was used to design the 3D mold prototypes. For the 3D printers, the supplied filaments were acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA). The filaments were available in various colors. After completing the designs in TinkerCAD, the files were uploaded to the 3D printers using a USB drive. For this study, paracetamol powder was used as the base material while drops of liquid excipient solutions was placed in each hole.

3D Printed Prototype Results

Several prototypes were created as a result of this project. However, only three specific designs and one alteration are discussed in this paper. Table 1 provides an overall summary of the prototypes and dimensions. Each prototype was designed and modified to improve the production of the granules, improve the overall drying process, and increase the ease and feasibility of removing the tablets without damage. In the preliminary designs, the tablet mold contained a flat, solid bottom and was formed using white ABS or PLA filament. Researchers immediately noted issues with drying the tablets and made a few adjustments to improve heat transfer/evaporation including switching to darker color (purple or black) filaments, placing the holes in a grid structure, and using a combination of a drying oven and desiccant cabinet. The first prototype (PLA, Makerbot Replicator +) discussed in this paper was a redesign of an initial design which had 8 holes in a simple hollow block. The purpose of Prototype 1 (Figure 1) was to improve the efficiency of the drying process of each granule while creating 12 granules in one batch. Despite the design of the mold being successful, the printing was not fully complete. It is alluded the scaling on the Makerbot file was not 100% therefore created incomplete production with holes being misaligned. To correct this issue, the shells were increased on the added MakerBot file and the model was set to 100% scaling. Prototype 1-A (Figure 2) was created to improve the issues of Prototype 1. Prototype 1-A was successful in printing and in creating tablet-like shapes (Figure 3); however, tablet formation saw additional issues. In particular, the granules still contained significant moisture after 24 hours in the oven. After some observations, the group decided to test if a decrease in diameter or increase in heat transfer area would improve the drying process.

Table 1: Dimensions of All Prototypes. Prototype 1 and 1-A had the same design, but different processes while Prototype 3 had a removable base.

<table>
<thead>
<tr>
<th>Prototype</th>
<th>Outer Hole Diameter, mm</th>
<th>Inner Hole Diameter, mm</th>
<th>Height Outside Hole, mm</th>
<th>Height Inside Hole, mm</th>
<th>Bridge Thickness, mm</th>
<th>Base Height, mm</th>
<th>Piston Height, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23.0</td>
<td>17.00</td>
<td>10</td>
<td>8</td>
<td>5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1-A</td>
<td>23.0</td>
<td>17.00</td>
<td>10</td>
<td>8</td>
<td>5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>16.5</td>
<td>12.75</td>
<td>18</td>
<td>15</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>17.0</td>
<td>13.00</td>
<td>22</td>
<td>-</td>
<td>6</td>
<td>14</td>
<td>20</td>
</tr>
</tbody>
</table>
Figure 1: Prototype 1 is the first design created using TinkerCAD software program.

Figure 2. Prototype 1-A is the first design with modified changes in the MakerBot Replicator + program. This modification is to prevent the filament creating “web-like” impression on the prototype.

Figure 3: Tablet results from Prototype 1-A mold.
Prototype 2 (Figure 4) was designed with an increased depth and decreased in the diameter of the granules. The printing of Prototype 2 was successful on MakerBot Replicator + using PLA filament. Despite a successful 3D mold printing, the granule depth and overall shape did not correspond to the original tablet specifications. Moreover, one goal was to have an ease of tablet removal from the mold. However, the smaller diameter proved difficult in removing the granules.

![Figure 4: Prototype 2 included decreased diameter and increased height from Prototype 1-A.](image)

To create a better removal process, Prototype 3 was created. The new design was more complicated as it included 3 parts and required a unique design created on TinkerCAD. Prototype 3 (Figure 5) was inspired by a literature reference, where researchers developed a set of 3 prototypes that successfully extracted 3 granules at the same time. Prototype 3 will extract a minimum of 10 tablets in its design is specifically unique on its own by extracting 3 or more granules at the same time and was primarily used for creating uniformity molds to test non-synthetic granules. In our design, one piece is used to mold the granules whereas the 2 other parts play the role of a piston to push out the granule feasibly. An advantage to this design is that the granule is held in place during the drying process. Currently, the goal is to develop a successful printout of 6 holes on the Makerbot Replicator+. The next step of the process is to use the Flashforge Guider II 3D printer with ABS filament and a larger Stratasys printer with acrylonitrile-styrene-acrylate (ASA) filament to compare the performance different types of filaments.

![Figure 5: Prototype 3 design used to efficiently remove granules.](image)
Summary and Conclusions

In summary, APAP tablets of similar geometric shape were successfully created using the Prototype 1-A design. However, some issues with the tablets drying were noted. To combat this issue, Prototype 2 was developed. For that design, attempts to remove the granule results in breakage of the product. This project has proven that designing, creating, and printing 3D molds using the TinkerCAD software and 3D printers is feasible. The new push system design will eliminate the granule removal issue seen in Prototype 2. The future goal is to scale up the current Prototype 3 design to produce more tablets with a single mold. By creating the ideal prototype, the creation of tablets made from non-synthetic excipients will be achieved and potentially allow tailoring of a new and effective drug formulations.

References


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