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RESEARCH ARTICLE

Perceptions, preferences and acceptability of patient designed 3D printed medicine by polypharmacy patients: a pilot study

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Abstract

Background 3D-printing, compared to conventional medicine manufacturing technologies, is a versatile and highly modifiable technique that has the flexibility to produce medicine that meet patients' specific requirements such as individualized dosing, but also to customize the appearance of the dosage form, e.g., shape and colour. *Objective* To explore polypharmacy patients' perceptions and preferences regarding 3D-printed medicine, including their acceptability of patient-designed medicine. *Setting* The study was conducted in Zealand, Denmark. *Method* Polypharmacy patients were recruited using convenience sampling (mostly on Facebook) and interviewed twice using semi-structured interviews. Interviews were analysed thematically into five predetermined themes (shapes, colours, embossing designs, polypills, and patient-designed dosage forms). At the first interview patients were asked about their perceptions and preferences towards 3D-printed solid dosage forms, and were presented to different shapes, colours, embossing designs and examples of polypills. They were also invited to design their own medicine from the ones presented. Their self-designed medicines were presented at the second interview, where acceptability of both their self-designed medicine and the concept of designing one's own medicine, was investigated. *Main outcome measure* Patients' perceptions, preferences towards and acceptability of 3D-printed medicines. *Results* Eight patients were included. They tended to prefer shapes similar to conventional medicine. Different colours were preferred by different people. The presented embossing designs seemed to be irrelevant. Polypills were generally believed to be a good idea due to the reduction of number of medicines. Acceptability of patient-designed medicine was mainly determined by whether patients thought 3Dprinting technology was reliable or not. *Conclusions* The patients had various perceptions and preferences of 3D-printed medicine. Factors affecting the patient views were aesthetic (appealing), physiological (swallowing), practical (handling), pedagogical (understanding) and psychological (relate to). Trust in the technology seemed to be important for acceptability.

Keywords 3D printing · Denmark · Patient-designed medicine · Patient acceptability · Personalized medicine · Semi-structured interviews · Pharmaceutical technology

Impacts on Practice

- Patients using polypharmacy have various perceptions and preferences of 3D-printed medicine
- Solid dosage forms in the shape similar to conventional medicine, such as heart and almond shape, seems to be preferred among patients
- Some patients are able, and willing, to design their own 3D-printed medicine

Introduction

The Food and Drug Administration (FDA) approval in 2015 of the first three-dimensional printed tablet Spritam® (levetiracetam) showed the potential of three-dimensional printing (3DP) and possibly the future of this type of manufacturing within the pharmaceutical industry [1]. 3DP, compared to conventional manufacturing technologies, is a versatile and highly modifiable technique that has the flexibility to produce medicine that fit to meet patients' specific requirements such

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as individualized dosing. Although there are still many challenges (e.g. technical, regulatory, societal), it can also potentially revolutionize manufacturing of pharmaceuticals, not least as a 3D-printer can be used in different settings, such as pharmacies, hospitals, or even patients' homes [2, 3].

3DP has a potential to customize the appearance of the dosage form, e.g., shape and colour [4, 5]. Furthermore, 3DP has the capability to manufacture polypills with up to five different active pharmaceutical ingredients (API) in a single dosage form that can easily be adjusted for each patient [6, 7]. Reduction in the number of dosage units could have a positive effect on patients' compliance and adherence to the treatment [8, 9], and improve the perception of their illness and treatment. The versatile possibilities with 3DP could mean that patients in the future could design their own medicine in different shapes, colours, embossing designs, and have it all combined in the same dosage form (polypill).

A patient group that could benefit from many of these opportunities are polypharmacy patients. They consume large amounts of medicines, which often is a crucial factor related to adverse side effects and life threatening incidents caused by overdoses and medical errors [10]. Giving polypharmacy patients the opportunity to individualize their medicines and have them combined in a polypill could improve their quality of life. 3DP could also offer a unique opportunity for patients to be part of the decision process and to get and feel some self-control regarding their own medicine treatment. With 3DP, the current perception in western medicines of 'one size fits all' might be outdated in the future, and could be replaced with the idea of medicine being designed 'for the patient by the patient'.

Much research has currently been invested to find out the possibilities of the 3DP, regarding its technical aspect such as material selection, design of the dosage form, its functionality, in order to produce personalized medicine [11–13]. Despite that many resources are spent on solving issues in relation to 3DP, there have so far been very few studies investigating if patients even want to use 3D printed medicine. Goyanes et al. [4] investigated patients' acceptability with regard to picking and swallowing different shapes of 3DP drugs (printlets) and patients' willingness to take the printlets every day; and found some variation in patient acceptance. Patients' perceptions of various aspects of 3DP medicines, other than in terms of swallowability, along with their interest in designing their own medicine in the future, however remains unknown.

Aim of the study

The aim of this study was therefore to explore polypharmacy patients' perceptions and preferences regarding 3DP medicine, including their acceptability of patient-designed medicine.

Methods

Polypharmacy patients of different gender, age and societal status in Denmark were interviewed using semi-structured interviews. For practical reasons, i.e. the patients should be able to relate to the polypill (see below), polypharmacy was defined as using more than two medicines. Placebo solid dosage forms, including polypills, were 3D printed by fused deposition modelling (FDM) in different shapes, colours and embossing designs (see Box 1). The development of the shapes was inspired by the literature [4–7, 14], conventional medicine and food products—particularly sweets and candy.

Box 1 Manufacturing of placebo solid dosage forms by 3D printing

Polylactic acid (PLA) filaments (2.85 mm in diameter), in nine different colours, white, red, orange, green, purple, yellow, blue, pink and light blue, from Innofil® 3D (Emmen, The Netherlands) and Verbatim (Charlotte, NC, USA) were used for production of various placebo solid dosage forms. Polyvinyl alcohol (PVA) (2.85 mm in diameter) from Ultimaker® (Geldermalsen, Netherlands), was used as the supporting material during 3D printing. 3D models of all solid dosage forms were designed using the browser-based computer-aided design (CAD) softwares, Tinkercad (Autodesk, Inc.) and Free-CAD (version 0.17). The latter was used to modify and fine-tune the edges around certain shapes. 3D models were created by modifying the available geometrical structures from online libraries of Thingiverse, GrabCAD and Tinkercad. The 3D models with embossing were made by using descriptive symbols and customizable text/number templates available in Tinkercad. The designs of the solid dosage forms were exported as stereolithography files (.stl) into the 3D printer software (Cura v. 2.3.1, Ultimaker B.V., Netherlands) to make them readable by the fused deposition modelling (FDM) printer (Ultimaker 3 Extended, Ultimaker B.V., Netherlands). The following printing settings were selected: printing temperature 195 °C, infill parameter 50%, layer height 0.06 mm, print speed 60 mm/s and build plate temperature 60 °C. PVA-based aqueous solution was sprayed on the build plate during warm-up of the 3D printer to increase adhesion of the 3D printed models. In addition, all 3D prints were initiated by printing a 'skirt' to further improve adhesion. The 3D-models with the risk of overhang were printed with a support made of PVA to avoid collapse during printing. All 3D printed dosage forms were polished lightly with a sandpaper to even out any irregularities. The designed solid dosage forms were designed and manufactured in dimensions in the range of conventional tablets but varied in sizes, ranging from height: 4–9 mm; length: 10–13 mm and width: 8–10 mm

To explore various aspects around patients' perceptions and preferences regarding 3DP medicine, semi-structured interviews was chosen as the method. This method is ideal for capturing the ideas, experiences, perceptions, etc. of the individual [15]. Repeat interviews, i.e., two interviews, were carried out with polypharmacy patients, the second one approximately a week after the first. This was as 3DP medicines are unknown to most people and having a repeat interview made it possible for respondents to reflect on the issue between the interviews. Both interviews mainly focused on the respondents' thoughts, reflections, and preferences of the 3D-printed solid dosage forms.

Interview 1

The interview guide used for the first interview consisted of socio-demographic questions and questions on respondents' current medication in order to collect background information. The main part consisted of four central topics: shapes, colours, embossing and polypills, where each topic had additional questions regarding the respondents' general perceptions of the impact on compliance. The respondents were first asked questions about their preferences of shapes and colours, and then 3D-printed solid dosage shapes/colours/embossing designs were shown. This was done to prevent preconceptions and bias of the respondents' answers.

Respondents were then asked to pick five shapes out of 17 presented placebo dosage forms, and afterward the two best among the five. Additionally, the respondents were asked to select two colours (out of nine) and two embossing designs (out of eight) of their likings.

Between the two interviews, customized dosage forms were manufactured based on respondents' preferences.

Interview 2

The interview guide designed for the repeat-interview consisted of follow-up questions to get deeper into the respondents' answers, but also to make it possible for them to reflect or even change their minds between the two interviews. The customized dosage forms were then presented to further obtain respondents' perceptions and acceptability of self-designed medicine, but also to show the respondents the possibilities of 3DP in designing their own medicine.

Both interview guides were adjusted after the first repeat-interview to exclude irrelevant questions. A heterogeneous sample was strived for regarding sex, age and socio-demographic background. A convenience sample strategy was used; respondents were mainly recruited via Facebook, but in order to find a younger polypharmacy patient, a personal network was used. All interviews were held in Danish, one-to-one, at a location decided by the respondent to create a relaxed environment [15]. Interviews were audio-recorded, transcribed verbatim and analysed using thematic coding [16]. The five themes (shapes, colours, embossing designs, polypills, and patient-designed dosage forms) were predetermined. Quotes were translated into English and are presented in the result section to illustrate perceptions. Each respondent has been given a number that is added to the quote, with information about if it was the first or repeat interview.

Ethics approval

Before the interviews, respondents received an information letter explaining the purpose and procedure of the interview. The information letter also stated that participation was voluntary, and that the respondents at any time could deny answering a specific question, or simply withdraw from the interview. All the respondents signed an informed consent sheet. All data collected during the interviews was anonymized. The processing of personal data was approved by the Faculty of Health and Medical Sciences, University of Copenhagen (Ref. No. 514-0353/19-3000).

Results

Eight polypharmacy patients, who were undergoing treatment with three or more medicines, were recruited for semi-structured interviews. Seven out of eight respondents were interviewed twice. The respondents consisted of four women and four men, ages ranged from 29 to 80 years (median 66.5), number of medicines was 3–16 (median 8) and their social backgrounds were diverse. All interviewees but one had never heard about, and none had previously seen 3D-printed medicines.

Shapes

Most of the respondents talked about today's medicine as mainly round or oval as their own medicines had those designs. The resemblance in shape of their current medication was an important issue for some of the respondents due to difficulties in recognizing their medicine, especially if it also had the same size. However, several of the respondents mentioned the cardiovascular tablet in the shape of a little heart (Hjertamagnyl®) that was easy to recognize due to its different design. In addition, the shape had an extra functionality.

> I like it because then I know why I am taking it and it has the shape for what you are using it for. [R1, interview 1].

The respondents had different preferences about shapes of their medicine before being presented with the 3D designed dosage forms in the first interview. Some were quick to imagine what shapes they would like. One of the respondents imagined his medicine being shaped like animals, which he explained with having lived in the countryside and therefore loved animals. Others thought it was difficult because conventional shapes were the only ones they were familiar with or because they thought of several possible preferences. Some explained their preferences from a physiological point of view, since they preferred an almond or an oval shape, due to prior experience with ease regarding swallowing and picking.

> Yes, then it should be the oval shape, it is easier to consume and easy to grab since it is still on the table it does not go anywhere. [R4, interview 1].

Some respondents could not imagine a preferred shape since their perception of shapes in relation to medicine was irrelevant for them.

In the first interview, patients' were presented with the 17 different solid dosage forms Eleven designs were made as nonconventional shapes (Fig. 1, nos.1–3, 6–9, 13, 14, 17). The rest (Fig. 1, nos. 4, 5, 10–12, 15, 16) were made to be comparable with conventional forms.

The respondents had both similar and different preferences when asked to pick out five shapes, and then two out of five. However, the heart (Fig. 1, no. 5), the almond (Fig. 1, no. 15) and to some extent the oval shape (Fig. 1, no. 16) were the most preferred designs. Some of the respondents focused primarily on the geometry of the shapes and only selected the ones they either thought was easy to swallow (physiological factor), handle (practical factor) or just felt appealing (aesthetic factor) and different in their hands.

Other respondents explained their selections from what they felt or associated with each shape:

> The bear is cute. The turtle, it is just little and slow, it could be one you would consume to reduce the heart rate a little, right? Reduce the pace a bit and eat a turtle, fish is healthy and the rabbit, it is just fun. [R1, interview 1].

There was, however, a tendency to deselect the shapes designed as animals. Some of the respondents explained that the animal shapes were too different and strange. Others disregarded the animal shapes due to their edges, which for some was an issue in relation to swallowability. However, most of the respondents thought that children would benefit of having these shapes, because they would find the animal shapes funny and that might help to administer medicine to children.

Some respondents deselected shapes based on them being 'boring' and others because they perceived shapes in general as irrelevant and therefore had no real preferences or dislikes. Among the 17 shapes, the sphere (Fig. 1, no. 4) was disliked by several of the respondents due to difficulties regarding handling or picking and the risk of losing one's medicine if dropped on the floor.

Colours

In interview one, before seeing the placebo dosage forms, the respondents were asked about the colours of today's medicine. A majority said that medicines were predominantly white, as it was the most represented colour in relation to their own medicine, even though some of their current medicine had other colours. Several of the respondents expressed that white made it difficult for them to tell the difference between their medicines, especially if it also had the same shape and size, and some perceived the frequent use of white as boring. Most of the respondents believed that having their medicine in several different colours would make it easier

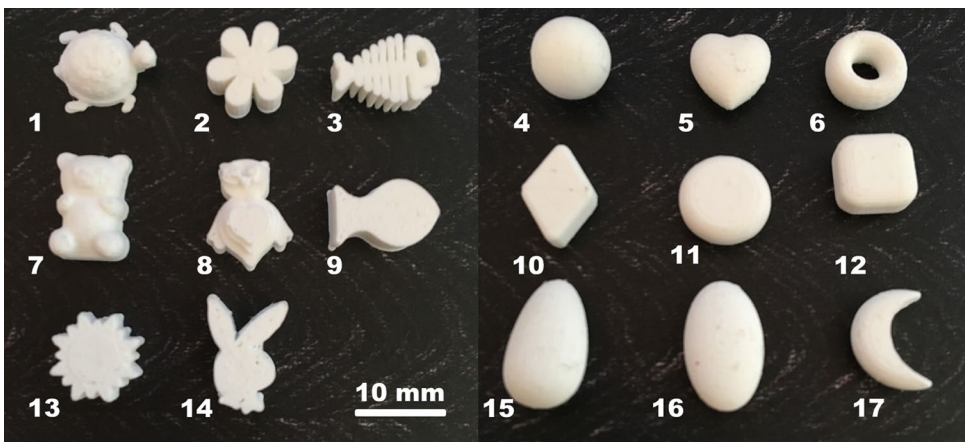

Fig.1 Different shapes of 3D printed solid dosage forms

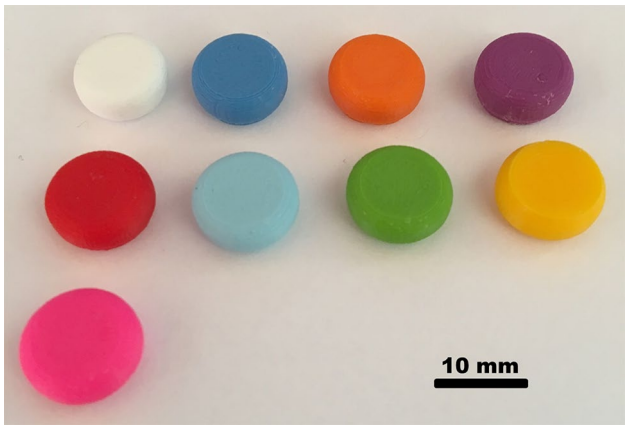

Fig.2 Different colours of 3D printed solid dosage forms

to identify their medicine. Others also believed that colours could help them remember when to take their medicine.

> Well, I would say that if the pills look alike – I would like that they had a bit of colour. If they were round all of them, it would be easier to remember to take three green ones and one yellow. [R7, interview 1].

In the first interview respondents were presented with the placebo dosage forms in nine different colours (see Fig. 2). Each respondent preferred different colours, and had various reasons for this. Green was by some thought to be optimistic, and the colour of spring, blue was by others connected to the sky or described as warm, and red was by one thought to be the colour of blood, which for her would indicate medicine for her heart.

> Then I would like them in three or two different red colours, so a pink one could be the one that dilutes the blood, it is obvious when they are pink and the dark red would be for the blood pressure. [R3, interview 1].

However, not all the respondents had specific preferences regarding colours. Some thought that colours were irrelevant and therefore had no preferences and others thought that colours in soft nuances such as pastel colours were more suitable. One respondent explained how the colour of her medicine should imply seriousness and fit the purpose.

> Well, red means danger or love or something like that. As medicine I would properly argue that most people would connect it with danger, so to me, it has to be something that seems serious, since it is not harmless to use medication, so it cannot be unserious, it has to fit the purpose. [R8, interview 1].

Each respondent had different preferences when asked to pick out two colours (see Fig. 5 for specific colours). However, several colours such as orange, red, purple, and blue were picked by more than one respondent. Some respondents selected the colours that they thought were easy to recognize and identify (pedagogical factor), because of the contrast differences between them. Others picked out their favourite colours or just colours that appealed to them (aesthetic factor). One of the respondents explained that a strong colour intensity was a deterrent for her and therefore selected the white and light blue colour. Another respondent, who stated that she was very attracted to and affected by colours, said that it was difficult to choose since she could relate to each of the colours presented to her.

> Well yes, the pink colour just glows with joy of life, the yellow is the sun, lovely warm and the orange has always been my favourite colour because I love tulips, and the red is again this thing with the blood and the green one I'd would like that one too, it's the colour of hope, well I just love colours it just makes me happy, it can be hard to explain why. [R3, interview 1].

Some colours were disregarded by the respondents. The presented green colour was of concern, because its brightness and intenseness was perceived as a sign of toxicity. Black (not presented) was considered the least favourite colour in relation to medicine. The colour black was by several of the respondents believed to signify death and grief, which was not something they liked to connect with their medicine. However, as mentioned above not all respondents were concerned with colours.

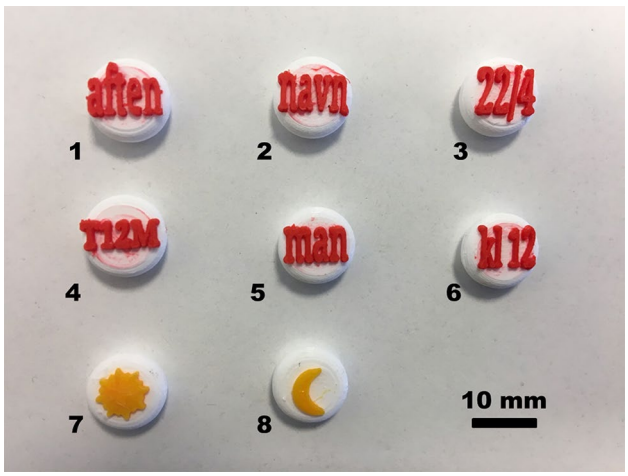

Fig.3 Different embossing designs of 3D printed solid dosage forms. Translation of Danish words and abbreviations: (1) evening (2) name (3) 22/4—April 22 (4) T12F—Tuesday at 12 a.m. with food (5) male patient (6) 12 a.m.

> It is about what you get, if you are used to a black pill, then you eat a black pill. Well, I do not have an opinion about colour as such. [R6, interview 1].

Embossing designs

The embossed solid dosage forms were manufactured in three different colours using eight different designs, see Fig. 3. The eight embossed solid dosage forms were designed to indicate the time for administration (Fig. 3, no. 1, 6–8), date and/or weekday for administration (Fig. 3, no. 3–5), or and individual identification (Fig. 3, no. 2) customizable to each patient.

In interview 1, respondents were presented to the solid dosage forms with eight different embossing designs. Only a few of the designs were found appropriate among the respondents, mainly sun and moon due to their informative, simple and logical design (Fig. 3, nos. 7 and 8). The respondents believed that these embossed shapes could help them remember when to take their medicine. However, many of the respondents found the embossing designs irrelevant, since their current condition did not require this type of information related to their medicine. Furthermore, the designs were believed to be unnecessary by some respondents, since the information was already written on the medicine packaging or because they organized their medicine in a pill box. Some also thought that the embossed designs were difficult to read and that they generally would be concerned about the size of the writings. In addition, the respondents found the embossed shapes to be too fancy and too innovative, and that the expected positive outcome might not be as significant as presumed. In spite of that, several respondents expressed that embossing might be more useful in the future and perhaps more suitable for people older than themselves, or for non-complaint patients with cognitive challenges who struggle with remembering the time of administration during the day. Furthermore, the idea might be useful for nurses and health assistants working at hospitals and nursing homes to help them to provide the correct medication for each patient, which might help reduce the number of medical errors.

Polypills

In interview one, fourteen different variations of polypills were shown to the respondents. They had three different shapes (Fig. 1, nos. 5, 11, 15) and nine different colours, see Fig. 4. The polypills were designed so that each of the colours would represent an API.

Most of the respondents were excited about polypills, because it could reduce the number of medicines consumed each day, especially for those who consumed large quantities of medicines. Even though many of the respondents tended to focus on the positive outcome of the polypill, they were also aware of potential limitations. For example, how to deal with if sudden changes in dose or regular dose adjustments are needed, and/or a certain drug should be discontinued or replaced. This was believed to increase the risk of errors involved in manufacturing.

> I get this blood thinner that is measured approximately once a month, and it can be anything from one to two tablets, so it's not an advantage if you put it together with something else. [R2, interview 1].

Most of the respondents thought the designs of the presented polypills were easy to understand when it was explained that each of the colours indicated a different drug.

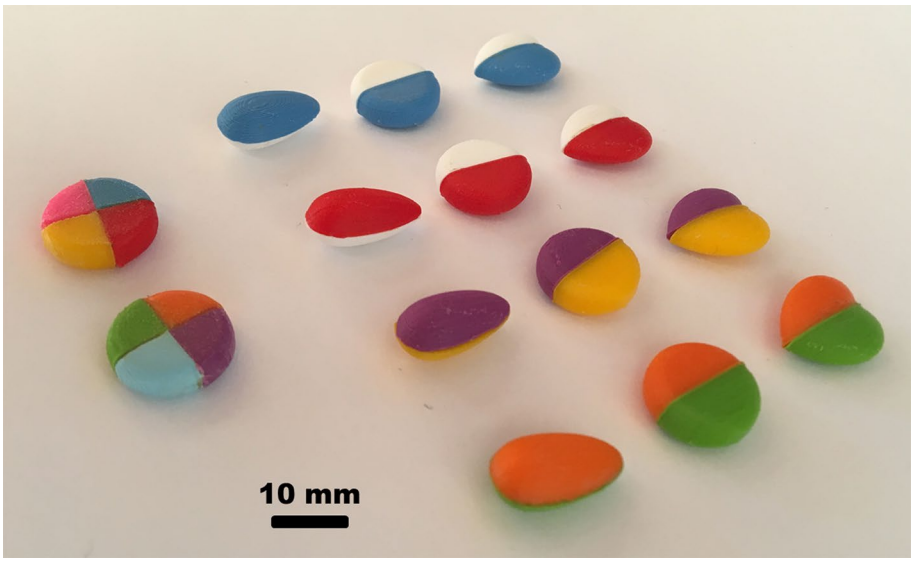

Fig.4 Different placebo polypills manufactured by 3D printing

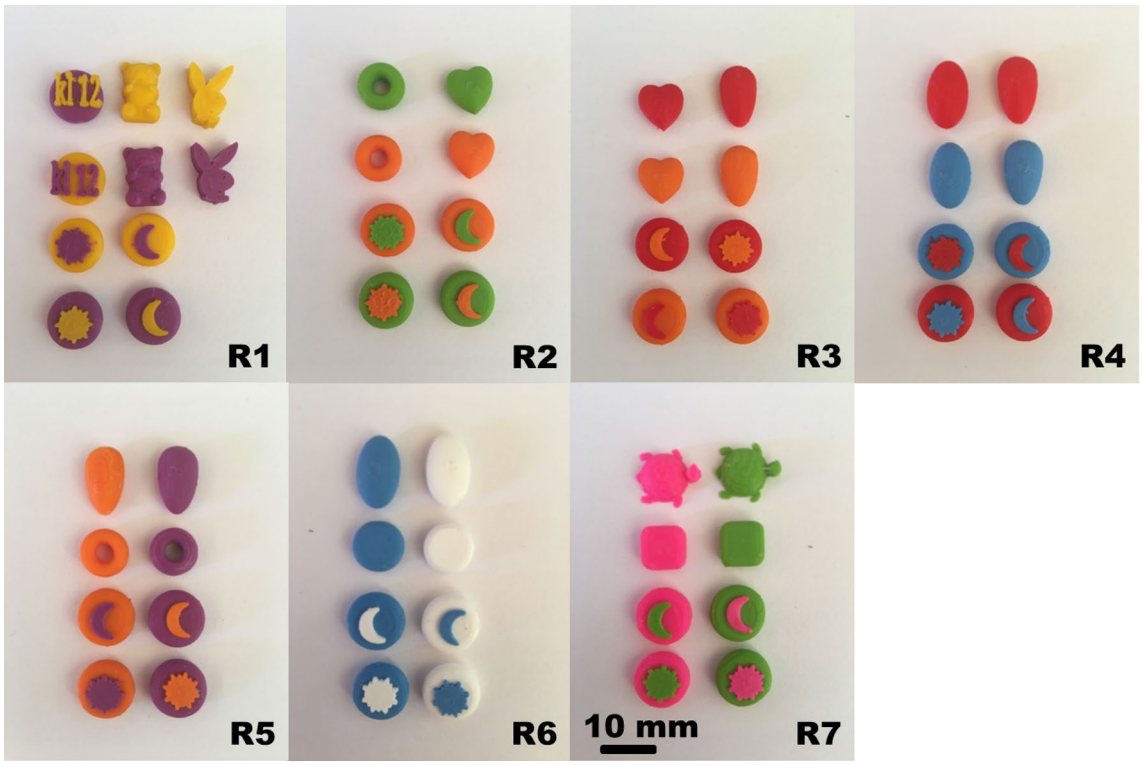

Fig. 5 Customized dosage forms manufactured by 3D printing based on the preferences of seven respondents (R1–R7)

Patient-designed dosage forms

Before the second interview, 3D printed solid dosage forms were manufactured from the respondents' preferences regarding shapes, colours, and embossing designs presented above, see Fig. 5. As can be seen from the figure the preferences regarding shape and especially colour differed.

Many respondents liked the customized designs of the solid dosage forms, reasons given were that the designs were both eye-catching, fun, pretty, recognizable and forthcoming. One respondent explained that seeing the examples of medicine designed by and manufactured just for her made her feel happy. Another stated that two-coloured designs were very appealing and made the person want to take them. Nevertheless, some respondents were still sceptical and unimpressed with the designs.

The respondents were asked about their willingness to administer patient-designed medicines if it could be offered to them. Half of them were positive about 3D printed medicine, because being able to decide and design their own medicine would not only help to recognize and remember their drugs, but also give them a feeling of being part of their treatment and more related to their own medicine. In addition, there was an opinion that it would be more fun if they could design it themselves.

Two respondents were neutral and thought that the idea was fascinating and interesting, but each of them had their concerns, e.g., possible extra expenses, extra practicalities and increased difficulties for up-taking the medicine. The last two respondents seemed to have negative and sceptical thoughts about patient designed medicine. One of them had difficulties understanding the need for it and believed it was a waste of time and irrelevant since patients are controlled by their habits, and, therefore, have difficulties with seeing medicine in new and different designs. The other respondent believed that the 3D printing technology was unreliable and would only be trusted by young people.

> But they (young people) have been raised with a computer in their hand, they believe what it says, we old don't, I do not trust it, I'm sceptical. [R7, interview 2].

Discussion

Preferences regarding patient-designed medicine and their appearance varied between respondents, which is interesting as this was shown even though a limited number of patients were interviewed. This makes 3DP attractive as individual preferences potentially can be met with this technique.

The polypharmacy patients, interviewed in this pilot study, tended to prefer solid dosage forms in shapes that were easy to handle, recognize, and swallow; shapes similar to conventional forms were most preferred. Preferences regarding colours varied a lot, which can be explained by people's subjective perceptions and preferences. However, different colours were perceived as a help to recognize and remember the different types of medicine, but also an opportunity to make the medicine more appealing and fun. Embossing designs were generally seen as irrelevant, but designs that indicated the time of administration with descriptive symbols, e.g., sun and moon, seemed to be useful. Combining medicine in a single dosage form, i.e., polypill was perceived as potentially complicated if, e.g., a frequent dose titration is needed. However, the opportunity to reduce large quantities of medicine to only a few tablets seemed to outweigh the potential limitations.

The respondents' different perceptions and preferences of 3D-printed shapes and colours can be divided into five main aspects, i.e. aesthetic, physiological, pedagogical, psychological and practical. The results indicate that the respondents preferred shapes and colours they found appealing (aesthetic), they can relate to (psychological), recognize (pedagogical), and handle (practical, e.g. easy to pick up from box).

One physiological factor that seemed to be very important for several of the respondents was the swallowability of the shapes. Studies have shown a high prevalence of complications with swallowing among polypharmacy patients [17, 18], which could explain the respondents' focus on swallow difficulties of certain shapes. The respondents' perception of the almond shape, regarding improved swallowability compared to other shapes, is supported by a study, where three different shapes, namely, almond, round and elongated were tested [14]. It was found that the almond shape is significantly easier to swallow than the round shape, while the difference between the elongated and almond was insignificant [14].

Among shapes, the heart was among the most preferred, this has also been found by other researchers despite that the designs of the hearts varied between this project and that study [4]. A reason for this could be that many of the respondents received treatment with acetylsalicylic acid under the brand name Hjertemagnyl® to prevent heart attacks. Hjertemagnyl® is shaped as a little heart, i.e. a recognizable shape, which has an informative design that reminds patients of why they need it. This pedagogical factor could in the future be further used, to help patients identify the indication of their medicines in the same way. Examples of such medicine-related shapes could be a moon for the treatment of insomnia, a mushroom for antimycotic treatment or a flower for prevention of pollen allergies.

When it comes to polypills, respondents thought that dose-or other changes could increase the risk of errors if polypills were to be individually manufactured with 3D-printing. This is an issue that could affect compliance and adherence due to confusion and misunderstandings. In addition, the patients can lose the overview of their medication when it is combined [3, 8]. Another foreseen challenge is that patients might lose the possibility to self-regulate their medicine if several APIs are combined in one pill [3].

The respondents all designed their own medicine (shape, colour, embossment), even though not all found it meaningful to do so. Although this study is small, considering the heterogeneity of the respondents, it indicates that patients can, and many are probably willing or even very happy to, design their own pills. This means that truly individual medicines can be part of the future, and can be yet another means to empower and engage patients—most likely leading to more rational medicine use.

This pilot study had several limitations. First and foremost it was a small study with a limited number of interviewees, and a finite number of e.g., shapes and colours were presented to them. Also, the placebo solid dosage forms could not be consumed hence e.g. swallowability could not be tested. The concept of 3D-printed medicines was new to the respondents, which could make it difficult for them to have opinions. This bias was however reduced by conducting a second interview. The study is also limited to patients living in Denmark. It can be noted that Denmark in 2015 was number two among OECD countries when it comes to online devices per capita [19]—hence Danes might be more prone to accept new technologies than others.

As this was a pilot study in an area where knowledge is scarce, additional studies are needed, for example further qualitative studies reaching more in-depth, looking at other perspectives, and in other contexts; and quantitative studies to e.g. investigate what groups of patients can see more benefits with the technique. Overall, it is important to include the patient perspective when a new technology is developed.

Conclusions

Most respondents accepted and held overall positive views on patient-designed medicines in the form of 3D-printed solid dosage forms. Those who were negative either did not trust the technique or saw no benefits of individually designed medicines.

Factors affecting the patient views were aesthetic (appealing), physiological (swallowing), practical (handling), pedagogical (understanding) and psychological (relate to).

Patients, who trusted the technology behind 3D-printed medicine and found the variously designed solid dosage

forms appealing and beneficial, would also be willing to use patient designed medicine.

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Conflicts of interest The authors declare that they have no conflict of interest.

References

1. Di Prima M, Coburn J, Hwang D, Kelly J, Khairuzzaman A, Ricles L. Additively manufactured medical products—the FDA perspective. 3D Print Med. 2015;2:1.
2. Lind J, Kälvemark Sporrong S, Kaae S, Rantanen J, Genina N. Social aspects in additive manufacturing of pharmaceutical products. Expert Opin Drug Deliv. 2017;14:927–36.
3. Kaae S, Lind JLM, Genina N, Sporrong SK. Unintended consequences for patients of future personalized pharmacoprinting. Int J Clin Pharm. 2018;2018(40):321–4.
4. Goyanes A, Scarpa M, Kamlow M, Gaisford S, Basit AW, Orlu M. Patient acceptability of 3D printed medicines. Int J Pharm. 2017;530:71–8.
5. Scoutaris N, Ross SA, Douroumis D. 3D printed "Starmix" Drug loaded dosage forms for paediatric applications. Pharm Res. 2018;35:34.
6. Khaled SA, Burley JC, Alexander MR, Yang J, Roberts CJ. 3D printing of five-in-one dose combination polypill with defined immediate and sustained release profiles. J Control Release. 2015;217:308–14.
7. Khaled SA, Burley JC, Alexander MR, Yang J, Roberts CJ. 3D printing of tablets containing multiple drugs with defined release profiles. Int J Pharm. 2015;494:643–50.
8. Bryant L, Martini N, Chan J, Chang L, Marmoush A, Robinson B, Yu K, Wong M. Could the polypill improve adherence? The patient perspective. J Prim Health Care. 2013;5:28–35.
9. Williams B, Shaw A, Durrant R, Crinson I, Pagliari C, de Lusignan S. Patient perspectives on multiple medications versus combined pills: a qualitative study. QJM Int J Med. 2005;98:885–93.
10. Saedder EA, Lisby M, Nielsen LP, Bonnerup DK, Brock B. Number of drugs most frequently found to be independent risk factors for serious adverse reactions: a systematic literature review. Br J Clin Pharmacol. 2015;80:808–17.
11. Aho J, Bøtker JP, Genina N, Edinger M, Arnfast L, Rantanen J. Roadmap to 3D-printed oral pharmaceutical dosage forms: feedstock filament properties and characterization for fused deposition modeling. J Pharm Sci. 2019;108:26–35.
12. Smith DM, Kapoor Y, Klinzing GR, Procopio AT. Pharmaceutical 3D printing: design and qualification of a single step print and fill capsule. Int J Pharm. 2018;544:21–30.
13. Trenfield SJ, Awad A, Goyanes A, Gaisford S, Basit AW. 3D Printing Pharmaceuticals: Drug Development to Frontline Care. Trends Pharmacol Sci. 2018;2018(39):440–51.
14. Bar-Shalom D, Seric S, Dalsgaard L, Saaby L, Kramer Vig K, Hansen G, Vinicoff PG. The quest for easier-to-swallow tablets. Tablets Capsul. 2016. https://tabletscapsules.com/wpcontent/uploads/pdf/tc_20160101_0035.pdf.
15. Kvale S, Brinkmann S. Interview: det kvalitative forskningsinterview som håndværk. Copenhagen: Hans Reitzels Forlag; 2015.
16. Robson C. Real world research. 3rd ed. Hoboken: Wiley; 2011.
17. Marquis J, Schneider M-P, Payot V, Cordonier C, Bugnon O, Hersberger KE, Arnet I. Swallowing difficulties with oral drugs among polypharmacy patients attending community pharmacies. Int J Clin Pharm. 2013;35:1130–6.
18. Liu F, Ghaffur A, Bains J, Hamdy S. Acceptability of oral solid medicines in older adults with and without dysphagia: a nested pilot validation questionnaire based observational study. Int J Pharm. 2016;512:374–81.
19. OECD. OECD digital economy outlook 2015. Paris: OECD Publishing; 2015.