Development of a Novel Pillbox Design

A Technical Report submitted to the Department of Biomedical Engineering

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

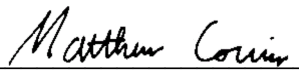
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

Matthew Cousins

Spring, 2020

Technical Project Team Members:
Robert Boettner

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments



Advisor
Dr. Shannon Barker, Department of Biomedical Engineering

Development of a Novel Pillbox Design

Matthew K. Cousins[a,*]. Robert C. Boettner[a,*]. Nolan Thornton[1]

[a] Biomedical Engineering, University of Virginia
[1] Correspondence: ngt23224@gmail.com
[*] Authors contributed equally on this work.

Abstract

Lack of adherence to prescription medications is an often-overlooked issue in the U.S. healthcare system. There are a variety of contributing factors with one being lack of convenient on-the-go storage for daily dosages. Creating an easier way for patients to keep their medication on their person throughout the day could be a useful method in addressing some of the concerns associated with medication adherence. Making a pill carrier that can fit inside of a wallet would provide an easy way to carry pills while not having to worry about a stand-alone storage entity. Limitations with current designs include small capacities, bulkiness, and lack of overall discretion. Here, we present a novel design of a wallet pill carrying device meant to fit in a credit card slot of a standard wallet. Thickness, durability, and capacity testing were performed on the device to analyze effectiveness. With more small adjustments and improvements moving forward, we are confident this could be used as a legitimate tool for improving patient outcomes in terms of medication regime.

Keywords: medication, adherence, pillbox

Introduction

Taking medication is a routine practice in the United States with nearly 3 in 5 adults having to take at least one prescribed medication per day. This is a practice that is consistently becoming more extensive as the number of people taking five or more prescription medications doubled from 2000-2012. Being able to take medication with you on the go and keep it in a portable, discreet container can be a major benefit for those taking regular doses of medication throughout the day. Despite the importance of complying to a recommended regimen, approximately half of Americans do not take medications for chronic diseases as prescribed[1].

There are a wide variety of factors at play that contribute to this lack of adherence such as the following: lack of communication and education between medical professionals and their patients, the complexity of certain regimens when multiple medications are prescribed to a single individual, and an overall lack of interest or general forgetfulness by the patient[2].

Non-adherence can not only pose a threat to the individual's health and financial situation, but it can have a taxing effect on the economy and the healthcare industry. An estimated 10% of total healthcare costs can be linked to non-adherence, totaling nearly $300 billion annually[3]. While having a way to carry around medication in a convenient manner throughout the day won't solve the issue of medication adherence, it can be a beneficial tool for individuals who live a busy lifestyle and are constantly away from home. Moreover, creating new habits through portable pillboxes that act as a reminder system can be a major promoter of better adherence behaviors[4].

Not only are prescribed drugs of interest when it comes to daily medicinal intake, but a variety of over-the-counter (OTC) medications can be beneficial to have on-hand throughout the day. For example, aspirin is widely known to prevent serious heart and blood vessel problems as well as colorectal cancer in older adults if taken daily. It is also a useful drug to have on hand at all times if an individual is at high risk for a heart attack. Furthermore, prescribed drugs such as nitroglycerine can have major health implications because it is a vasodilating nitrate that helps blood flow more easily through the heart. This medication is typically taken three to four times per day, and it is vital that it is consumed at the same time each day unless told otherwise by a doctor[5]. These drugs, among others, highlight the importance of having an easy way to carry them on person throughout the day as immediate availability can have major consequences on an individual's well-being.

Currently, some of the primary challenges of designing a portable pillbox design include reducing bulkiness, compartmentalization, maximizing carrying capacity, and making the design inconspicuous. Other

considerations that must be taken into account include low cost design as well as meeting a certain threshold of durability as to prevent any damage to the drugs. Currently, most portable pillbox designs with organizers are similar to the size of a smartphone and not necessarily convenient nor discreet. There are a few patents for pill carriers that can fit into a wallet providing reduced bulkiness; however, these designs fail to hold more than a few pills at a given time (Figure 1). Our goal for our pill carrier design is to combine the wallet-compatible aspects of current carriers while incorporating a greater overall capacity through maximizing the use of available free space in the wallet. Accomplishing this would allow users of the device to ideally carry with them a daily dose of all their medicine throughout the day as opposed to a select few (or none). Additionally, making the design wallet-compatible would not require users to carry an additional bulky object with them through the day, which can be inconvenient and thus disincentivize medication adherence.

Fig. 1. Blister Package. Pictured above is a common blister package pillbox design. Pill size is restricted to small circular pills.

Results

Survey for Design Criteria

Healthcare professionals were surveyed to help guide the design of a novel portable pillbox. A majority of respondents indicated that a portable pillbox would be used by patients and that it can help improve medication adherence (Figure 2). Respondents also indicated that

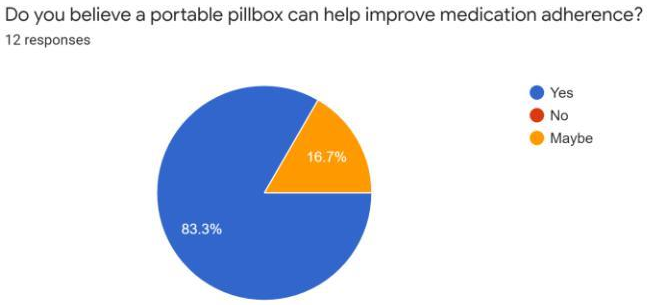


Fig. 2. Survey Question 1. Figure 2 shows the responses of 12 surveyed healthcare professionals on whether or not they thought a portable pillbox would be used by patients on medication.

discreet/inconspicuous design was the most important feature in the design. Inclusion of compartmentalization to separate pills into multiple pouches/dividers was voted second-most important (Figure 3). Finally, most respondents indicated the product should be sold for no more than $10 (with one respondent saying as low as $2) to reach as wide an audience as possible. This indicated that we should consider very low-cost options for the pillbox. Including retail markup, labor expenses, and any other expenses involved in manufacturing or distribution, the product's materials should cost no more than a couple dollars.

Pillbox Design

Plastic Sides

The final pillbox design consists of two joined plastic sheets with a fabric pouch inside. The bottom and sides of the device are sealed, leaving an opening at the top where pills can be inserted into the pouch (Figure 4). When the edges are pinched towards each other, the sides bow outwards and the opening widens for pill insertion or removal. When released, the sides retract and the opening closes. The device is in the shape of a credit card, measuring 3 ⅜ inches in length and 2 ⅛ inches in width. One side is a high-density polyethylene (HDPE) sheet measuring 1/64 inches thick, and the other side is a HDPE sheet measuring 1/32 inches thick. This combination of

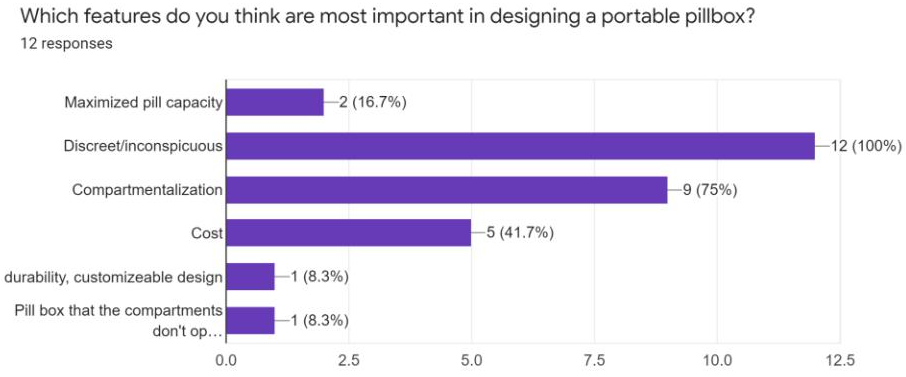


Fig. 3. Most Important Features in a Portable Pillbox. Figure X shows the responses of 12 surveyed healthcare professionals on what are the most important features to include in a portable pillbox design. Maximized pill capacity, discreet/inconspicuous design, compartmentalization, and cost were available options to select, and respondents could select more than one option. "Durability/customizable design" and "Compartments that don't open easy (so that pills spill out into purse/bag)" were write-in answers receiving one vote each. A discreet/ inconspicuous design was the most popular option with unanimous selection.

Fig. 4. Pillbox Top View. Figure 4 shows an overhead view of the pillbox opening. Pills of different sizes can be separated through the compartmentalization offered by the dividing middle flap.

two thicknesses best allows for ease of opening the device, optimal flexibility in the sides when pinching, and sufficient protection for the pills.

Fabric Pouch

The fabric pouch runs along the entire length of the pillbox and has a depth of approximately 1 inch when closed. Having an open pouch allows for maximized pill capacity and pill storage of all shapes and sizes. The pouch strategically doesn't extend deeper to concentrate pill storage towards the top of the pillbox. This allows for better insertion into a wallet by keeping the bottom of the device thin enough to slide in a credit card slot (Figure 5).

Compartmentalization was achieved through sewing in a fabric divider in the center of the fabric pouch. This allows for two different compartments to separate pills if needed. This can be seen in Figure 4.

Fig. 5. Pillbox in Wallet. Figure 5 shows how the pillbox easily inserts into a credit card slot of a wallet.

Closing Mechanism

Two buttons serve as a closing mechanism for the pouch to prevent pills from falling out when the device is closed. These buttons are sewn into the fabric, and can be easily closed by pinching the two sides together. They are also located in the center of each compartment, so a user can open one compartment while keeping the other compartment closed to selectively dispense or insert pills.

Durability Testing

To test pillbox durability, pills were dropped from various heights. Pills exhibited no damage when dropped, whether the pillbox was inside a wallet or outside of a wallet. There was also concern that pills may be damaged if a user puts his or her wallet in a back pocket and sits on it. While this is not recommended because of health reasons, compressive testing was performed for this audience[6,7]. Pills again remained undamaged in simple compressive testing (detailed in Methods and Materials), inside and outside a wallet. Full results for durability testing can be seen in Supplementary Table 1 in Appendix.

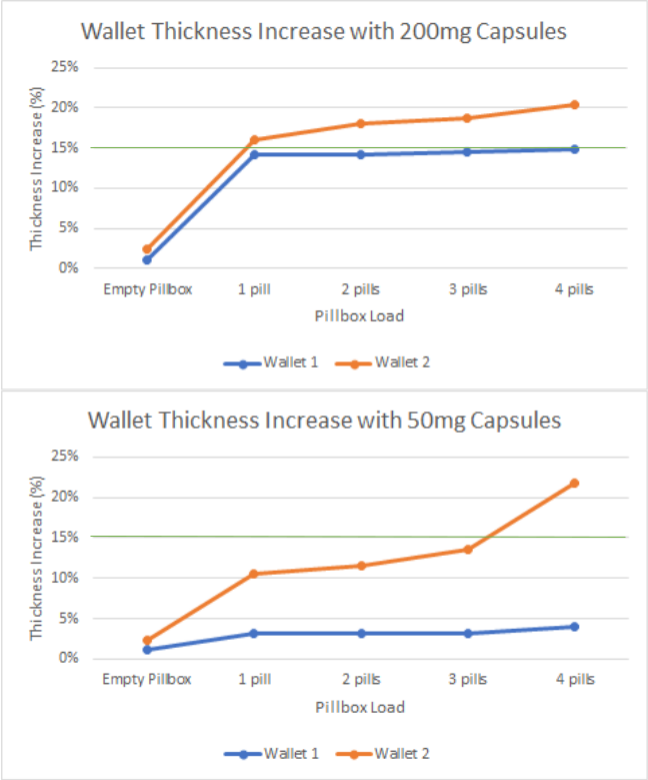


Fig. 6. Thickness Testing. The wallet thickness was measured in two different wallets with two different sized pills. With the exception of 4 pills in Wallet 2, the addition of 50mg pills stayed below the design constraint of not increasing wallet thickness more than 15%.

Thickness Testing

Thickness testing was conducted to examine pill capacity against the percent change in wallet thickness. Figure 6 shows the results of this test using pill sizes of 50mg and 200mg for the wallets of the two researchers. The

target mark we looked to stay under was a 15% increase in wallet thickness. In order to be discreet and not change the wallet shape, thinness of the device was a major concern. As expected, smaller pills could reach a higher capacity while remaining below the set threshold. Around the 200mg size pill, capacity does seem somewhat limited if the 15% mark is honored. A key takeaway from this test was how it highlighted the variability between different wallets and how different loads change the thickness in different ways. More is hoped to be uncovered as social distancing eases and more wallets can be accessed for testing.

Discussion

Limitations

The portable pillbox in its current form is bound on the bottom and sides by tape. If the device is taken to market, tape will not suffice as a binding method. Plastic welding techniques to permanently attach the plastic sheets together are much more expensive, and using these techniques are only financially justifiable in mass production. Moreover, better fabric to plastic adhesion will need to be further explored to provide a higher quality device.

Another possible concern is difficulty opening the device for patients with arthritic finger joints. Because the elderly population is a large component of the target market, (people over 65 make up 34% of all prescription medication use) it is important to consider the physical capabilities of older individuals[8]. There is some force required to open the buttons that serve as the closing mechanism on the device, and there is a risk

The current situation with the pandemic also posed as a major obstacle, as feedback from a patient population would have provided more beneficial insight. Without access to local stores and outside help with specialty components, certain design processes were delayed or halted depending on the needed resource.

Impact

If this novel product is met with success in the target market, the medical industry may put more attention towards development of portable pillboxes. Because portable pillboxes will likely never have the same capacity as current non-portable pillboxes, it is unlikely portable pillboxes will completely replace current pillboxes or prescription bottles. However, the industry may transition to a co-existence of designs. Prescriptions could be filled and refilled in larger bottles, and patients can keep a smaller reserve of medication in a portable wallet-accessible pillbox. This product hopes to create habits among patients to increase medication adherence. The co-existence of pillboxes could create the habit of transferring medication to a portable pillbox in the morning that can be accessed through the day. Regardless of its exact adoption into the market, this portable pillbox design should help improve medication adherence among patients because of its unique combination of convenience and functionality.

Materials and Methods

Survey of Healthcare Professionals

A Google Form with the questions below was sent to an individual in the UVA Department of Internal Medicine. The survey was then forwarded anonymously to other healthcare professionals in the UVA Health System. The respondents were asked four questions, and these questions are listed below.

1. Do you believe a portable pillbox will be used by patients taking medication?
2. Do you believe a portable pillbox can help improve medication adherence?
3. What features do you think are most important in designing a portable pillbox?
4. In your opinion, what would be an appropriate price for a portable pillbox?

Material Selection

Various material types and thicknesses were tested for their performance. Plastic was chosen as the main material because it was cheap, lightweight, and would offer a good balance between rigidity and flexibility. Research showed HDPE would be an ideal for a flexible plastic, so sheets 1/32” and 1/64” thick were ordered. Neoprene was also tested, but it quickly proved to be flimsy to be effective. Two sheets of 1/32” thickness had too little flexibility when pinching from the sides to open the device, and it was also too thick to easily fit inside a wallet. Two sheets of 1/64” was too flexible and didn’t sufficiently recoil when tension was released in an attempt to close the opening. A hybrid of 1/64” and 1/32” optimized all desired features and functioned most optimally. Summary of material testing for the plastic is summarized in Table 1.

Finding a fabric was difficult because most fabrics are too thick to keep the pillbox from increasing wallet thickness more than 15%. A silk-like fabric was selected, which added minimal thickness. A black fabric was chosen for easy visualization of pills in the pillbox pouch since most pills are white or a lighter color.

Table 1. Material Testing. Various material combinations were tested for flexibility, opening ability, and thickness.

Material Combination	Met Requirements?	Reasoning
1/32" PE and Neoprene Sheet	No	Poor opening abilities/too thick
1/32" PE and 1/32" PE	No	Too thick/no flexibility
1/64" PE and Neoprene Sheet	No	Zero durability/flimsy
1/64" PE and 1/64" PE	No	Too flexible/difficult to open
1/64" PE and 1/32" PE	Yes	Proper opening, durable, meets thickness

Durability Testing

With the situational limitations, durability was examined through drop testing. Tests were conducted with three pills in the device at a time, and the trials included three 50mg pills or three 200mg pills. For each pill size, the device was dropped from heights of 2 feet, 4 feet, and 6 feet both inside and outside of the wallet. The ground surface the test was conducted on was hardwood flooring. To examine the effects of a user who sits on their wallet, "sit tests" were performed where both researchers sat on the device holding 3 pills. Again, this was conducted both inside and outside of the wallet on different sitting surfaces. Sitting surfaces included hardwood floor, couch cushion, carpeting, and marble countertop. The weights used in this test were simply the weights of the researchers (155lbs and 170lbs).

Thickness Testing

Thickness testing was also slightly limited in on-hand materials. Two standard male wallets were used as well as 50mg and 200mg sized pills. Wallets were not altered in any way, and nothing was removed from them before the test was conducted. Each wallet's thickness was measured without the device, with the empty device, and then with the device filled with different amounts of each pill size. Pills sizes were kept independent of each other and measurements were taken after each sequential pill addition. Millimeter calipers were used to make all thickness measurements.

End Matter

Author Contributions and Notes

M.C. and R.B. designed research, M.C. and R.B. performed research, M.C. and R.B. analyzed data; and M.C. and R.B wrote the paper.
The authors declare no conflict of interest.

Acknowledgments

We would like to thank Dr. Timothy Allen and Dr. Shannon Barker for their feedback and advice throughout the project, as well as Nolan Thornton for funding and advising.

References

1. Viswanathan, M. *et al.* Interventions to Improve Adherence to Self-administered Medications for Chronic Diseases in the United States: A Systematic Review. *Ann Intern Med* **157**, 785 (2012).
2. Brown, M. T. & Bussell, J. K. Medication Adherence: WHO Cares? *Mayo Clin Proc* **86**, 304–314 (2011).
3. Medication Adherence: How to improve compliance. *NEJM Catalyst* https://catalyst.nejm.org/optimize-patients-medication-adherence/ (2017).
4. Donna M. Sudak, M. D. Psychotherapeutic Strategies to Enhance Medication Adherence. Psychiatric Times https://www.psychiatrictimes.com/psychotherapeutic-strategies-enhance-medication-adherence (2017).
5. Nitroglycerin Oral : Uses, Side Effects, Interactions, Pictures, Warnings & Dosing - WebMD. https://www.webmd.com/drugs/2/drug-18030/nitroglycerin-oral/details.
6. Green, J. (2019, February 25). Why a Fat Wallet Causes a Bad Back. Retrieved from https://www.menshealth.com/health/a19544148/why-fat-wallet-causes-bad-back/
7. Reavy, D. (2017, December 4). Why You Should Never, Ever, Put Your Wallet in Your Back Pocket. Retrieved from https://www.mensjournal.com/health-fitness/why-you-should-never-ever-put-your-wallet-in-your-back-pocket-w472908/
8. Fact Sheet: Prescription Medication Use by Older Adults. (2005, March 25). Retrieved from https://www.medscape.com/viewarticle/501879

Supplementary Table 1

Test	Outside of wallet	Inside of wallet
2-foot drop	No damage	No damage
4-foot drop	No damage	No damage
6-foot drop	No damage	No damage
Sit Test (compression)	No damage	No damage